

GEOLOGY

COURSE - III

STRUCTURAL GEOLOGY, ECONOMIC GEOLOGY INDIAN GEOLOGY



"We may forgo material benefits of civilization, but we cannot forgo our right and opportunity to reap the benefits of the highest education to the fullest extent..."

Dr. B.R. Ambedkar

Dr. B.R. AMBEDKAR OPEN UNIVERSITY

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GEOLOGY

Course Development Team **Course Revision Team**

Editor

Prof. N. Ramana Rao

Editors

Prof. S.V. Rajasekhara Reddy

Dr. P. Madhusudhana Reddy

Associate Editor

Prof. S.V. Rajasekhara Reddy

Course Co-ordinator

Prof. S.V. Rajasekhara Reddy

Writers

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Writers

Prof. Y. Umapati Varma

Prof. Y. Umapati Varma

Prof. S.V. Rajasekhara Reddy

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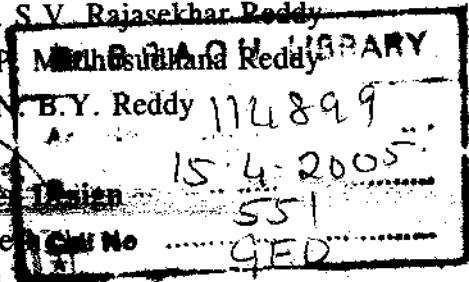
Prof. S.V. Rajasekhara Reddy

Cover Design

Ramesh

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Ramesh



Dr. B.R. Ambedkar Open University, Hyderabad.

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Further information on Dr. B.R. Ambedkar Open University Course may be obtained from The Director (Academic), Dr. B.R. Ambedkar Open university, Prof. G. Ram Reddy Marg, Road No. 46, Jubilee Hills, Hyderabad - 500 033.

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BRAOU

PREFACE

This course deals with the topics in Geology included in the syllabus for the Third Year of the B.Sc. course offered by the Dr. B.R. Ambedkar Open University. The topics generally cover the 'core' areas of the subject to be studied in the Third Year of the Three Year Degree Course in Science. The syllabus for the sake of convenience is divided into blocks, each of which comprises a number of Units. Each block generally covers a specified area of the subject. The Units are prepared by specialists in accordance with a format so designed as to enable the student to read and understand them without much difficulty. Each Unit begins with a statement of its objectives, and assignments at the end of the course material intended to test the student's comprehension of subject. Technical terms with which the student may not generally be familiar with are given appropriately under the head, 'Glossary'.

The University hopes that this course material will help the student to get acquainted with the concepts and principles of structural geology, Economic geology and Indian Geology.

The total content is divided into 6 blocks and 24 units. Block 1 and 2 consists of structural geology, here the basic principles and structures were explained. Block 3 and 4 are allotted to economic geology. In this blocks the different processes of ore formation and their distribution in India was discussed. Block 5 and 6 deals with Indian Geology various stratigraphic divisions of India were described along with its economic importance. The unit 24 is specially incorporated in this course about the Andhra Pradesh Geology.

BRAOU

UNIT : 1 STRUCTURAL GEOLOGY - AN INTRODUCTION

Contents

- 1.0 Objectives
- 1.1 Introduction
- 1.2 Primary and Secondary Structures
- 1.3 Objectives and Methods of Structural Geology.
- 1.4 Applications of Structural Geology.
- 1.5 Structural Geology and its relation to other branches of Geology.
- 1.6 Summary
- 1.7 Check Your Progress - Model Answers.
- 1.8 Model Examination Questions

1.0 OBJECTIVES

In this Unit, we have presented the method of study and applications of Structural Geology.

At the end of this Unit, you will be able to

- * explain the primary and secondary structures
- * describe the methods of structural geology
- * describe the applications of structural geology
- * describe the structural geology and its relationship with other branches

1.1 INTRODUCTION

Structural Geology is the study of the structural (in contrast to compositional) features of rocks, their geographic distribution and their causes. **Billings** defines structural geology "as the study of the architecture of the earth's crust as it has resulted from deformation." The expression architecture of the earth's crust is very appropriate because structural geology aims at understanding and interpreting the form, symmetry, geometry and certainly the elegance and artistic assembling of the components of the earth's crust on all scales. Geologists are concerned with structural features which range in size from those observed in an outcrop (megascopic size) to those of regional size which are to be represented on geological or structural maps. Features of a still large scale are considered in 'tectonics' which is "the study of the features of much broader or larger components of the earth and their causes".

1.2 PRIMARY AND SECONDARY STRUCTURES

A structural feature is one produced in rock by movements after its formation after the consolidation of the rock or rock units. The term structural feature or simply structures refer to the shape and attitude of the various rock units present in any part of the earth. The shapes and attitudes of the several rock-units, as they now exist in earth, are the results of process connected with their original formation and also of all later processes.

the displacements, rotations and distortions that gave rise to the structure. By integrating this knowledge with theoretical concepts and experimental data, one can analyse the nature of crustal deformation. All this structural analysis has an important bearing on our understanding the formation and structural control of natural resources, especially energy resources and metallic mineral deposits.

The knowledge of the structure of rock bodies is basic to the understanding of other aspects of geology. Structural knowledge is of great importance in applied fields of geology such as ground water hydrology, mining geology and engineering geology. In all these fields it is essential to learn about the subsurface configuration of rock bodies as well as their surface distribution. The occurrence of oil pools, the size and shape of ore bodies or other economically important rock formations such as coal or limestone and distribution of ground water are very often controlled by geological structures and as such a detailed knowledge of structures forms a prerequisite for successful and economic exploitation of each resources.

In the field of engineering geology also, selection of sites for dams, bridges and such other projects is based on the proper evaluation of the foundation rock, particularly with reference to its structure as the presence, for example, of an active fault may endanger the engineering construction.

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. Describe where the knowledge of structural geology is useful?

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1.5 STRUCTURAL GEOLOGY AND ITS RELATION TO OTHER BRANCHES OF GEOLOGY

The scope of 'structural geology' has been explained in the foregoing paragraphs. Some geologists use the terms 'tectonics' or 'tectonic geology' with the same meaning as 'Structural geology. Some however, consider structural geology is to be concerned with the geometry of the rocks within an area. The study of a small area naturally leads the structural geologist to consider the 'setting' of his area in the broader frame-work of the surrounding region. He desires to fit the beds, folds and faults he mapped into the pattern of the folded or faulted belts of the whole country and ultimately proceeds to think on a continental scale. Although such investigations, irrespective of the size or area, also come within the scope of structural geology, traditionally the wider aspects of continental and oceanic and eventually of global structures are referred to as 'tectonics' or 'tectonic geology' or 'geotectonics'. Discussions on major fold belts, fault zones and the like which require a thorough understanding of the nature of the earth's deep interior, form the subject matter of 'tectonics.'

In the investigation of the structural problems of an area or region the structural geologist has to first study the nature of the rock mass in which the structure is present. A knowledge of geomorphology, which is concerned with the study of landforms, is of particular importance to the structural geologist because in regions of recent tectonic activity the structure may be directly expressed by the topography, petrology, which deals with the systematic description of rocks and their origin throws much light on the structural history of igneous, sedimentary and metamorphic rocks. As rocks are composed of minerals, mineralogy, which deals with the classification, internal structure and genesis of minerals is another branch of geology with which the structural geologist should be familiar. For the study of the structure of folded and faulted sedimentary formations a knowledge of stratigraphy, a branch of geology concerned with the sequence in which formations were deposited, is essential. Paleontology, the study of fossils is indispensable when rocks containing fossils are encountered.

In addition to the branches of geology mentioned above, the structural geologist has got to be familiar with the methods and instruments of other branches of science as well particularly, physics and chemistry. Geophysics, which involves the application of physics to geological problems and includes studies in seismology, gravity, electricity and magnetism, is being used extensively and successfully in solving problems with which the structural geologist is concerned. Indeed, for most of the information available on the nature of the interior of the earth which is source of tectonic energy, the principal source is seismology. The subject of rock mechanics deals with the physical properties of rocks and their significance in rock deformation. The study of the ancient magnetic field of the earth and its role in tectonic processes forms the subject matter of Paleomagnetism. Geochemistry deals with the application of the principles of chemistry in geological investigations and overlaps mineralogy and petrology. Geochronology is concerned with the dating of geological events through the application of such advanced techniques as radiogenic dating.

The science of geology originated and progressed from observations made mainly on the continents. Although oceans occupy a larger part of the earth's surface and have been familiar to man for many thousands of year, his concern for the subsurface parts of the ocean is only of recent origin. Oceanography, science dealing with the ocean, involves many other sciences like biology, physics and chemistry in addition to geology. The study of the structure of the sea floor, the underlying crust as also the mantle has now become the primary concern of structural geologists. Lunar geology, which involves mineralogy, petrology and geomorphology is attracting the attention of geologists in recent times.

1.6 SUMMARY

Structural geology is the study of the structural features of rocks, their geographic distribution and their causes. This branch of geology is useful in understanding the interpretation of form, symmetry, geometry and other components of earth's crust. Structural features are of two types, normal primary and secondary, structures that originate during the formation of rocks are called primary structures. Structures produced by forces that tend to displace and destroy the rocks or by metamorphism are called secondary structures. The latter are the result of essentially of deformational processes such as uplift, tilting, faulting and folding.

The primary objective of structural geologist is the recognition, representation and genetic interpretation of the rock structures. It is essential to study the rock bodies

and determine their size, shape and structural characters. The out crops are to be correctly located and geological maps should be prepared. The geometry of the rock masses is to be described in terms of the various linear or planar structural elements and the structure is to be represented by means maps, cross sections, block diagrams and photographs. After the preparation of maps the geologists may explain the origin of the structure and the geological history of the area.

The knowledge of structural geology is basic to the understanding of other aspects of geology. Structural knowledge of great importance in applied fields of geology such as ground water hydrology, mining geology and engineering geology. On all these fields it is essential to learn about the subsurface configuration of rock bodies as well as their surface distribution.

Structural geology has relation with other branches of geology. It is related to geomorphology, petrology, Mineralogy paleontology, geophysics, geochemistry, seismology, oceanography, lunar geology etc.

1.7 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Structural geology.
 2. Imagery Photographs.
 3. Groundwater hydrology, Mining geology, Engineering geology etc.
-

1.8 MODEL EXAMINATION QUESTIONS

- I. Answer the following question in about 30 lines each.
 1. Explain about structural geology; Describe the objectives and uses.
- II. Answer the following questions in about 10 lines each
 1. Explain the terms - primary structures and secondary structures.
 2. Explain briefly the applications of structural geology.

* * *

UNIT : 2 MECHANICAL PRINCIPLES

Contents

- 2.0 Objectives
- 2.1 Introduction
- 2.2 Force
- 2.3 Stress
- 2.4 Strain
- 2.5 Three Stages of Deformation
 - 2.5.1 Elastic deformation
 - 2.5.2 Plastic deformation
 - 2.5.3 Rupture
- 2.6 Factors Controlling Behavior of Materials
- 2.7 Summary
- 2.8 Check Your Progress - Model Answers
- 2.9 Model Examination Questions.

2.0 OBJECTIVES

In this unit, we have presented the mechanical principles as force, stress, strain and the three stages of deformation.

At the end of the unit, you should be able to

- * describe force, stress and strain
- * explain three stages of deformation
- * describe the factors controlling the behaviour of materials

2.1 INTRODUCTION

The outer shell of the earth consists of sedimentary, igneous and metamorphic rocks. The structural geologist, however is interested primary in the mechanical properties of the rocks with which he deals rather than in their origin. Geologists usually observes rock deformation. This deformation may be due to internal forces or external stress. So it is essential to know about mechanical principles related to elasticity, plasticity and rupture. This type of characters are usually developed with different forces.

2.2 FORCE

It is an explicitly definable vector quantity that changes or tends to produce a change in the motion of a body. The locomotive of a train exerts the force that moves the cars. Force is defined by its magnitude and direction, hence it may be expressed by an arrow, the length of which is proportional to the magnitude of the force and the direction of which indicates the direction in which the force is acting.

An unbalanced force is one that causes a change in the motion of a body. The acceleration is the rate of change of velocity. If a train starts from rest and acquires a velocity of 20 miles per

hour at the end of 10 minutes, the acceleration is two miles per hour per minute. A body dropped from a high building is subjected to an unbalanced force because of the gravitational pull of the earth, and the body accelerates at the rate of approximately 32 feet per second per second.

Balanced forces exist where no change in motion occurs. If a train is moving at a constant velocity, the frictional resistance of the tracks and the air equals the force exerted by the locomotive. If a man pushes against a wall that he cannot move, the wall is exerting a force equal and opposite to the exerted by the man.

Most problems confronting the structural geologist may be analyzed by assuming balanced forces because the velocity of rock bodies is so small that acceleration is negligible. Along faults, however, the motion causing earthquakes may be so rapid that acceleration is important.

The pressure on a small body immersed in a liquid is described as **hydrostatic pressure**. Rocks in the lithosphere, because of the weight of whatever rocks are above them, are subjected to similar but not identical kind of pressure known as **Lithostatic pressure**. But in experimental work this equal, all-sided pressure on solids is called the **confining pressure**. This lithostatic pressure increases with depth in the earth and reaches tremendous values in the interior. It is equal to the weight of the overlying column of rocks. An increase in confining or lithostatic pressure causes a decrease in the volume of rocks, but an increase in the density. A decrease in confining pressure causes an increase in volume but a decrease in density.

In many instances the forces acting on a body are not equal on all sides. A body is said to be under **tension** when it is subjected to external forces that tend to pull it apart. Tension may be represented, as in Fig. 2-1A, by two arrows that are on the same straight line and are directed away from each other; the arrows represent the forces, whereas the rectangle represents the body or part of a body upon which the forces act. The rectangle may be omitted.

A body is said to be under **compression** when it is subjected to external forces that tend to compress it. Compression may be represented, as in Fig. 2-1B, by two arrows that are on the same straight line and are directed towards each other; the arrows represent the forces, whereas the rectangle represents the body or part of the body acted upon. The rectangle may be omitted.

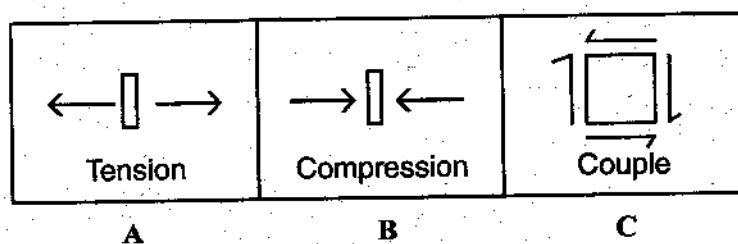


Fig. 2.1. Arrows representing tension, compression, and a couple.

A **couple** consists of two equal forces that act in opposite directions in the same plane, but not along the same line. In Fig. 2-1C a couple is represented by the upper and lower arrows, which are not on the same straight line and which are directed away from each other. To prevent rotation and preserve equilibrium a second couple is necessary, as shown by the vertical arrows. The rectangle, which represents the body or part of the body acted upon, may be omitted.

Torsion results from twisting. If the two ends of a rod are turned in opposite directions, the rod is subjected to torsion.

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 lithostatic pressure?

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2.3 STRESS

Imagine a vertical column of material. Along any imaginary horizontal plane within this column, the material above the plane, because of its weight, pushes downward on the material below the plane. Similarly, the part of the column below the plane pushes upward with an equal force on the material above the plane. The mutual action and reaction along a surface constitutes a stress.

Moreover, along any imaginary plane within the column there are similar actions and reactions. The imaginary plane may be horizontal, vertical, or inclined at any angle. The force, due to the weight of the part of the column that lies above the plane, acts in a vertical direction. This force would be directed normally to horizontal plane. Along an inclined plane, however, the vertical directed force would be resolved into a normal component and a tangential component.

The normal component is a compressive stress if it tends to push together the material on opposite sides of the plane. The normal component is a tensile stress if it tends to pull apart the material on opposite sides of the plane. The tangential component is generally called a shearing stress or shear.

Physicists measure stress as the force per unit area; it is stated in pounds per square inch, tons per square foot - kilograms per square centimeter, or similar convenient units. Engineers prefer to use unit stress force per unit area.

It is essential to distinguish between the external force that is applied to a body and the resulting internal action and reactions that constitute the stress.

CALCULATION OF STRESS

There is no direct way to measure stress in a body, but they may be calculated if the external forces are known. If a body is compressed or stretched, the stress is referred to a plane perpendicular to the direction in which the external force are acting. Thus if a vertical square column 10 inches on a side supports a load of 5000 pounds, every horizontal plane in the column is subjected to a compressive force of 5000 pounds if we neglect the weight of the column itself. Each square inch of these horizontal planes supports a load of 50 pounds per

square inch. The compressive stress is said to be 50 pounds per square inch. If a vertical rod with a cross-sectional area of 10 square inches carries a weight of 5000 pounds at its lower end, every horizontal plane in the rod is subjected to a pull of 500 pounds per square inch. The tensile stress is said to be 500 pounds per square inch.

2.4 STRAIN

Strain is the deformation caused by stress; strain may be dilation, which is a change in volume, or distortion, which is a change in form, or both.

When there is a change in the confining pressure, an isotropic body—that is, a body whose mechanical properties are uniform in all directions—will change in volume, but not in shape. With increasing confining pressures, the volume of the body decreases and the dilation is negative. With decreasing confining pressure, the volume of the body increases and the dilation is positive.

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 are stress and strain?

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2.5 THREE STAGES OF DEFORMATION

If a body is subjected to directed forces lasting over a short period of time—minutes or hours—it usually passes through three stages of deformation, although in brittle substances the intermediate stage may be omitted. At first, the deformation is elastic; that is, if the stress is withdrawn, the body returns to its original shape and size. There is always a limiting stress, called the elastic limit; if this is exceeded, the body does not return to its original shape. Below the elastic limit, the deformation obeys Hooke's law which states that strain is proportional to stress.

If the stress exceeds the elastic limit, the deformation is plastic; that is, the specimen only partially returns to its original shape even if the stress is removed. Steel rods under tension, for example begin to get thinner or "neck" in the middle, and, even after the stress is released, the constriction remains in the rod.

When there is a continued increase in the stress, one or more fractures develop, and the specimen eventually fails by rupture.

Brittle substances are those that rupture before any significant plastic deformation takes place. Ductile substances are those that undergo a large plastic deformation before rupture. After the elastic limit has been exceeded, ductile substances undergo a long interval of plastic deformation, and in some instances they may never rupture.

2.5.1 Elastic Deformation

At room temperature and pressure, and under stress applied for a short period of time, most rocks are brittle. They behave elastically until they fail by rupture. For such rocks the elastic limit or yield points is the stress at rupture. Ideally an elastic substance will return to the original shape after the deforming stress has been removed, although there may be a slight delay as unloading occurs.

Elastic deformation is primarily of importance in analyzing tidal deformation of the solid earth and in investigating the transmission of seismic waves through the earth. It is of even more direct significance to structural geology in studying elastic rebound associated with earthquakes, in the fracturing of rocks to produce joints and faults, and in certain aspects of folding. Although most structural features observed by structural geologists are the result of deformation beyond the elastic limit, the same parameters of length, mass, time, and force are involved.

2.5.2 Plastic Deformation

Although most rocks at room temperatures and pressure fail by rupture before attaining a stage of plastic deformation, most rocks, at sufficiently high temperatures and confining pressures deform plastically even in experiments lasting for a short time. This plastic deformation is not recoverable or is only partially recoverable. This is, if the stress is removed, the material does not return to its original shape.

In much experimental work the deformation of rocks results from internal adjustments within the mineral grains, notably gliding and dislocation. Hence metallurgists tend to confine the concept of plasticity to such deformation. But in nature other factors are also important, notably the rotation of grains and recrystallization.

2.5.3. Rupture

Rocks, when subjected to stress, deform elastically. Under atmospheric pressure and room temperature most rocks are brittle and fail by rupture at the elastic limit. But under high confining pressure and high temperatures most rocks undergo plastic deformation above the elastic limit. But under sufficiently high stress they may eventually fail by rupture.

Several factors are of concern: (1) the nature of the deformation preceding rupture; (2) the physical conditions at the time of rupture; (3) the stresses necessary to cause rupture; and (4) the orientation of the fractures relative to the causative stresses.

All ruptures may be classed as tension fractures and shear fractures. Tension fractures result from stresses that tend to pull the specimen apart. When the specimen finally breaks, the two walls may move away from each other. Shear fractures result from stresses that tend to slide one part of the specimen past the adjacent part. When the specimen finally breaks, the two walls may slide past 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.

3. What are the three stages of deformation?

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2.6 FACTORS CONTROLLING BEHAVIOR OF MATERIALS

The mechanical behavior of rocks is controlled not only by their inherent properties - mineralogy, grain size, porosity, fractures, etc. - but also by factors that are of little or no concern in planning man-made structures at the surface of the earth. These factors are confining pressure, temperature, time, and solutions.

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. What are the factors controlling the mechanical behaviour of rocks?

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2.7 SUMMARY

Structural geologist must know the mechanical principles involved in rock deformation. Rock deformation will occur with internal forces or with external stress. Force is defined as a vector quantity that change or tends to produce change in the motion of a body. Forces are two types an unbalanced force and balanced force. An unbalanced force tends to change in the motion of a body where as balanced force exists where no change in motion. As velocity of rock bodies is less balanced forces are important to geologists. The pressure on a small body immersed in a liquid is hydrostatic pressure. The overlying rocks exert pressure on underlying rocks and is called lithostatic pressure. The all sided pressure on solids is confining pressure. A body is said to be under tension when it is subjected to external forces that tend to pull it apart. A body is said to be under compression when it is subjected to external forces that tend to compress it. A couple consists of two equal forces act in opposite directions in same plane. Torsion results from twisting.

The mutual action and reaction along a surface constitutes a stress. There are compressive stress, tensile stress and shear stress. Strain is the deformation caused by stress. It may be dilation, a change in volume or distortion, a change in form or both.

In the process of deformation there are three stages. At first the deformation is elastic, that is if the stress is withdrawn the body will return to its original size and shape. If the stress exceeds elastic limit, the deformation is plastic, that is the specimen only partially returns to original shape. When there is a continued increase in stress one or more fractures develops and the specimen eventually fails by rupture.

The mechanical behaviour of materials or rocks are controlled internally by mineralogy, grain size, porosity, fracture etc. and externally with confining pressure, temperature, time

2.8 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Rocks in the lithosphere because of the weight of what ever rocks above them are subjected to a kind of pressure known as lithostatic pressure.
2. The mutual action and reaction along a surface is stress, and deformation caused by stress is strain.
3. Elastic deformation, plasuc deformation and rupture are the three stages of deformation.
4. The mechanical behavior of rocks are controlled internally by mineralogy, grain size, porosity, fracture etc. externally by confining pressure, time, temperature solutions etc.

2.9 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in about 30 lines each.
 1. Explain about force, stress and strain.
 2. What are the three stages of deformation? Explain in detail.
- II. Answer the following questions in about 10 lines each.
 1. Hook's Law
 2. Factors controlling mechanical principles in Rocks.

* * *

UNIT - 3 FIELD PROCEDURES

Contents

- 3.0 Objectives
- 3.1 Introduction
- 3.2 Study of Out Crops
- 3.3 Geological Mapping
 - 3.3.1. Components of a geological map
 - 3.3.2. Structural elements
- 3.4 Summary
- 3.5 Check Your Progress - Model Answers
- 3.6 Model Examination Questions

3.0 OBJECTIVES

This Unit aims to make you aware of the field procedures and its applications in the field. At the end of this Unit, you will be able to:

- * define the character of out crops
- * describe the geological maps
- * explain distribution of rock formation within an area.

3.1 INTRODUCTION

Field work forms the first and the most essential phase of activities connected with structural geology. The structures are to be studied in their natural setting. In doing so, the structural geologist is concerned with a descriptive analysis of the structures which includes recognizing the structures, measuring their orientations and describing their physical and geometrical components. He has to make a direct observation and of the field relationship, probe the subsurface features through drilling or geophysical methods and study the stratigraphy and petrography of the rocks in which the structures occur. In a sense descriptive analysis required geologic mapping of rocks and structure, measuring the physical dimensions of structures using tape, scale, surveying instruments on topographic map, measuring the orientations of structures with a compass-clinometer; plotting graphically the orientations of structures; determining orientations of minerals in thin sections of deformed rocks using a microscope; and examining the geological characteristics of fracture patterns with the help of aerial photographs.

3.2 STUDY OF OUT CROPS

Rocks, beds or formations sometimes project through the overlying cover of detritus or soil and thus become exposed. These exposures are called outcrops. Geologists search for outcrops where they can study the character of the rock formations. This is the first step in geological field work. The rocks are described in a suitable field note book in terms of their colour, mineralogy, textures, primary features, topographic expression of rocks and structures, weathering characteristics and the nature of bedding or foliation. Finally the name of the formation, if known, is entered. If the outcrop disclosed a contact with some other rock formation,

the contact relationship and the nature of the contact, whether depositional, deformation or igneous, are also described.

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 the scope of geological field work?

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2. Define the term out crop.

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3.3 GEOLOGICAL MAPPING

Geological mapping is the art of descriptive analysis in structural geology. The geologic map provides an image of the distribution of rock formations within an area. It also discloses the form and structural pattern of rock bodies. Even the internal structures are sometimes represented on the geologic maps. In effect, the geological map is a two-dimensional sheet of paper disclosing the three-dimensional description of rocks, structures and contacts in a given area, through the use of standard symbols.

In the geological mapping, the initial step is selecting a suitable base on which mapping can be carried out. The traditional base for geological mapping is the topographic map. The topographic map show details of physiography (ground elevations, drainage etc) and culture (town and related details) with the help of which the positions of structures and contacts can be accurately indicated. Topographic maps for different areas are prepared and published by the survey departments of the government (in India by survey of India). In some cases however, topographic maps may have to be prepared as part of the geologic mapping process, particularly when there is a need to carry out large-scale mapping of small area to unravel the three dimensional structure forms of the area. Large scale topographic maps can be constructed through the use of the plane table and alidade. In some cases aerial photographs serve as the most valuable base for geological mapping.

3.3.1. Components of a geologic map

The geologic map shows the distribution of rock formations in an area by means of colour and/or pattern and letter symbols. Each colour, pattern or symbol on the map should coincide exactly with the distribution of the corresponding rock formation. The meaning of the colours, patterns and symbols is given in the explanation.

Each formation shown on the geological map is enclosed by a contact except where the formation extends outside the map area. These contact lines are usually of two types-lithologic (depositional and intrusive contacts) and fault contacts. Lithologic contacts are represented by thin lines and fault contacts by thick lines.

After mapping the rock formations, the geometric and physical nature of the structures present, like bedding, foliation, faults, joints, folds, cleavage and lineation is indicated through standard symbols. The size and orientations of the features shown on geologic map can be understood with the help of the scales and north arrows given on the map. The map becomes complete when the borders are drawn and title given. The title conveys the name and general location of the map area.

3.3.2 Structural Elements

There are many major and minor structures and many different types of each major structure also occur in nature. In order to make a complete descriptive analysis of the structure, it is necessary to identify and describe the concerned structural element. Structural elements are the physical and geometric components of structures. The physical elements are real and visible and their shape, size and orientations can be measured. The geometric elements, on the other hand, are imaginary lines and surfaces, with the invisible but can be identified in the field. They too have shapes, sizes and orientations which are measurable.

In describing the physical and geometric elements, measurements are required to be made for features some of which are linear and other planar. All linear geologic features like the grooves on a fault surface or lineation are called linear elements. Bedding planes, joints, fault planes, dykes etc. come under planar elements.

One basic equipment that is indispensable for measuring orientations of structures in field is the compass-clinometer. This is used for measuring trend and inclination of structural elements. Trend refers to the Azimuth or bearing of a line. Azimuth is measured in degree clock-wise from north (eg. 100° , 275°). Bearing is measured in degrees east or west from north or south (eg. $N55^{\circ}E$; $S25^{\circ}W$). Inclination is the angle measured in degrees between an inclined line or plane and the horizontal. Its value may vary from 0° to 90° . Trends are measured with the compass and inclinations with the clinometer which is located inside the compass.

The orientation of a linear element in space is expressed in terms of trend and plunge, the latter being a measure of inclination. While the trend is measured in a horizontal plane, plunge is measured in a vertical plane containing the line. Plunge is the angle between the line and the horizontal in the vertical plane.

The orientation of a planar feature is given by measuring the orientation of two lines in that plane is determined by two lines. Any two lines which are not parallel can be chosen. For convenience two lines in a plane one a horizontal line and the other a line at right angles to it are chosen strike and dip. The first is called the line of strike and the second the line of the dip.

Strike and Dip

Strike and Dip are the two measurements required to define the attitude or three dimensional orientation of a plane. The strike of a plane or a planar feature like bedding is its trend measured on a horizontal surface, or more precisely, it is the trend of a line formed by the intersection of the planar feature and horizontal plane. It is expressed in terms of degrees of azimuth (50°) or bearing ($N50^{\circ}E$).

The dip of a plane or planar feature is the angle between the plane and a horizontal plane measured in a vertical section that is at right angles to the strike. It is expressed in terms of the angle of inclination and the direction. The dip direction is not directly measured because

it can be determined from the strike direction. For example a plane with N 50°E strike, will dip either N40°E or S40°W. In field work, the dip is always measured in a vertical section which is at right angles to the strike as mentioned above. This dip is called **true dip**. The angle of inclination measured in a vertical section which is not at right angles to the strike, is called apparent dip. While there can be only one true dip, there can be many apparent dips depending on the direction of the vertical section. Apparent dip is always less than true dip. The strike and dip along with the symbols used for them are illustrated in (figure.3.1) the upper part of each figure is a block diagram and the lower part a plan or map. The attitudes of inclined, horizontal and vertical beds are shown. In all cases strike is north. The dip in 60°E in A, 0° in B and 90° in C.

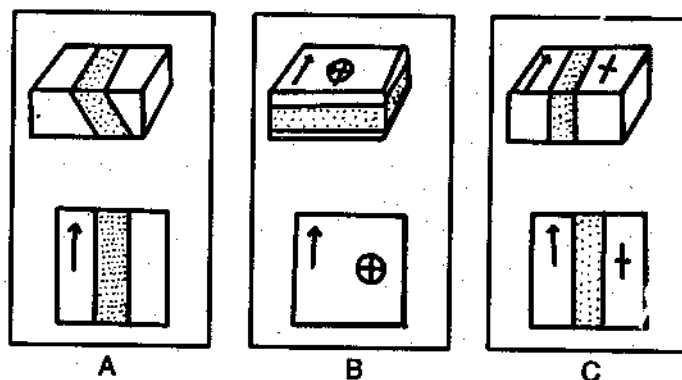


Fig. 3.1 Dip - Strike Symbols

A. Inclined bed B. Horizontal bed C. Vertical bed.

The strike and dip are measured with the help of the compass clinometer. The strike is measured with the help of the compass and the dip with clinometer. For a detailed description of the compass-clinometer and the method of using it any book on field geology (Ref: Manual of Field Geology-by Crompton; Field geology by Lahee) can be referred.

The relationships of formation shown in the geological map and the structural data collected through measurements in the field form the basis for understanding the physical and geometric characters of different structures through the preparation of profiles, projections and plots.

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 is a Geological Map?

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3.4 SUMMARY

Field work is very vital for geologist because structures are to be studied and mapped. In order to do field work field procedures are important to study. The structures are to be

studied in their natural settings. It includes recognising the structures, measuring their orientation and describing their physical and geometrical components. The geological field work required geologic mapping of rocks and structures. The Major requirements to conduct geological field work are toposheet, scale, tape, surveying instruments and clinometer compass.

Rocks, beds of formation sometimes project through the overlying cover of detritus or soil and thus become exposed, and are called as out crops. Study of out crops begins the duty of field study. These out crops are described in terms of their colour, mineralogy, textures, primary features topographic expression, weathering characteristics and nature of bedding or foliation.

Geological mapping is the art of field work. This geological map provides an image of the distribution of rock formations. Geologic map is a two-dimensional sheet of paper disclosing the three dimensional description of rocks, structures and contacts in a given area. The base map for geological mapping is the toposheet. The contact lines are of two types one is lithologic and the second is fault contacts. The features are like bedding, foliation, faults, joints, folds, cleavage and lineation. The orientation of a linear element in space is expressed in terms of trend and plunge. Plunge is the angle between a line and horizontal in the vertical plane. Strike and dip are the two measurements required to define the attitude or three dimensional orientation of a plane. The strike of a plane or a planar feature like bedding is its trend measured on a horizontal surface. Dip of a plane or planar surface is the angle between horizontal plane and bedding plane. These two are measured with the help of clinometer compass.

3.5 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Geological field work is essential to map the field characters like structures, mineralogy, petrology for further interpretation
2. The area, strip of ground, line or place where a rock-body or a rock surface (bedding surface, fault or any other) emerges at the earth's surface is known as "Out Crop". The term "Out Crop" is also used as a verb, derived from the substantive, but some prefer to use 'crop out'.
3. Geological map is a two dimensional sheet of paper disclosing the three dimensional description of rocks; structures and contacts.

3.6 MODEL EXAMINATION QUESTIONS

- I. Answer the following question in about 30 lines each.
 - I. Write down the field procedures for the determination of structures?
- II. Answer the following questions in about 10 lines each.
 - I. Geological map and its components.
 2. Structural elements.
 3. Strike and dip.
 4. True dip and apparent dip.

* * *

UNIT - 4 PRIMARY STRUCTURES

Contents

- 4.0 Objectives
- 4.1 Introduction
- 4.2 Sedimentary Structures
 - 4.2.1 Stratification or bedding
 - 4.2.2 Graded Bedding
 - 4.2.3 Cross Bedding
 - 4.2.4 Pebble Imbrication
 - 4.2.5 Marking on Bedding Planes
 - 4.2.6 Mud Cracks
- 4.3 Igneous Structures
 - 4.3.1 Flow and other structures in lava
 - 4.3.2 Columnar Jointing in lavas
 - 4.3.3 Flow structures in plutonic rocks
- 4.4 Importance of Primary Structures
- 4.5 Summary
- 4.6 Check Your Progress - Model Answers
- 4.7 Model Examination Questions

4.0 OBJECTIVES

In this Unit we shall present a brief description and importance of Primary Structures - Sedimentary and Igneous Structures.

At the end of this unit, you will be able to

- * describe the Primary Sedimentary Structures
- * describe the Primary Igneous Structures.
- * explain the importance and applications of primary structures.

4.1 INTRODUCTION

Primary structures are those that are present in rock before the onset of deformation. They are called primary because they are the original features of sedimentary or igneous rocks resulting from deposition or emplacement. In sedimentary rocks primary structures form before lithification and in igneous rocks during the flow and later-stage congealing of magma, before and during final crystallisation. Metamorphic rocks do not possess primary structures because they are formed secondarily from pre-existing rocks.

Primary structures of sedimentary origin include :

1. Stratification or bedding.
2. Graded bedding.
3. Cross bedding.
4. Pebble imbrication
5. Markings on bedding planes.
6. Mud cracks

Primary structures of igneous origin include :

1. Flow and other structures of lavas.
2. Columnar jointing in lavas.
3. Flow structures in plutonic igneous rocks. Foliation and lineation.

4.2 SEDIMENTARY STRUCTURES

Sedimentary structures are those which are observed in sedimentary rocks. These structures are formed with the origin of sedimentary rocks.

4.2.1 Stratification or Bedding

Stratification or bedding is a fundamental primary structure in sedimentary rocks. No structure of sedimentary rocks is more universal than stratification. The beds may vary from massive layers to delicate laminae. They are separated from each other by bedding planes. Stratification arises from variations in one or more physical or chemical characteristics of sediment which occur vertical to the bedding. Some of the factors that cause stratification are difference between layers in (1) Chemical composition, (2) Colour, (3) Grain size, (4) Degree of sorting, (5) Degree and type of packing, (6) Cohesion, (7) Cementation, (8) Permeability or porosity and (9) Resistance to erosion.

The nature of the layers, the arrangement of material within the layers, features on the bedding planes, sometimes the layer shape of the sedimentary unit depend on the conditions like the depth of water, nature of current under which the sediments is deposited. As **E.S. Hills** observes it is the sum of its lithological features that characterizes a bed, with the implication that it was laid down under a particular set of conditions, either uniform or systematically varying.

Stratification may result directly from sedimentation as in the case of varves, layering in deep sea carbonate and siliceous oozes, evaporites and chemical precipitates in general. Stratification may be produced indirectly when the water is agitated so that sediment is reworked and the sediment deposited previously may be broken up and redeposited. This occurs most commonly in shallow water. Some bedding may be produced under combined conditions of direct and indirect stratification.

4.2.2 Graded Bedding

Sediments are said to be graded when there has been a sorting of sizes and the sediments are separated vertically to some extent within the sequence. Graded sediments show a gradual decrease in grain size from bottom to top of the layer. Graded bedding is produced due to the settling of suspended materials from a rapidly flowing, sediment, laden current when it experienced a sudden decrease in the velocity of flow. Turbidity current deposits usually show graded bedding (Fig 4.1)

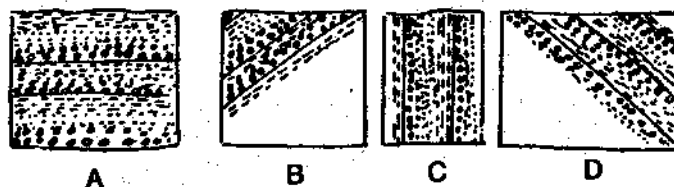


Fig. 4.1 Graded Bedding

- A. Normal horizontal beds each bed get thinner towards the top. B. Dipping beds right side up.
C. Vertical beds top towards right. D. Dipping beds over turned.

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. Bedding or Stratification can be marked by

2. The bedding showing gradation in grain size is known as

4.2.3. Cross Bedding

Cross bedding, also called false bedding or current bedding, is characterised by bedding or lamination oriented at an angle to the true bedding at both the upper and lower extremities. In their most diagnostic form, the cross beds or cross-laminations are tangential to the lower bedding surface and are sharply truncated along the upper surface. Cross bedding is inclined in the general direction of the sediment transport and current flow. Truncation of the upper ends of cross-beds is due to erosion shortly after deposition. While it is true that the truncated edge is the top edge in cross bedded strata, in some cases, however, the intersection of the foreset beds (in deltas) with the lower beds can be quite abrupt. This leads to the information of cross bedding which is truncated at both top and bottom (Fig. 4.2)



Fig. 4.2 Cross bedding

- A. Normal Cross bedding.
B. Torrential Cross bedding

Cross bedding develop in many different environments, including dunes, rivers, beaches, shallow seas and deltas and it is a useful indicator of current direction.

4.2.4 Pebble Imbrication

Pebble imbrication is characterised by overlapping of disc shaped or flat pebbles laid down in the beds of streams or on stony beaches. These pebbles are often piled against each other, leaning at an angle. These are called edgewise conglomerates.

In streams the pebbles lean down-stream and on beaches away from the water's edge. Thus these become valuable in interpreting current direction and direction of source are for the conglomerates. Such cross bedding called torrential cross bedding, is supposed to develop under conditions of rapid sedimentation.

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. Define "Current bedding".

4.2.5 Markings on Bedding planes

Marking on bedding planes may be of both inorganic and organic origin. The inorganic markings include ripple marks, channels, rain prints, sole markings, load casts etc. The organic markings include tracks, trails burrows etc.

Ripple marks are repeated wave forms seen on sand, silt and mud. These may be produced in shallow water due to the action of currents, waves and the play of wind on the surface of the water or by wind action at the surface of the earth. (Fig. 4.3)

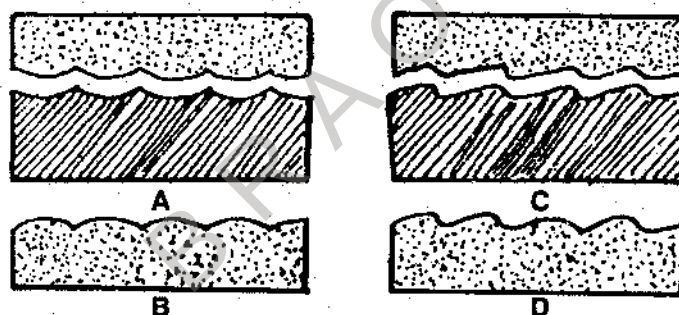


Fig. 4.3. Ripple marks

- A. Original Oscillation ripple marks (bottom)
- B. Over turned cast of oscillation
- C. Original current ripple mark (bottom) and cast top
- D. Over turned cast of current ripple marks.

Two types of ripple marks are commonly seen. The oscillation ripple marks have a symmetrical concave form. They consist of broad troughs that are convex downward and sharp crests that point upward. These are formed in bodies of standing water. The current ripple marks, on the other hand, are asymmetrical. Both the crest and trough are rounded. These ripple marks develop when a current either of water or air moves across sand or mud. These are useful in finding out the direction of the current.

During the accumulation of sediments, particularly by river action, erosion may alternate with deposition. After the deposition of a sediment, channels may be curved on them by swiftly

flowing streams during flood time. As the flood was subsiding these channels may be filled with gravel which truncates the bedding of the original sediment (Fig.4.4)

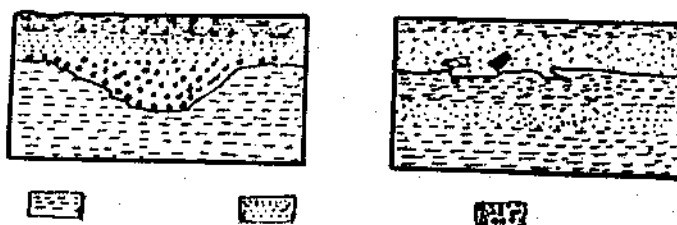


Fig. 4.4. Channelling

- A. Channel cut into shale filled up by conglomerate.
- B. Fragments of shale deposited in overlying sandstone.

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. "Ripple marks have wide application in sedimentology" Name them.

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Rain drop impressions are another common type of marking found on bedding planes. Rain drops leave imprints in soft sediment in the form of small craters with rimmed edges, which are preserved in the consolidated rock.

Sole marks are so named because they are best preserved on the underside or sole of a bed. They are certain irregularities occurring in the interface, that is along the bedding plane between sandy mud below and sand or silt above. After the deposition on the mud and before the deposition of sand or silt over it, irregular depression are cut and scoured on the top of the mud, due to current erosion or material being dragged or bounced across the surface. Some of the depression may be animal tracks also. These depression are filled by sand or silt during the burial of the mud. After lithification the sand or silt casts filling the depression indicate the sizes and shapes of the original bottom markings. The marking become exposed on the underside of a sandstone or a siltstone bed when the underlying shale is removed by erosion.

Load casts are structures which are believed to have developed in soft sediment under the influence of gravity. The structure is generally found at the interface between a sandstone above and a mud stone or coal below. It is supposed to form by the sand sinking into the underlying sediment which, due to its high water or gas content is very ductile and less dense than the overlying sand. One property is very common among all load cast structures the coarser one of the two beds forming the deformed interface is the younger of the two.

Organic markings are produced by animals living in shallow water. Many of these animals leave tracks or trails which are preserved in the consolidated sediments. The tracks and trails consist usually of furrows and ridges left in a pattern which is typical of the animals.

Some animals bore into the sediments. Many invertebrates burrow in sediments producing tube like bores. Foot prints of animals are also commonly preserved, especially in soft sediments.

4.2.6 Mud Cracks

When the wet mud of a river bottom or lake bed or beach dries out, it will characteristically become broken into polygonal blocks that are bounded by mud cracks or sun cracks. These cracks result due to the evaporation of water in the drying mud and the consequent shrinkage. Mud cracks, when filled by sand, may be preserved. Those found in ancient sediments are used to interpret depositional environments.

4.3 IGNEOUS STRUCTURES

These structures are seen only on igneous rocks. These are formed along with the solidification of primary magma.

4.3.1. Flow and other structures in Lavas

The primary structural characteristics of volcanic rocks are largely dependent on the flow of the lava, which in turn is controlled by the viscosity of the lava and the physical environment of extrusion. Chemical composition has great influence on viscosity, although temperature and gas content also are important factors. Mafic or basaltic magmas have low viscosity and are very fluid, whereas felsic or rhyolitic magmas possess high viscosity and thus tend to be very stiff. The difference in fluidity of basaltic and rhyolitic magmas partly accounts for the dominantly extrusive habit of basalt and dominantly intrusive habit of granites. The physical environment of eruption also has influence on the structure of the lava flows, as for example eruption of lava under water versus eruption under air. Rates of cooling differ in these two settings. Similarly the steepness and roughness of topography also influence the flow movements including relative speed.

Of all flow structures, ropy lava is the most impressive. Pillow structures, Vesicular structures and Amygdaloidal structures are the other common structures of lavas.

4.3.2. Columnar Jointing

The columns which are very characteristic of some basalt flows are produced by columnar jointing, a fracturing that occurs during the final congealing and shrinkage of the flow. The columns tend to be polygonal because the fracturing is polygonal as in the case of mud cracks. Orientating of the columns may sometimes reveal the direction of the lava flow. Columns may locally plunge toward the rear of the flow. The columns tend to be polygonal because the fracturing is polygonal as in the case of mud cracks. (Fig. 4.5)

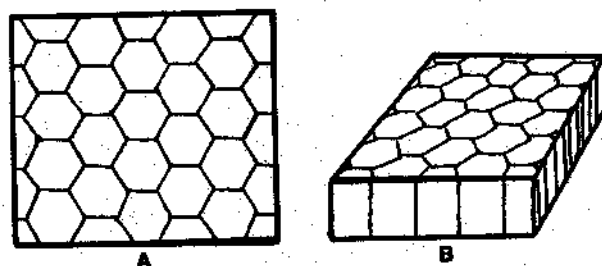


Fig. 4.5 Columnar jointing

A. Plain View

B. Block diagram

4.3.3. Flow Structures in Plutonic Rocks

In plutonic bodies, flow structures form relatively early in the process of emplacement of magma and they continue to form until the mass becomes rigid. Primary fractures form late.

The flow characters of a pluton are reflected often in the alignments of crystals. The most commonly occurring crystals which are useful in the study of alignment patterns are the needle-like crystals of hornblende, tubular crystals of felspar and platy mica. Elongate minerals like hornblende and felspar on alignment produce lineation. (Fig. 4.6) Mineral lineation is commonly oriented parallel to local flow direction. Tabular and platy minerals, when aligned produce flow foliation (Fig. 4.7) in igneous bodies. Foliations in igneous rocks are typically produced by parallel arrangement of mica sheets or parallelism of the broad 010 faces of felspar crystals. Foliation reflects laminar flow of the intruding magma.

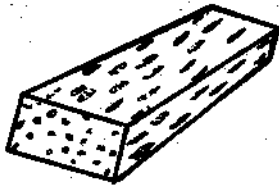


Fig. 4.6 Lineation



Fig. 4.7 Foliation

Alignments of Xenoliths and inclusions also help in understanding the primary internal structure in plutonic bodies.

In addition to foliation and lineation, which are produced in a relatively early stage of crystallisation of magma, plutonic bodies are also characterised by fractures produced at later stage, before final crystallisation, as a natural response to the thermodynamics of intrusion. These are primary fractures exhibit a geometrical co-ordination with the primary foliation and lineation. They may be filled with aplite or pegmatite dykes genetically related to the magma or with veins produced by late stage hydrothermal solutions circulation within the still hot body.

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 are the names of igneous Structures?

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4.4. IMPORTANCE OF PRIMARY STRUCTURES

1. As guide to deformation

Evaluation of primary structures, the sedimentary structures in particular, is useful in many ways. They are useful in the interpretation of the structure of deformed areas. It is only through a proper understanding of the primary shape and attitude of strata that we are able to perceive that they are deformed and measure the amount of deformation. For example, if there were no bedding in sedimentary rocks, there would be far less evidence of deformation in deformed rocks. This point becomes clear when we consider the case of deformed igneous rocks. In such rocks, there may be abundant microstructural evidence which indicates deformation, but because the shape of the various units before deformation is not known, it is generally difficult to interpret or predict the structure with confidence. But interpretation of a deformed, bedded sequence can be done with more confidence because it can be assumed that the bedding was initially more or less planar.

Primary structures provide considerable information on the tectonic environment. In the study of deformed rocks the ultimate aim is to understand the total history of a deformed rock and not just its deformational history. Further more, the processes of deposition deformation may not necessarily be isolated in time. For example, the history of a mountain chain may show an intermingling of the processes of deposition and deformation in such a way that the type of sediment being deposited can often provide clues for understanding the tectonics. For example, an unusually thick sequence of shallow water sediments (as indicated by primary structures) must have been deposited in a gradually subsiding basin, because otherwise the lowest members of the sequence would show deep water features.

2. As evidence for distinguishing top from bottom beds

Primary structures are very useful in recognizing the top and bottom of beds, and therefore in arriving at the correct sequence of rock formations. In this connection ripple marks, graded bedding, cross bedding, sole marks, load casts and mud cracks are of particular importance. The original ripple mark or its cast may be preserved in sedimentary rocks. Oscillation ripple marks can readily be used to know whether a bed is right-side up or overturned. The sharp crests whether in the original or in the cast point toward the younger strata, in other words point upwards. Current ripples cannot be used to distinguish top from bottom because an overturned ripple has the same form as the one which is right-side up. (Fig. 4.8)

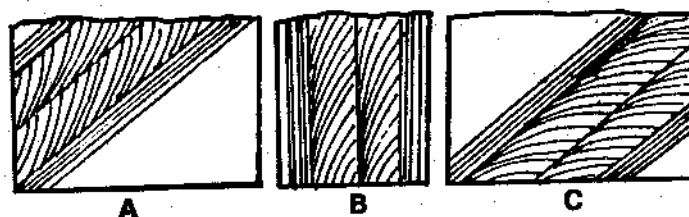


Fig. 4.8 Determination of top of beds with the help of cross bedding

A. Beds are right side up. B. Top is to the right. C. Both are overturned

In graded bedding, the grains are progressively finer from bottom to top. In cross bedding, the cross beds are tangential at the lower surface but are sharply truncated at the upper surface. The sole marks and load casts point downwards.

Mud cracks are preserved by becoming filled with sand or mud of a different formation. When exposed to weathering, the original mudstone with mud cracks slowly disintegrates leaving behind casts of the cracks on the lower surface of the overlying sandstone. In a similar way rain

prints, organic markings or even fossils when preserved properly can offer evidence for distinguishing the top of a bed from its bottom.

In pillow lavas, the tops and bottoms of the pillows are generally convex upward. Vesicular and Amygdaloidal structures are characteristic of the tops of lava flows. (Fig. 4.9)

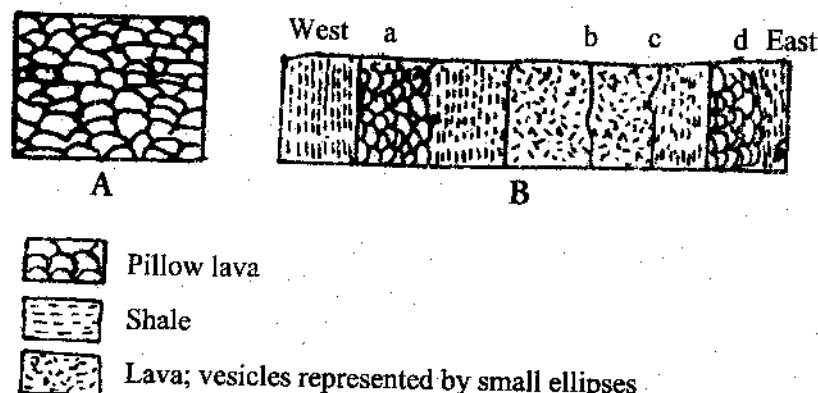


Fig. 4.9 Top of lava flows

- A. Pillow structure right side up.
- B. Pillow vesicles structure indicate that the top is to the right.

In addition, primary structures, when studied carefully, after information concerning the source of sediments, the depth of deposition and the direction of movements of current and materials, in other words, concerning the environment of deposition.

4.5 SUMMARY

Primary structure are those that are present in rocks before the on set of deformation. They are the original features formed during the deposition one can observe primary structures only in sedimentary and igneous rocks. Metamorphic rocks do not possess primary structures. Primary structures are of two types namely primary structures of sedimentary origin and primary structures of igneous origin.

Primary structures of sedimentary origin are stratification, graded bedding, cross bedding pebble imbrication, marking on bedding planes, mud cracks etc. Generally stratification develops from variations in one or more physical or chemical characters of sediment. In graded bedding sediments are graded with sorting of grain size, and will show gradual decrease in size from bottom to top of the layer. Cross bedding is characterised by bedding or lamination oriented at an angle to the true bedding at both the upper and lower margins. Pebble imbrications are charecterised by overlapping of disc shaped or flat pebbles laid down in the beds of streams on stony beaches.

Markings on bedding planes are represented both organic and inorganic origin. The in-organic markings includes ripple marks, channels, rain prints, sole markings, load casts etc. The organic markings include tracks, trails, burrows etc. When the wet mud of a river bottom or lake bed or beach dries out, it will charactergtically become broken into polygonal blocks that are bounded by mud cracks or sun cracks.

Igneous structures are grouped as flow structures, columnar jointing, foliation and lineation. Flow structures are mainly represented by volcanic rocks, ropy lava, pillow structures, vesicular structures, amygdaloidal structures etc. Columnar jointing is the characteric features of basalts. In this, fracturing occurs during the contraction of magma. Foliation and lineation are the other plutonic structures.

Primary structures are very important as guides to know about deformation and as evidences for the determination of top beds from bottom beds, Primary structures are also useful in studying the depositional environment.

4.6 CHECK YOUR PROGRESS - MODEL ANSWERS.

1. a) Difference of composition b) Difference of colour c) Hardness and texture
2. Graded bedding
3. In current bedding major bedding planes are parallel and with subsidiary bedding planes, running in different directions. The subsidiary bedding planes indicate the direction of current flow.
4. a) Paleocurrent and flow analysis
b) Depth of water in which they are formed
c) Stratigraphic order
5. 1. Flow and other structures in lavas.
2. Columnar jointing
3. Flow structures in plutonic rocks.

4.7 MODEL EXAMINATION QUESTIONS

- I. Answer the following question in about 30 lines each.
 1. Explain the importance of Primary Structures.
- II. Answer the following questions in about 10 lines each
 1. Mention the primary structures seen in sedimentary and igneous rocks.
 2. Explain the following.
 - a. Stratification
 - b. Cross Beddings
 - c. Ripple marks
 - d. Columnar jointing
 - e. Foliation and Lineation

* * *

**BLOCK - I STRUCTURAL GEOLOGY -
FUNDAMENTALS**

BRAOU

For field work and in the preparation of geological maps, topographic maps are used as base maps. During field work as much data as possible is collected and recorded from as many outcrops as possible, because it is only then that a geologist will be in a position to interpret the data and arrive at the correct geological setting of the area. Much of the information necessary is usually gathered from direct observation either in-outcrops or in pits or mines. But in recent times this is being supplemented by data collected from the depths of the earth (sub surface geology) by indirect means. Vast amounts of data are obtained from the study of drill hole data and from geophysical investigations.

Aerial photographs are also of immense use in geological mapping as they often disclose structural features, which are missed in normal mapping. In recent times the technique of 'remote sensing' through orbiting satellites is being widely employed for obtaining imagery photographs.

After arriving at a conclusion regarding the possible structure based on the facts available after representing it in the proper way through maps, sections, diagrams etc., the geologist is faced with the problem of explaining the origin of the structure and fit it into the geological history of the area or the region or of the whole earth, if possible. The conditions of temperature and pressure at the time the structural feature developed, the nature and distribution of forces as also the movements responsible for the deformation and such other factors involved in the evolution of the structure are to be carefully interpreted. Experimental studies provide significant data for understanding the process of deformation. Although it is difficult to produce in the laboratory the conditions that exist in the earth to consider all the variables involved, much knowledge is gained and information gathered through the use of specially conceived apparatus and through experiments involving application of known forces on rocks.

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. Remote sensing is used for obtaining - photographs

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1.4 APPLICATION OF STRUCTURAL GEOLOGY

The study of structure is fundamental to the understanding of how crustal rocks have responded to physical processes that have been operating through out the long geological time, Masses of crustal rocks, from the size of specks to the size of continent have been shifted, rotated, uplifted and distorted in response to earth forces. Structures like faults, folds, joints cleavage, foliation and lineation are abundant in the earth's crust because the rocks in which these structures are found were forced to change their size, shapes, and even their position.

As mentioned earlier students of structural geology learn to recognize and describe the structure, measure the structural elements and understand the methods of interpreting

the displacements, rotations and distortions that gave rise to the structure. By integrating this knowledge with theoretical concepts and experimental data, one can analyse the nature of crustal deformation. All this structural analysis has an important bearing on our understanding the formation and structural control of natural resources, especially energy resources and metallic mineral deposits.

The knowledge of the structure of rock bodies is basic to the understanding of other aspects of geology. Structural knowledge is of great importance in applied fields of geology such as ground water hydrology, mining geology and engineering geology. In all these fields it is essential to learn about the subsurface configuration of rock bodies as well as their surface distribution. The occurrence of oil pools, the size and shape of ore bodies or other economically important rock formations such as coal or limestone and distribution of ground water are very often controlled by geological structures and as such a detailed knowledge of structures forms a prerequisite for successful and economic exploitation of each resources.

In the field of engineering geology also, selection of sites for dams, bridges and such other projects is based on the proper evaluation of the foundation rock, particularly with reference to its structure as the presence, for example, of an active fault may endanger the engineering construction.

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. Describe where the knowledge of structural geology is useful?

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1.5 STRUCTURAL GEOLOGY AND ITS RELATION TO OTHER BRANCHES OF GEOLOGY

The scope of 'structural geology' has been explained in the foregoing paragraphs. Some geologists use the terms 'tectonics' or 'tectonic geology' with the same meaning as 'Structural geology'. Some however, consider structural geology is to be concerned with the geometry of the rocks within an area. The study of a small area naturally leads the structural geologist to consider the 'setting' of his area in the broader frame-work of the surrounding region. He desires to fit the beds, folds and faults he mapped into the pattern of the folded or faulted belts of the whole country and ultimately proceeds to think on a continental scale. Although such investigations, irrespective of the size or area, also come within the scope of structural geology, traditionally the wider aspects of continental and oceanic and eventually of global structures are referred to as 'tectonics' or 'tectonic geology' or 'geotectonics'. Discussions on major fold belts, fault zones and the like which require a thorough understanding of the nature of the earth's deep interior, form the subject matter of 'tectonics.'

BLOCK - II : STRUCTURES

BRAOU

UNIT - 5 UNCONFORMITIES

Contents

- 5.0 Objectives
- 5.1. Introduction
- 5.2 Types of Unconformities
 - 5.2.1 Angular Unconformities
 - 5.2.2 Disconformity
 - 5.2.3 Local unconformity
 - 5.2.4 Non conformity
- 5.3 Recognition of Unconformities
 - 5.3.1 Out crop characteristics
 - 5.3.2 Aerial Mapping
 - 5.3.3 Sharp contrast in the degree of induration
 - 5.3.4 Distinct difference in the grade of metamorphism
 - 5.3.5 Difference in the intensity of folding
 - 5.3.6 Relation to plutonic rocks
 - 5.3.7 Fossils
- 5.4 Importance of Unconformities
- 5.5 Summary
- 5.6 Check Your Progress Model Answers
- 5.7 Model Examination Questions

5.0 OBJECTIVES

After completion of this unit, you should be able to

- * define unconformity
- * describe types of unconformities
- * explain recognition of unconformities
- * describe the importance of unconformities

5.1 INTRODUCTION

Sedimentary beds which constitute a sequence of parallel to sub-parallel beds by virtue of their deposition in a continuous manner are said to be conformable.

During the process of deposition sedimentary layers (and volcanic layers) are deposited one over the other forming a sequence of parallel to subparallel beds. Such beds are said to be conformable. They show conformity. Conformable beds are formed during continuous deposition or during separate events so close in time that the age difference between the younger and older layers cannot be detected with the available methods. Contacts formed between beds in a conformable sequence are referred to as normal depositional contacts. These contacts are usually planar or slightly irregular in form. Normal depositional contacts are distinctive because of the properties like colour, composition, lithology, texture and thickness of the layers involved.

Depositional contact of a type different from the normal depositional contacts also occur in rocks. These are called unconformities. An unconformity is a depositional contact between two rocks of different ages. Unconformities represent breaks in the stratigraphic

sequence, that is they indicate periods of time that are not represented in the stratigraphic columns, by rock unit. This break may be due to a period of nondeposition or to a period during which previously formed rocks are eroded. Hence the unconformity is defined as a surface of nondeposition or erosion that separates younger strata from older strata. It is more commonly a surface of erosion. (Fig.5.1)

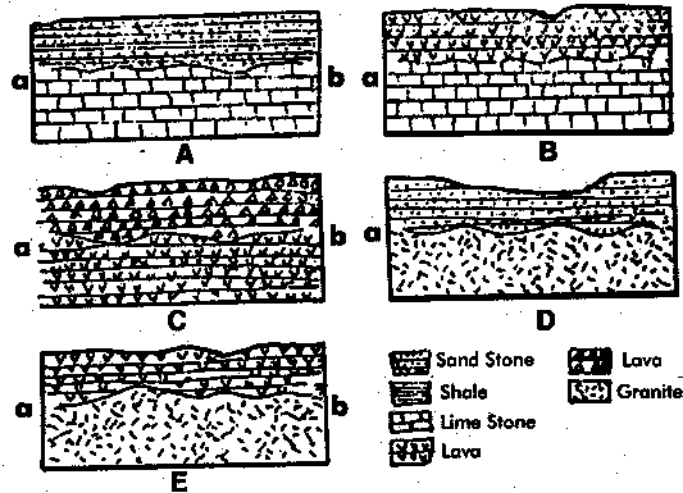


Fig. 5.1 Unconformity
a b : Unconformity

- A. Sedimentary rocks above and below.
- B. Sedimentary rocks below and volcanic above.
- C. Volcanic rocks above and below.
- D. Plutonic rocks below sedimentary rocks above.
- E. Plutonic rocks below and volcanic rocks above.

The Evaluation of the time gap or hiatus represented by and unconformity is not easy. For example, if tertiary beds rest on devonian beds it is possible that deposition originally continued through carboniferous time, the carboniferous beds having been subsequently eroded away leaving only the devonian beds. Again it is possible that deposition may be occurred at any time between carboniferous and tertiary, say during jurassic, and erosion again may have removed these rocks before the tertiary rocks were deposited. Although regional mapping will help in clarifying the situation, much will invariably remain hypothetical about any major unconformity.

An unconformity develops through several stages. First the older rocks are formed. These are later uplifted, sometimes deformed, and subjected to subaerial erosion. Finally the younger beds are deposited. Unconformities may be present between rocks of the same origins or rocks of different origins. Sedimentary rocks, volcanic igneous rocks, plutonic igneous rocks or metamorphic rocks may be involved. The rocks both above and below the unconformity may be sedimentary or they may be plutonic below and sedimentary above, or sedimentary below and volcanic above or vice versa, or plutonic below, volcanic above or volcanic both above and below and so on.

The topography of unconformities may differ greatly. In some localities it may be an extensive peneplain, the older rocks having been reduced to a uniform level by erosion. Elsewhere the relief on the unconformity may be some hundreds even a few thousands of feet indicating that only a middle strata in the cycle or erosion was reached before the younger rocks were deposited.

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 an Unconformity?

5.2 TYPES OF UNCONFORMITIES

Different types of unconformities are recognised depending upon the rocks involved and their relationship. The important varieties are - 1) Angular unconformity. 2) Disconformity, 3) Local unconformity and 4) Nonconformity.

5.2.1 Angular Unconformity

An angular unconformity is a surface of erosion that separates strata which are not parallel. The two groups of strata show differences in dip or in both strike and dip. The older strata are usually tilted or folded and subsequently eroded before the overlying strata were deposited. The younger strata are essentially parallel to the unconformity. Some angular unconformities represent many millions of years of geological time (Fig. 5.2)

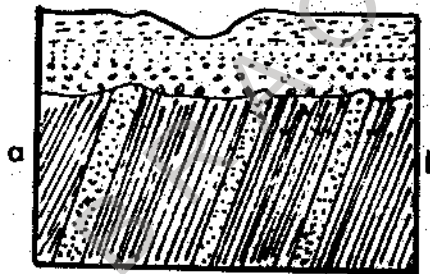


Fig. 5.2 Angular Unconformity
A. b Unconformity

5.2.2 Disconformity

In a disconformity, the strata on opposite sides of the unconformity are parallel. A disconformity covers a large area and represents a considerable interval of time. A depositional break of less magnitude than a disconformity is called diastem. Diastems are the smallest breaks recognizable in the deposition of a sedimentary series.

5.2.3. Local Unconformity

A local unconformity is a disconformity, but as the name implies it is distinctly local in extent. The time involved is very short. During the deposition of continental sediments such as gravels, sands and clays, the streams move back and forth across the basin of sedimentation. During flood time these streams scour out channels which may be many feet wide and deep. As the flood recedes the channels filled up again with sediments.

5.2.4 Non Conformity

A nonconformity is an unconformity that separates younger sedimentary or volcanic rocks from underlying older crystalline rocks (metamorphic or intrusive igneous rocks or both). The great unconformity known the **Eparchaeon unconformity** is a nonconformity. This unconformity separates the archaean crystalline rocks from the overlying younger sedimentary rocks.

Another, but a less common type of unconformity is also recognized. A surface of erosion, may sometime be covered by a thick, residual soil that grades into the underlying bed rock. Younger sediments deposited above this erosion surface may not be visible. Such a contact is called a blended unconformity.

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. Name the different types of Unconformities.

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5.3 RECOGNITION OF UNCONFORMITIES

Unconformities are some times confused with faults and igneous contacts. The following criteria, if employed with care, will be useful in recognizing unconformities.

1. Outcrop characteristics and presence of basal conglomerate etc.
2. Aerial mapping.
3. Sharp contract in the degree of induration.
4. Distinct difference in the grade of metamorphism.
5. Differences in the intensity of folding.
6. Relation to plutonic rocks.
7. Fossils.

While these criteria may indicate an unconformity, it is to be confirmed through structural mapping, subsurface exploration and biostratigraphic studies.

Unconformities can be recognised in many ways. But care should be taken to see that angular unconformities are not confused with fault contacts and nonconformities with igeous contacts.

Disconformities may be completely overlooked because they lack geometric experssion, the rocks above and below the unconformity being parallel.

The chief ways of recognizing unconformities are explained

5.31 Outcrop Characteristics

34 Observation of an unconformity in a single outcrop is the most satisfactory method of recognizing it. The outcrop may be small and only a few feet across. It may be a natural

exposure such as the side of a valley or a canyon or it may be an artificial opening such as a quarry or a tunnel.

An angular unconformity is easy to recognize because the beds on opposite sides are not parallel. The strata above any unconformity commonly show a basal conglomerate normally composed of clasts of the rock below the unconformity. However, basal conglomerates are not necessarily present along angular unconformities. Faults and dykes will be found truncated at the unconformity.

Disconformities can be recognized by sharp contrast in colour between the rocks above and below the contact, wavy nature of the contact and thin conglomerate present above the contact. It is necessary to study the regional relations in order to distinguish between a disconformity and a local unconformity. Nonconformities are to be distinguished between a disconformity and a local unconformity. Nonconformities are to be distinguished from intrusive igneous contacts. In nonconformities the rocks above usually contain fragments of the older igneous rock. In some cases the plutonic rocks may seem to grade into the overlying strata through arkose which may be many feet thick. In the case of an intrusive contact, not only metamorphic effects are seen in the adjacent strata along the contact but the dykes may penetrate the adjacent rocks.

5.3.2 Aerial Mapping

Aerial maps are often useful in recognising unconformities. When beds belonging to one group and abruptly against another bed belonging to a different group, an angular unconformity may be indicated. In a disconformity also older beds are truncated to some extent by younger beds. A nonconformity is indicated if the sedimentary rocks above contain pebbles of the plutonic rock. If dykes of the igneous rock do not cut into the sedimentary rocks or if inclusions of the sedimentary rock are not found in the plutonic rock, the contact is nonconformity. It is not an intrusive contact. Similar situations may arise even by faulting. Hence the actual contact is to be observed in the field in order to decide about its origin.

5.3.2 Sharp Contrast in the Degree of Induration

If significant difference is found in the degree of induration of sedimentary beds lying one over the other, an unconformity may be indicated. For example, if unconsolidated sands and clays occur above well-cemented sandstones and compact shales, it may be presumed that the unconsolidated sediments are lying unconformably over the consolidated rocks. However, it is to be kept in mind that unconsolidated rock may become indurated locally weathered to become loose sands and clays.

5.3.4 Disinct Difference in the Grade of Metamorphism

If two groups of rocks occurring in the same region show distinct difference in the grade of metamorphism, it is probable that the less metamorphosed rocks were formed unconformably over the more metamorphosed rocks.

The grade of metamorphism can be normally known from the nature of minerals present, particularly in the case of regionally metamorphosed argillaceous sediments. Under conditions of regional metamorphism, a shale becomes a slate or phyllite with such minerals as sericite and chlorite. With increasing intensity of metamorphism biotite, garnet, staurolite and sillimanite appear successively. In sufficiently large areas it will be possible to map out successive zones of metamorphism as characterised by the index minerals or mineral assemblages. Thus an area originally occupied by a single formation say, shale, may show different metamorphic facies characterised by one or more of the following minerals, the order of minerals indicating an increasing grade of metamorphism, Chlorite, biotite, garnet, staurolite, sillimanite. Normally the change from one facies to the other is gradual.

If shale and silimanite schist are found in adjacent out crops an unconformity is probably indicated, the more metamorphosed rock being the older.

It is, however to be remembered that rocks of different metamorphic facies of the same formation may as well be brought together by a fault.

5.3.5. Difference in the Intensity of Folding

If some formations in an area are highly folded while others are not affected or are gently inclined or horizontal, it is probable that an unconformity exists between the two, the uneffected or less deformed rocks lying unconformably over the highly deformed rocks. The intensity of folding however depends on the nature of the beds subjected to deformation. Thick massive sand stones which are competent may show only a few broad, open folds, while thin bedded shales which are incompetent and deformed at the same time as sandstones, may be thrown into many small folds.

5.3.6 Relation to Plutonic rocks

If two beds are separated from each other by an igneous intrusion, say granite, and do not come into contact with each other, an unconformity is indicated when only one of them is introduced by the granite while the other is not affected, but contains pebbles of the granite, the former being below the unconformity and the latter above.

5.3.7 Fossils

Fossils may afford evidence to an unconformity. If a rock with upper devonian fossils is directly overlain by a rock with lower permian fossils, a break corresponding to the whole of carboniferous period is clearly indicated. This is obviously true even if the strata appear to be conformable.

The above criteria are not, by themselves, of a confirmatory nature and as such establishing an unconformity requires a through study of the region, through structural mapping, sub-surface exploration and bio-stratigraphic investigations.

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. A sharp contrast in the degree of induration and grade of metamorphism in the formation on both the sides suggest the presence of

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5.4 IMPORTANCE OF UNCONFORMITIES.

Unconformities are structural features. Their origin involves erosional, depositional and tectonic processes. Sometimes they may be confused with some kinds of faults.

Major unconformities extended over wide area and represent the effect of important earth movements followed by prolonged erosion and later deposition. As such they have been used in the subdivision of the geological columns.

Unconformities are used in dating orogenic and epiorogenic movements.

Like other surfaces, unconformities also may become folded and overturned. In areas where such a situation exists, they are of much value in interpreting the geometrical aspects of the structure and they may as well throw light on other aspects of the stratigraphic and structural history of the area.

Lastly, unconformities are important because certain valuable deposits of petroleum and minerals are associated with them.

5.5 SUMMARY

Unconformity may be defined as a break in the stratigraphic sequence or is a surface of erosion or nondeposition; and occur between rocks of different origin. An unconformity develops through several stages, first older rocks are formed, then uplifted or deformed and subjected to erosion, subsequently younger rocks are deposited. Different types of unconformities are recognised depending upon the rocks involved and their relationship. The important types are angular unconformity, disconformity, local unconformity and nonconformity. Angular unconformity is a surface of erosion that separates strata which are not parallel. In disconformity the strata on opposite side of the unconformity are parallel. Local unconformity is distinctly local in extent. In nonconformity the unconformity separates younger sedimentary rocks from older crystalline rocks.

Unconformities are sometimes confused with faults and igneous contacts. For the recognition of unconformities there is a criteria. It includes careful observations of out-crop characteristics, aerial mapping, sharp contrast in the degree of induration, distinct difference in the grade of metamorphism, difference in the intensity of folding, relation to plutonic rocks, fossils etc. If the above criteria is not worked out, then structural mapping, sub-surface exploration and Bio-stratigraphic investigations may be useful in the recognition of unconformities.

Unconformities are used in the sub division of stratigraphic column; in dating orogenic and epiorogenic movements. valuable deposits of oil and minerals are sometimes associated with unconformities.

5.6 CHECK YOUR PROGRESS - MODEL ANSWERS

1. An Unconformity is a surface of erosion or non-deposition - usually the former - that separates younger strata from the older rocks. Rocks of various origins may participate in Unconformities - Sedimentary rocks, Volcanic rocks, Plutonic rocks and Metamorphic rocks.
2. (i) Angular Unconformity (ii) Disconformity (iii) Local Unconformity (iv) Non Conformity
3. Unconformity

5.7 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in about 30 lines each.
 1. What is unconformity? Explain various types.
 2. Explain the criteria used in the recognition of unconformities.
- II. Answer the following questions in about 10 lines each.
 1. Explain the terms conformity and unconformity
 2. Describe the importance of unconformity.
 3. What is Epiorogenic unconformity?

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UNIT - 6 JOINTS

Contents

- 6.0 Objectives
 - 6.1 Introduction
 - 6.2 Attitude of Joints
 - 6.3 Classification of Joints
 - 6.3.1 Geometric classification
 - 6.3.2 Genetic classification
 - 6.4 Importance of joints
 - 6.5 Summary
 - 6.6 Check Your Progress - Model Answers
 - 6.7 Model Examination Questions
-

6.0 OBJECTIVES

After completion of this unit, you should be able to

- * define joints
 - * describe the attitude of beds
 - * describe the classification of joints
 - * explain the importance of joints
-

6.1 INTRODUCTION

Joints are relatively smooth fractures found in rocks. These result from the brittle behaviour of rocks, which are subjected to shearing or tensional forces. The word "joint" was first used by coal-miners of Britain for smooth straight cracks separating blocks of rock which appeared to them to have been joined as in brick work, the joints being at right angles to the bedding planes. Most joints are planes, but a few are curved surfaces. Many of the joints are initially tight fractures. Due to weathering they become enlarged to form open fissures. There should have been no visible displacement parallel to the joint surface. If there is displacement it is called a fault. However, there may sometimes be slight movement at right angles to the joint and this produces open fissures.

Joints may extend from a few meters to some hundreds of meters. They may be spaced very closely a centimeter or even less apart, or at distances of a few meters. Fractures which are very small and can be observed only under the microscope are called **microjoints**. Joints which penetrate several strata and persist for long distances are called **master joints**. The master joints seen in aerial photographs can sometimes be traced for distances of several kilometers. Joints usually occur as groups of fractures with more or less regular spacing in a given rock type. A group of joints of common origin is called a **joint set**. The joints are usually more or less parallel to each other. There may be one or more sets of joints in a rock body. Two or more joints sets or any group of joints with a characteristic pattern constitute a Joint system. The characteristics of a joint system, that is the sizes, spacings, and orientations of the joints, show variation of some degree across contacts between rocks of different lithology.

6.2 ATTITUDE OF JOINTS

Joints may have any attitude. Some joints are vertical, some horizontal, but many are inclined. The attitude of joints is described, in the same way as for bedding, in terms of its

strike and dip. The strike of the joint is the direction of the line of intersection of the joint plane with the horizontal plane and the dip is the angle between the joint plane and a horizontal plane measured in a vertical plane at right angles to the strike of the joint. (Fig. 6.1)

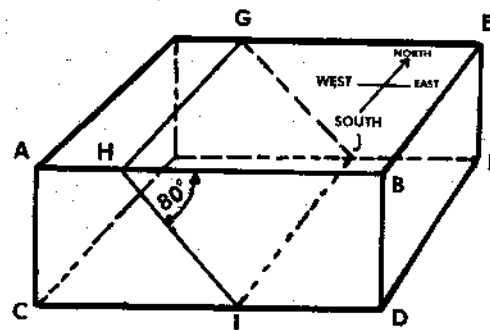


Fig. 6.1 Attitude of joints
 ABCD - Vertical joints striking E - W
 BDEF - Vertical joints striking N - S
 GHJ Joint striking N - S dipping 50° East

6.3 CLASSIFICATION OF JOINTS

Joints may be classified based on their geometry or their genesis. The geometrical classification is of a descriptive nature and can be easily applied. The genetic classification on the other hand, involves the interpretation of forces responsible for joints and is therefore not readily applicable.

6.3.1 Geometric Classification

In a geometrical classification the joints are classified on the basis of their attitude in relation to the attitude of the bedding or some similar structure in the rocks in which the joints occur. Four types of joints are recognised. They are strike joints, dip joints, oblique or parallel joints and bedding joints. (Fig.6.2)

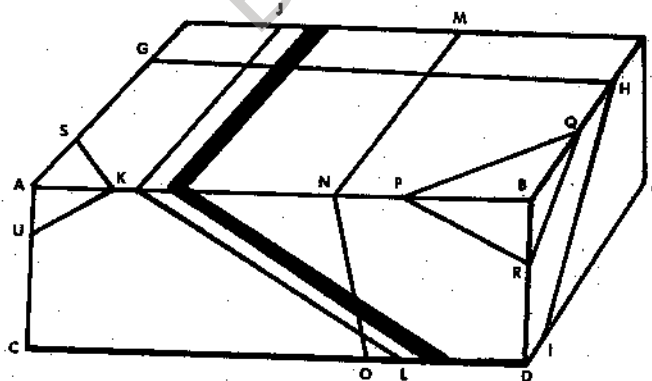


Fig. 6.2 Classification of joints thick black layer in a bed
 ABCD ; GHI - dip joints
 BDEF ; MNO - strike joints
 JKL - Bedding joints
 PQR ; STU - diagonal joints

Strike joints are those that strike parallel or essentially parallel to the strike of the bedding of a sedimentary rock, the schistosity of a schist or the gneissic structure of gneiss. **Dip joints** are those that strike parallel or essentially parallel to the direction in which the bedding, schistosity or gneissic structure dips. **Oblique or diagonal joints** are those whose strike direction lies between the strike and dip directions of the associated rocks. **Bedding joints** are parallel to the bedding of the associated sedimentary rocks.

Joints may be classified based on their strike as north - south set, west-set or north-east set.

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. Name the basis for geometrical classification of joints and name the different types of joints.

6.3.2 Genetic Classification

In a genetic classification joints are classified based on their origin. The majority of joints are of tectonic origin. Some are produced by residual stresses, due to events which occurred long before fracturing some by contraction due to shrinkage because of cooling and some by surface movement such as rock slides or landslides. Joints, in general represents either tension fractures or shear fractures. Tension fractures result from stresses that tend to pull the rock apart while shear fractures result from stresses that tend to slide one part of the rock past the adjacent part. When the rock finally breaks, the two blocks may slide past one another.

In folded regions many joints are found to be systematically disposed about the folds. These are supposed to have resulted from the same compressive forces which have produced the axes of folds. These are called **extension joints**. They are formed perpendicular to the axes of folds. Some joints are produced due to expansion upon the released of load. These are called **release joints**. These are found to be parallel to the axial planes of folds. Both extension joints release joints are produced by tension. (Fig. 6.3)

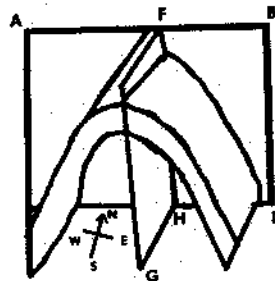


Fig. 6.3 Joints in a fold
 ABCD - Vertical dip joint, Extension joint
 EFGH - Vertical strike joint, Release joint

Two sets of joints that intersect at a high angle to form a conjugate system are considered to be shear joints. Shear joints are difficult to recognize.

Sheeting is a form of fracture similar to jointing. It is best exposed in quarries and other artificial openings. The surfaces of sheeting are generally parallel to the topographic surface, except in regions subjected to rapid erosion during recent times. The fractures are closed to each other, may be only a few centimetres apart and near the surface the earth. But with depth, the interval between them increases and a few metres below sheeting disappears. However invisible planes of weakness parallel to sheeting persist at depth. Sheeting is best development in granitoid rocks. It is also seen in sandstones. Sheeting is due to expansion upwards on the relief of load due to removal of overlying material by erosion.

Joints developed adjacent to major faults are called **feather joints**. These occur in the immediate vicinity of the fault plane and intersect the fault in an acute angle pointing in the direction of relative movement of the block containing the fractures. They are tension joints.

Some joints result due to tension developed during the shrinkage of the rock. The shrinkage may be due to cooling. Igneous rocks contract on cooling and mud silt contract because of dessication. The columnar jointing found in igneous rocks, especially basaltic lavas, sills and dykes is due to contraction.

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. Joints roughly perpendicular to fold axes, normally having steep dips are referred to as

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3. Joints roughly parallel to fold axes normally having steep sides are called

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6.4 IMPORTANCE OF JOINTS

Study of joints is important in many geological and other investigations. Quarrying of rocks for construction purposes is greatly influenced by the joints. A study of the orientation and concentration of joints is essential for engineering projects. Horizontal joints which are closely spaced are unfavourable for tunneling. Large joints dipping towards public passages are sites of potential land slides. Occurrence of ground water in hard rocks like granites is controlled by joints. Wells drilled into highly jointed granites are more productive than those drilled into less jointed granites. Study of joints is essential for deducing the nature of stresses to which the rocks have been subjected.

6.5 SUMMARY

Joints are relatively smooth fractures in rocks. There is no visible displacement parallel to joints. The size and spacing of joints vary widely. A group of joints of common origin and usually parallel to each other is called a joint set. Two or more joint sets with a characteristic pattern constitute a joint system. The attitude of joints is described in terms of strike and dip of the joint plane. Joints are classified based on their attitude in relation to the attitude of the rocks in which they are present, as strike joints, dip joints, diagonal joints and bedding joints. Joints are produced due to tensional or shearing forces. Extension joints or release joints found in folded regions are produced by tension. Two sets of joints intersecting at a high angle to form a conjugate system are produced by shearing. Sheeting is produced by removal of a load by erosion, feather joints by faulting and columnar jointing by shrinkage. Study of joints is important in drilling for water, for engineering projects and for understanding the stresses to which the rocks were subjected.

6.6 CHECK YOUR PROGRESS : MODEL ANSWERS

1. The basis for Geometrical classification are -
Attitude in relation to the attitude of the bedding or some structures in the rocks four different types of joints are recognised, they are strike joints (ii) dip joints (iii) oblique or diagonal joints (iv) bedding joints.
2. Extension joints.
3. Release joints.

6.7 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in about 30 lines each
 1. What are joints? Give an account of their classification.
- II. Answer the following questions in about 10 lines each
 1. Write your notes on Joints set, and Joint system.
 2. What are strike joints?
 3. What are columnar joints?
 4. What is the importance of joints?

* * *

UNIT - 7 FOLDS

Contents

- 7.0 Objectives
- 7.1 Introduction
- 7.2 Parts of the Folds
- 7.3 Kinds of Folds
- 7.4 Types of Folds
- 7.5 Causes of Folding
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- 7.7 Summary
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- 7.9 Model Examination Questions

7.0 OBJECTIVES

In this Unit, we have presented a detailed account folds - parts of folds, kinds of folds, types of folding, causes of fold and its importance in geology.

After reading this unit, you will be able to

- * explain the different parts of folds
- * describe the different types of folds
- * explain the causes of folding
- * explain the importance of folds.

7.1 INTRODUCTION

In many rocks, what were once approximately planar surfaces have been deformed to produce curved or nonplanar surfaces. These structures are called **fold**. Folds are bends in any planar structure. Of all earth's structures folds are visually the most obvious manifestation of ductile deformation of rocks.

Folds are best displayed by stratified formations such as sedimentary rocks or lava flows or their metamorphosed forms. Folds are also seen in the primary flow structures in plutonic igneous rocks. Folds are formed under different conditions of stress. Hydrostatic pressure, pore pressure and temperature. This is evident from the fact that they can be present in rocks of diverse origins.

Folds vary in their shape, size and orientation. They occur in every conceivable configuration. Some are upright. Some show layers which are neatly arranged and uniformly thick, others are irregular. They may occur as single isolated structures or as parts of a system or repeated wave-like forms. While some folds are a few kilometres across, others are a few metres or centimetres or even fraction of a centimetre in width. Regional folds are hundreds of kilometres wide and can be best studied only through satellite imageries.

There are innumerable varieties of folds some of which show very complex three dimensional patterns. A vast vocabulary has therefore been developed to describe the geometry of folds.

The geometry of folds is studied by viewing, in a profile section, a single folded surface which forms part of a deformed sequence. It is a two-dimensional study.

7.2 PARTS OF THE FOLDS

The sides of fold are called limbs. Every limb is shared by two adjacent folds. The hinge of a fold is the line of maximum curvature in a folded surface. Each folded surface has a separate hinge. The hinges may be horizontal, inclined or vertical. The axial plane is the surface connecting all the hinges. It may be a plane surface or a curved surface. It divides the fold more or less symmetrically. In profiles, the axial plane is represented by a line. The attitude of an axial plane may be horizontal, inclined or vertical. The attitude of an axial plane is defined by its strike and dip, just as in the case of a bedding plane. The axis of a fold is a line parallel to the hinges. It is formed by the intersection of the axial plane and a folded surface. Some use the term axis as synonymous with hinge.

The crest is a line connecting the highest points on the same bed in an infinite number of cross sections. Each bed has a separate crest. The plane or surface formed by all the crests is called the crestal plane. In many folds the hinge coincides with the crest. But this is not always the case.

The line connecting the lowest points on the same bed in an infinite number of cross sections is called the trough. The plane containing the trough lines is called trough plane.

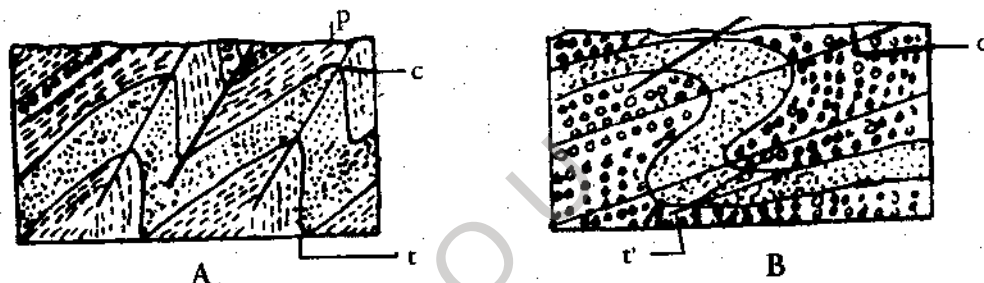


Fig. 7.1 Parts of a fold

A.P: Axial Plane

c: crest on the bed

t: trough on one bed

a'b: limb of fold

c': crest on another bed

t': trough on another bed

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. Write a note on 'Elements of folds'

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2. Hinge line is the line

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7.3 KINDS OF FOLDS

In view of the wide variations in the morphological and geometrical characters of folds, an extensive vocabulary has been developed to describe these structures. The most commonly used terms are briefly explained below.

An **anticline** is usually a fold that is convex upward or has such an attitude at some stage of development. In simple anticlines, the limbs are oppositely inclined, that is, they dip away from each other. In more complex anticlines, the limbs may dip in the same direction. An anticline may be defined more aptly as a fold in which the older rocks are towards the centre of curvature regardless of its configuration. The fold is convex in the direction of the youngest beds in the folded sequence (Fig. 7.2)

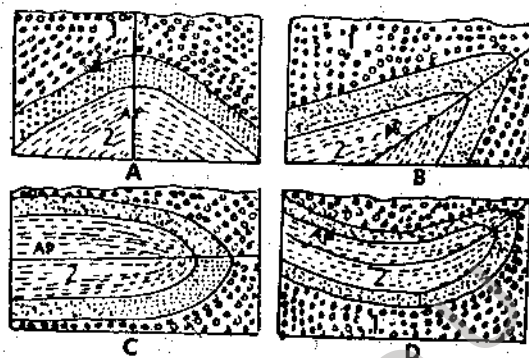


Fig. 7.2 Some types of anticlines
AP : axial plane

A **syncline** is usually a fold that is concave upward or had such an attitude at some stage of development. In simple synclines, the limbs are inclined inward from both sides, that is they dip towards each other. In complex synclines, the limbs may dip in the same direction. A syncline is more aptly defined as a fold in which younger rocks are towards the centre of curvature irrespective of its configuration. It is convex in the direction of the oldest beds in the folded sequence (Fig. 7.3)

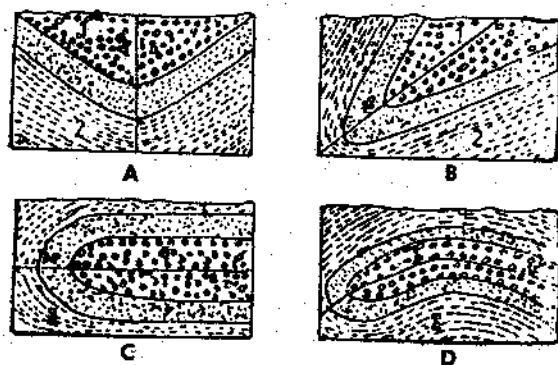


Fig. 7.3 Some types of synclines
AP - Axial Plane

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. A syncline is a fold in which the younger beds are towards....

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A **symmetrical fold** is one which the axial plane is essentially vertical. The two limbs dip at similar angles. This type of fold is also called an **upright fold**.

An **Asymmetrical fold** is a fold with an inclined axial plane. The limbs dip in opposite direction at unequal angles.

In an **overturned fold**, also known as an over fold, the axial plane is inclined and the limbs dip in the same direction but at different angles. The limb that has been rotated through more than 90° to attain its present attitude is called the overturned, inverted or reversed limb. The limb that is right-side up is called the normal limb. (Fig. 7.4)

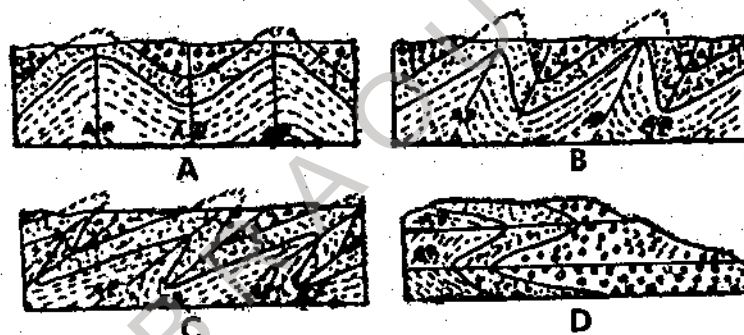


Fig. 7.4 Some types of folds

AP - Axial Plane

A. Symmetrical Fold

B. Asymmetrical Fold

C. Overturned Fold

D. Recumbent Fold

In a **recumbent fold** the axial plane is essentially horizontal. The fold lies on its side. Large-scale folds of this type are well exposed in the Alps. In recumbent folds any bed is usually much thinner in the inverted limb and thicker in the normal limb. The curved part of the fold between the normal and inverted limbs is called the arch bend. The inner part of the fold is called the core and the outer part is the shell. Many of the alpine recumbent folds have crystalline rocks in the core and sedimentary rocks in the shell. Many recumbent folds have subsidiary recumbent anticlines attached to them and these are called digitations. It may be possible trace the recumbent folds back to the place from which they arise and this is called the root or root zone. In the root zone the axial plane becomes much steeper. (Fig. 7.5)

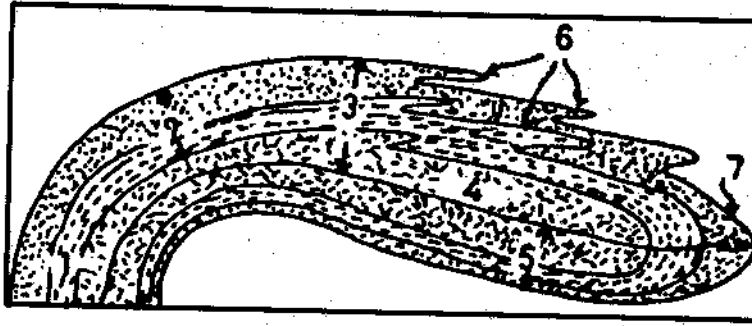


Fig. 7.5 Recumbent anticlines

A.P. Axial Plane

- R : Roof zone C : Crystalline core
S : Sedimentary shell I : Inverted limb
D : Digitations A : Arch Bed

A **isoclinal fold** is one in which the two limbs dip at equal angles in the same direction. In a symmetrical or vertical isoclinal fold the axial plane is vertical. In an asymmetrical or overturned isoclinal fold, the axial plane is inclined and in a recumbent isoclinal fold the axial plane is horizontal. Most of the recumbent folds are isoclinal. (Fig. 7.6)

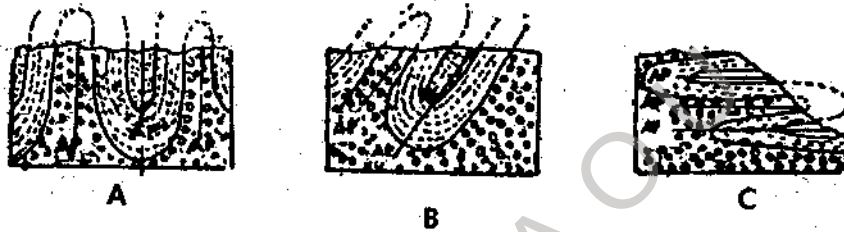


Fig. 7.6 Isoclinal folds

- A. Vertical Isoclinal fold
B. Inclined Isoclinal fold
C. Recumbent isoclinal fold

A fold with sharp and angular hinges is called a **chevron fold** while a fold with broad and flat crest is called a **box fold**. In a box fold there are two hinges, one on each side of the flat crest (Fig. 7.7)

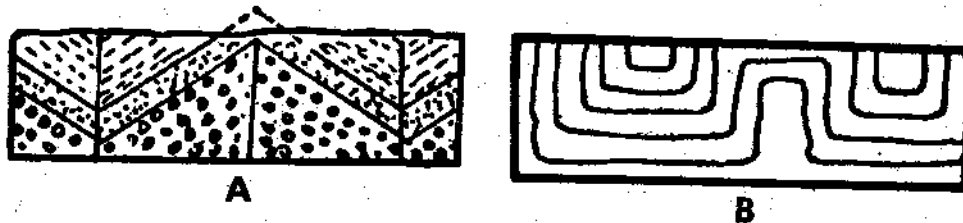


Fig. 7.7

- A. Chevron fold B. Box fold

In a **fan fold** both limbs are overturned. In an **anticlinal fan fold**, the two limbs dip towards each other and in a **synclinal fan fold** the two limbs dip away from each other (Fig. 7.8)

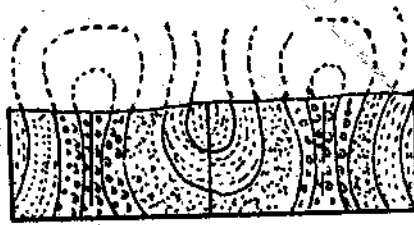


Fig. 7.8 Fan fold

A **monocline** is formed when relatively flat beds locally assume a steeper dip. A **structural terrace** is formed when dipping strata locally assume a horizontal attitude (Fig. 7.9)

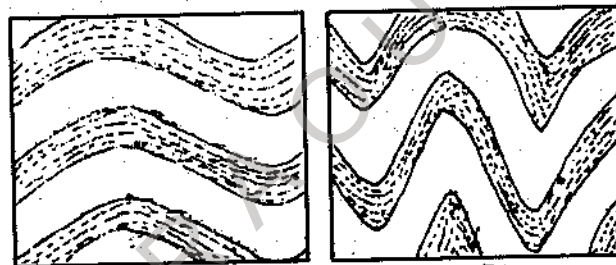


A. Monocline

Fig. 7.9

B. Structural terrace

In a **closed or tight fold** the more mobile beds are subjected to flowage under intense deformation and as a result these beds thicken and thin. In an **open fold** such flowage has not occurred and so the beds show uniform thickness (Fig. 7.10)



A. Open fold

Fig. 7.10

B. Close fold

Drag folds form when a competent bed slides past an incompetent bed. These folds may form on the limbs of the larger folds because of slipping of beds past each other or may form beneath overthrust blocks. The axial planes of the drag folds are inclined to the bedding of the competent strata and the acute angle between the axial planes and the bedding of the competent strata point in the direction of the differential movement (Fig. 7.11)

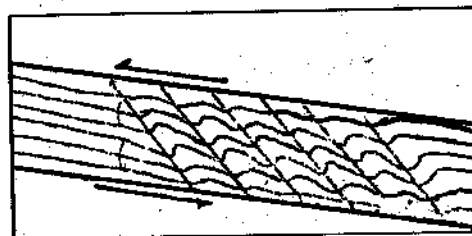


Fig. 7.11 Drag fold

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. Name the fold in which the hinges are sharp

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7.4 TYPES OF FOLDS

The shape of folds may vary with depth and depending on this different types of folding are recognized.

In **similar folding** each successively lower bed or bedding plane shows the same geometrical form as the bed of bedding plane above. Similar folding implies thinning on the limbs and thickening at the axes.

In **parallel or concentric folding** each bed maintains the same thickness throughout all parts of the fold, assuming it was initially of uniform thickness (Fig. 7.12)

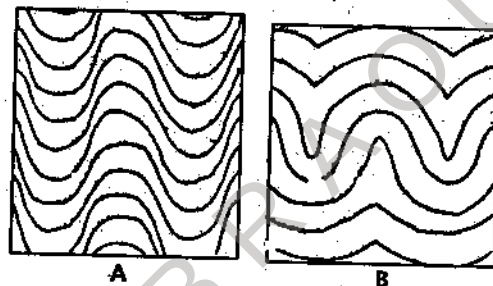


Fig. 7.12 A. Similar Folding

B. Parallel Folding

In **disharmonic folding** abrupt changes in geometrical relations occurs in passing from one bed to another, especially where alternations of plastic and rigid beds occur. The form of the fold change with depth (Fig. 7.13)

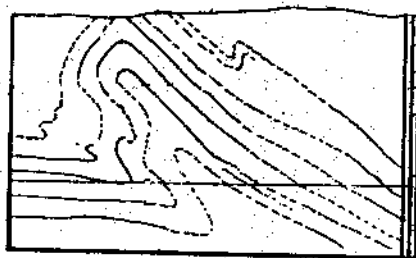


Fig. 7.13 Disharmonic Fold

A symmetrical anticline in the upper part gradually changes downwards towards right to an overturned fold.

In supratenuous folding the beds thicken towards the syncline because it was sinking

during sedimentation and the beds become thin above the anticline because it was rising during sedimentation. This type of folding occurs when folding and sedimentation are contemporaneous and the basin was subsiding during sedimentation.

Diapir or piercing folds are anticlines in which a mobile core, such as salt, has injected the more brittle overlying rocks.

A **decollement** is produced when a sheet of sedimentary rocks breaks loose from the underlying formations and folds independently (Fig. 7.14)



Fig. 7.14 Decollement

PLUNGING FOLDS : In the preceding sections different types of folds have been described with reference to their appearance in cross sections. In describing the third dimension of folds the attitude of the hinge or the axis is of great importance.

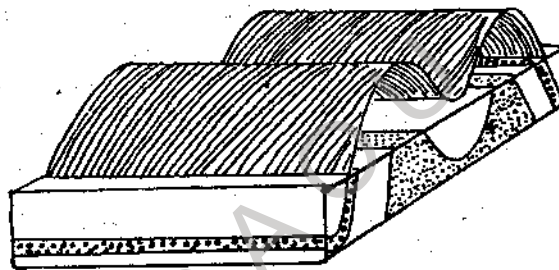


Fig. 7.15 Nonplunging Folds

In some folds, the axis or hinge is horizontal, in other it is inclined and in still others it is vertical. The attitude of the axis of a fold is described in terms of the trend of its horizontal projection and the plunge. Folds whose axes are horizontal, that is plunge is 0° , are said to be nonplunging folds, the others with plunge are said to be plunging folds. Some folds have plunging only in one direction. But some folds reverse their direction of plunge within the limits of an area. These are called doubly plunging folds. (Fig. 7.15 & 7.16)

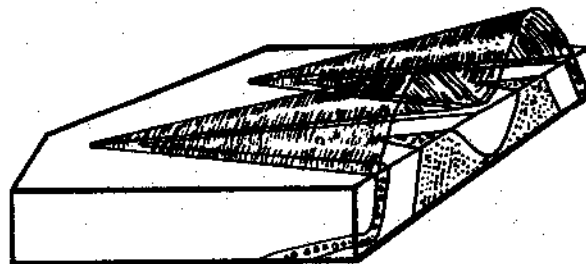


Fig. 7.16 Plunging Folds

Plunge is to the left

A dome is an anticlinal uplift which has plunge in all directions more or less equally.

The dome is a roughly symmetrical up fold. A basin is a synclinal depression which has plunge in all directions. The beds dip inward. (Fig. 7.17)

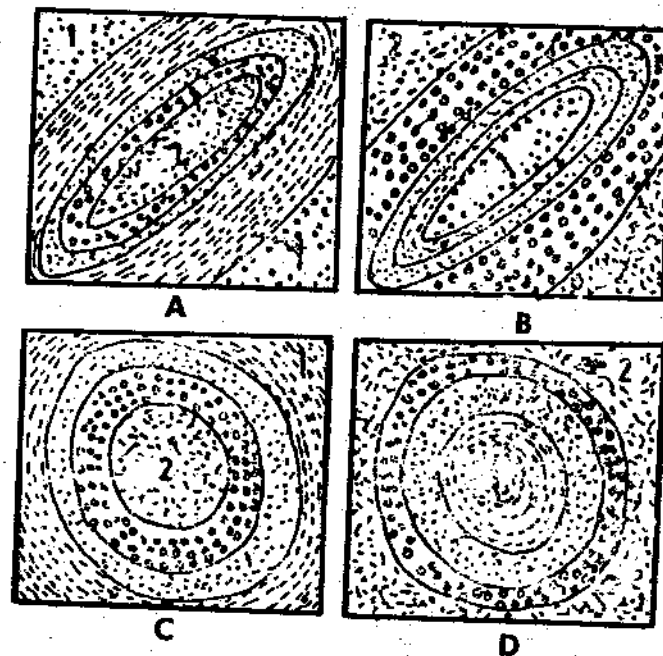


Fig. 7.17

- A. Doubly Plunging anticline
- B. Doubly Plunging syncline
- C. Dome
- D. Basin

7.5 CAUSES OF FOLDING

Processes operating at or near the surface of the earth, especially in relation to erosion, may cause nontechnical folding. These processes include hillside creep, collapse structures, glacial action, and differential compaction of sediments.

7.6 IMPORTANCE OF FOLDS

The study of folds and folding is essential for understanding the nature of deformation and the deformations processes. The stratigraphic sequence of a folded region can sometimes be established through the study of folds. The occurrence of valuable mineral deposits particularly those of oil, is controlled by folding and as such a detailed study of the folded structures is essential for the exploration and exploitation of mineral deposits.

7.7 SUMMARY

Folds are bends in planar structures in rocks. Folds vary in their shape, size and orientation. The parts of a fold include the limbs, hinge, axial plane, crest, crestal plane, trough and trough plane.

The most important kinds of folds are: anticline, syncline, symmetrical fold, asymmetrical fold, over turned fold, recumbent fold, isoclinal fold, chevron fold, box fold, fan fold, monocline, structural terrace, open and closed folds, drag folds. Folding may be of different

types. The common types are similar folding, parallel folding, disharmonic folding, supratenuous folding, diapir folding and decollement. When the axis of a fold is inclined, the fold is said to be plunging. Folds with horizontal axes are nonplunging. Domes and basins are plunging folds. A fold system includes a group of folds with common characteristics and of common origin. Terms anticlinorium, synclinorium, salient, recess, culmination, expression, en echelon folds and monocline are used for describing fold systems.

Folds may be produced by both tectonic and nontectonic processes. Compressional forces are the common cause of folding.

Study of fold is important for understanding deformation and for exploration of mineral deposition especially oil.

7.8 CHECK YOUR PROGRESS - MODEL ANSWERS

1. The elements of folds are :-
Core is the inner part of the fold.
Limbs are the sides of a fold.
Axial plane is the plane dividing the fold into two equal parts.
Axial line is the line of intersection of the axial plane of the fold with the earth's surface.
Crest is the line connecting the highest points on the same bed.
Trough is the line connecting the lowest points on the same bed.
2. Necessarily laying at the top of the fold.
3. Centre
4. Chevron fold

7.9 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in about 30 lines each.
 1. What is fold? Describe different kinds of folds.
 2. Explain the types of folding and causes of folding.
- II. Answer the following questions in about 10 lines each.
 1. What are plunging folds? Give examples.
 2. What are anticlinorium and synclinorium?
 3. Explain about culmination and depression.
 4. What are anticline and syncline?
 5. Differentiate between similar folding and parallel folding.

* * *

UNIT - 8 FAULTS

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- 8.2 Classification of Faults
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 - 8.4.6 Physiographic criteria
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- 8.6 Summary
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8.0 OBJECTIVES

In this unit, we have discussed about the faults, parts of a fault, classification of faults, causes of faults, recognition of faults in the field and importance of faults.

At the end of this unit you should be able to :

- * define the term "fault"
- * describe different classifications of faults
- * explain the causes of faults
- * explain the importance of faults.

8.1 INTRODUCTION

Faults are macroscopic shear or fracture planes in the earth along which blocks of rocks have moved past each other and there is observable displacement. The term 'fault' refers both to the plane, which is called the fault plane and to the displacements that have occurred along that plane. The movement is parallel to the surface of the fracture. The size of faults and the amount of displacement show wide variations. While some faults are only a few centimeters long, and the displacement is in fraction of a centimetre, there are faults which are hundreds of kilometres long and the displacement is measured in kilometres. Some joints are faults of very small displacements (microfaults). The attitude of a fault is expressed in terms of its strike and

dip in the same way as for bedding or jointing. The strike is the trend of a horizontal line in the fault plane. The dip is the angle between the fault plane and a horizontal plane, measured in a vertical plane at right angles to the strike of the fault. The hade is the complement of dip, that the hade is equal to 90° less the angle of dip (Fig. 8.1)

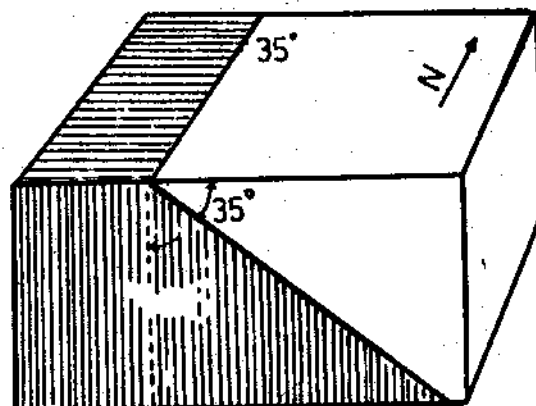


Fig 8.1 Parts of a Fault.
< dark black line is Fault Plane

□ Hanging wall
 ▨ Footwall
 $35^\circ = \text{dip}$
 —> hade

The block above the fault is called the **hanging wall** and the block below the fault is called the **foot wall**. The displacement between originally contiguous points in the hanging wall and footwall is called the **net slip**. The components of net slip parallel to the strike and dip of the fault are respectively called the **strike slip** and **dip slip**. The vertical component of dip slip is called **throw** and the horizontal component **heave** (Fig. 8.2). Both throw and heave are measured in vertical section that is perpendicular to the strike. The rake of the slip is the angle between the slip line and a horizontal line in the fault plane (Fig. 8.3)

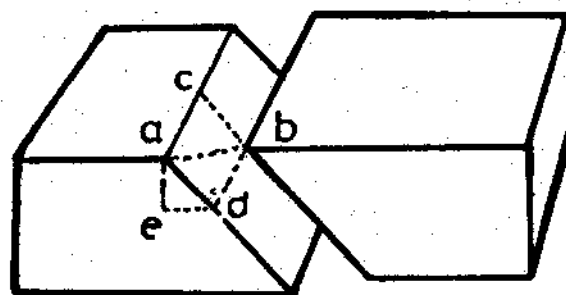


Fig. 8.2 Slip, Throw, Heave
 ab: Net slip ac: Strikeslip Ad: Dipslip ac: Throw ed: Heave

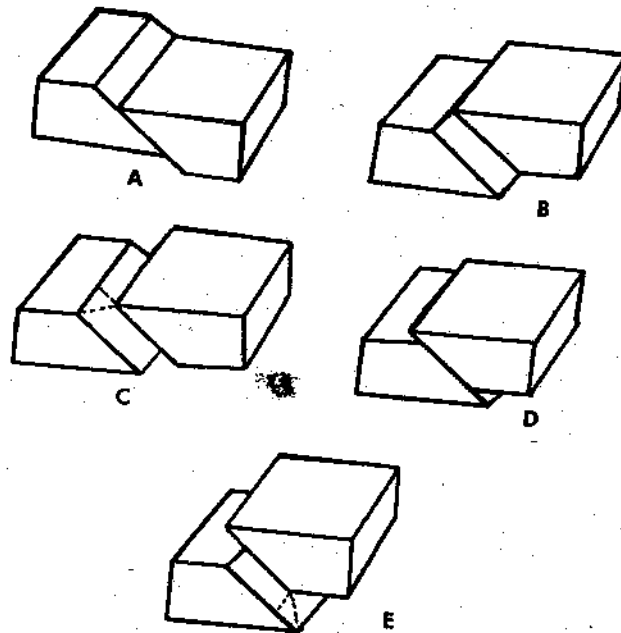


Fig. 8.3 Slip

- A: XY-Net slip equals dip slip, No strike slip
 B: XY-Net slip, equals strike slip, no dip slip.
 C: XY-Net slip, XZ-strike slip, ZY-dip slip.
 D: XY-Net slip, equals dip slip, equals dip slip; no strike slip
 E XY-Net slip, YZ-strike slips, ZX-dip slip.

In most of the faults the displacement is not confined to a single fracture but is distributed over a number of fractures spread over an area which may be a few hundreds of metres wide. This area is called the fault zone.

The intersection of the fault plane with the surface of the earth is called the fault line, fault trace or fault out crop.

Movement along faults

The movement along the fault may be of two types-translational and rotational. In translational movement there is no rotation of blocks relative to each other. All linear features of opposite sides of the fault that were parallel before displacement continue to be parallel afterwards also. In rotational movement the blocks are rotated relative to each other. The linear features on opposite sides of the fault that were parallel before displacement are no longer parallel afterwards (Fig.4)

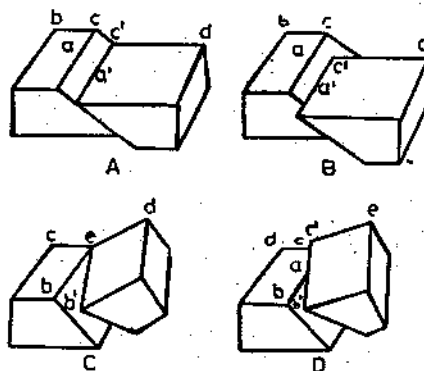


Fig. 4 Movements along a fault

- A,B. Translational movement
 C,D : Rotational movement

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. The lines which were parallel before faulting on two sides of fault remain parallel after faulting in case of

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8.2 CLASSIFICATION OF FAULTS

Faults are classified on the basis of their geometrical features and on the basis of their genesis. Geometrical classifications are easy to apply because no interpretation is involved in their use.

8.2.1 Geometric Classifications

Broadly, there are five different types of geometrical classifications based on the following factors 1) Rake of the net slip, 2) attitude of the fault relative to the attitude of the adjacent rocks, 3) pattern of the faults, 4) dip angle of faults and 5) apparent movement on the fault.

1. Based on the rake of net slip, the following three types of faults are recognized:

Strike-slip fault is a fault in which the net slip is parallel to the strike of the fault. The strike-slip equals the net slip and there is no dip-slip. The rake of the net slip is zero (Fig. 8.5)

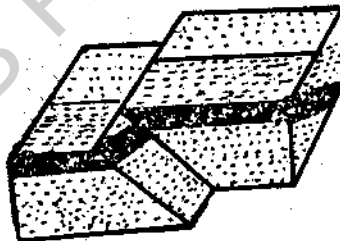


Fig. 8.5 Strike slip fault and also Dip fault.

Dip-slip fault is one in which the net slip is up or down the dip of the fault. The dip slip equals the net slip and there is no strike slip. The rake of the net slip is 90 degrees (Fig. 8.6)

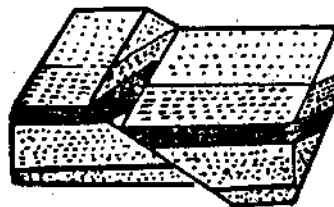


Fig. 8.6 Dip-slip fault

A **diagonal slip fault** is a fault in which the net slip is diagonally up or down the fault plane. Both the strike-slip and dip-slip components are present. The rake of net slip is more than zero but less than 90 degrees (Fig. 8.7)

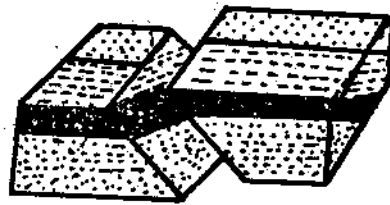


Fig. 8.7 Diagonal -slip fault.

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. A fault in which rake of net slip is zero is called

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3. When the rake of net slip of fault $> \text{zero}$ and $< 90^\circ$ the fault will be classed as

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2. Based on the attitude of fault relative to the attitude of adjacent rocks the following types are recognized.

A **strike fault** is one that strikes parallel to the strike of the bedding or schistosity or flow structure, as the case may be, of the adjacent rocks.

A **bedding fault** is a type of strike fault that is parallel to the bedding (Fig. 8.8 & 8.9)



Fig. 8.8 Strike fault

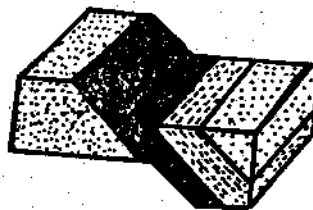


Fig. 8.9 Bedding fault.

A **dip fault** strikes parallel to the direction of dip of adjacent rocks; in other words the strike of the fault is perpendicular to the strike of the adjacent rocks (Fig. 8.10)

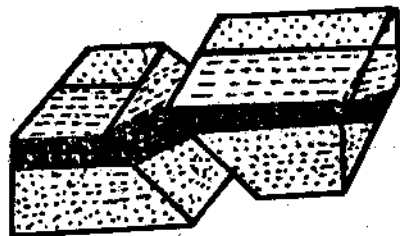


Fig. 8.10 Dip fault with diagonal slip

An **oblique or diagonal fault** is a fault that strikes obliquely or diagonally to the strike of the adjacent rocks (Fig. 8.11)

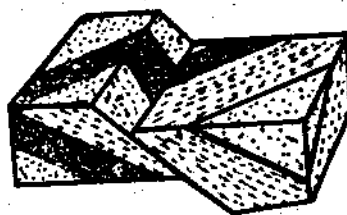


Fig. 8.11 Diagonal fault

On a regional scale, faults that strike parallel to the strike of the regional structure are called longitudinal faults and faults that strike perpendicularly or diagonally to the strike of the regional structure are called transverse faults (Fig. 8.12)

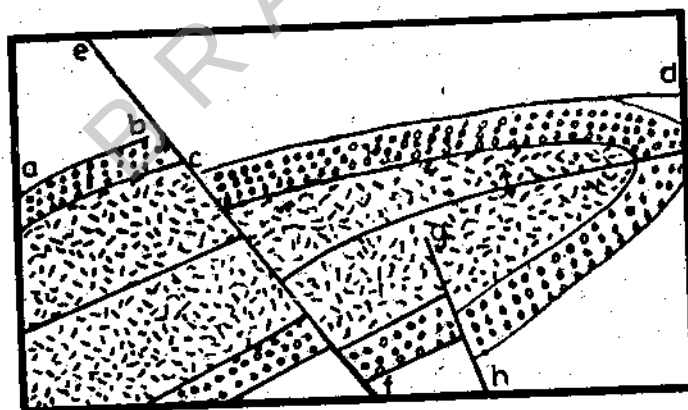


Fig. 8.12 Longitudinal faults (abcd) and transverse faults (ebcf&gh)

3. Based on fault pattern as seen on a map or in a cross section, the following types are recognized.

Parallel faults comprise faults occurring in a locality and having the same strike and dip. If the strikes are the same, but dip differ, the faults are considered as belonging to two or more sets of parallel faults. A series of parallel faults, which are all inclined in the same direction and have their successively down thrown blocks on the same side given rise to step

En echelon faults are relatively short faults that overlap each other (Fig. 8.13B).

Peripheral faults consist of circular or arcuate faults that bound a circular area or part of a circular area (Fig. 8.13C).

Radial faults comprise a system of faults that radiate from a point (Fig. 13.D)

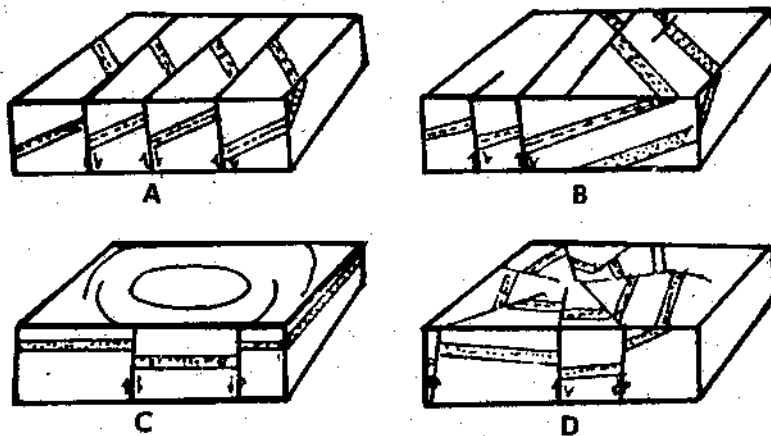


Fig. 8.13

A. Parallel faults B. En echelon faults C. Peripheral faults D. Radial faults

4. **Based on the angle of dip of the faults.** Faults are divided into high-angle faults with dip greater than 45° and low-angle faults with dip less than 45° .

5. **Based on the apparent movement seen in vertical sections.** The types of faults-normal and reverse faults-are recognized. Normal faults are those in which the hanging wall appears to have gone down relative to the footwall. Reverse faults are those in which the hanging wall appears to have gone up relative to the foot wall.

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. Faults relative short that overlaps each other are known as

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5. A fault that dips more than 45° is called

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8.2.22. GENETIC CLASSIFICATION

The genetic classifications are based on 1) The nature of the relative movement along the fault and 2) the absolute movements.

Based on the relative movements along the fault: Two types of faults, gravity faults and thrust faults are generally recognized. A **gravity fault** is a fault along which the hanging wall moved relatively downward.

A **thrust fault** or thrust is a fault along which the hanging wall has moved up relative to the footwall. Among thrust faults there are three varieties. A thrust fault that dips more than 45° is sometimes called as a reverse fault. The term thrust is limited to fault that dips less than 45° . An over thrust is a thrust fault that dips less than about 10° and has large net slip (the term is used in a different sense also.)

Based on absolute movements relative to datum plane, such as the sea level, an elaborate classification has been evolved. For example among gravity faults there can be five kinds.

1) those in which the footwall did not move, but the hanging wall moved down 2) those in which the footwall moved up, while the hanging wall remained stationary 3) those in which the hanging wall moved down and the footwall moved up 4) those in which both blocks moved down, but the hanging wall moved a greater distance and 5) those in which both blocks moved up, but the hanging wall moved a lesser distance. Similarly five kinds of thrust faults can be established.

Normally it is difficult to know the absolute movements, but in a few cases, where faulting occurred near the ocean within historic times, it is possible to establish which block moved. In such cases, the terms up-thrust, underthrust and overthrust are used.

Up thrusts are high angle gravity or thrust faults along which the relatively uplifted block has been the active element. **Underthrusts** are those thrust faults in which the footwall has been the active element. **Overthrusts** are those thrust faults in which the footwall has been the active elements.

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.

6. Classify the faults based on the relative movements along the fault.

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8.3 CAUSES OF FAULTS

The mechanism of faulting is very complex as each type of fault is caused by a set of conditions operating at the time of faulting. However a few general remarks can be made regarding the causes of the more common types of faulting-normal and reverse. Fractures are essential for faults to occur. Fractures are caused either by tension or by shear. The movement is generally due to gravity in the case of normal faults and due to compression in the case of reverse faults.

8.4 RECOGNITION OF FAULTS

Several criteria which offer evidence of faulting are employed by geologists for recognising faults in the field. In any single case, however, only a few of these criteria may be available. Small faults can be identified in outcrops or exposures, but large faults are to be demonstrated on the basis of stratigraphic or physiographic evidence.

The following criteria are generally useful in recognising faults.

1. Discontinuity of structures.
2. Repetition or omission of strata
3. Minor structures associated with faults.
4. Silicification and mineralization
5. Changes in sedimentary facies.
6. Physiographic criteria.

Some of these criteria may sometimes indicate other structures as well and hence care must be taken in confirming the occurrence of a fault through the use of as many criteria as possible. The above criteria are explained.

8.4.1 Discontinuity of Structures

A fault may be present when a group of beds suddenly end against different beds. In a map or exposure the discontinuity of the beds is seen to occur along a line. Similarly dykes, veins or older faults may end abruptly along some line. The displaced parts may be seen in the same outcrop or they may appear elsewhere. It is however to be remembered that dykes, veins or faults may form in a discontinuous manner as they are mostly guided by fracture planes. Similarly discontinuity or truncation of structures may sometimes indicate an unconformity or an intrusive contact.

8.4.2 Repetition and Omission of strata

In a region where the stratigraphic sequence of the rock formations is established, if the beds repeat in a sequence, say as a, b, c, d, e or one or more beds forming part of the sequence disappear, a fault may be indicated. Such a repetition or omission of strata can be best seen in a geological map of the region. Repetition of strata may some times be due to folding or may be a result of differential erosion and omission of strata may be due to an unconformity.

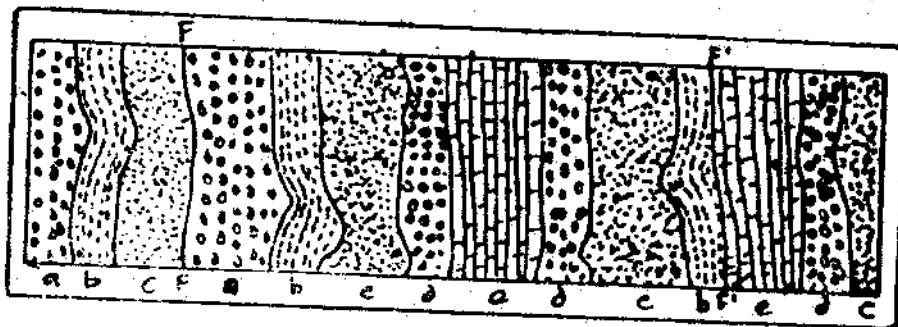


Fig. 8.14 Repetition and omission of strata by faults (FF, F'F').
The sequence of strata is a (oldest), b, c, d, and e (youngest).
A syncline is indicated in the central part of the map.

8.4.3. Minor Structures associated with Faults

Minor structures like slickensides, grooves, drag, gouge, breccia and mylonite which are usually associated with faults are often useful for recognising a fault.

Slickensides are smoothed or polished surfaces which are diagnostic of fault planes. They are produced due to friction along fault plane and show prominent parallel striations. The striations are believed to be parallel to the direction of movement. Some of the striations may be grooves scored on one side of a fault by hard particles drawn over it by the other side. Some of the striations are thought to be lineations in the fine grained material along fault plane.

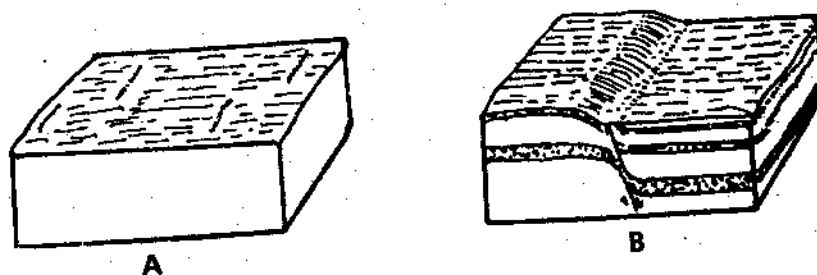


Fig. 815

A. Slickensides

B. Drag along fault.

Sometimes large grooves or furrows which are very wide and many centimeters deep are seen along the fault plane. They are parallel to the direction of movement.

Striations may be produced by glacial action also. **Drag** is another potential indicator of displacement along faults. Beds in a fault zone generally show, adjacent to faults, flexures giving an appearance as if the beds had been dragged back by frictional resistance on the fault plane. Drag can be used for determining relative movement. In a normal or gravity fault, the beds are dragged up in the hanging wall and dragged down in the foot wall. The opposite happens in the case of reverse or thrust faults.

Gouge is fine grained rock material found sometimes along faults. This is produced due to pulverization of rock along fault during faulting. Clays of glacial origin also look like gouge.

Large blocks of rock may sometimes be caught along faults. In normal faults such blocks are called horses and in reverse faults they are called slices.

Fault zones are generally characterised by what are called fault breccias or crush breccias which consist of angular to sub-angular fragments of different sizes associated with a finely crushed matrix. Sometimes due to prolonged movement along the fault the angular fragments may become rounded and in such a case the material is called **crush conglomerate**.

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.

7. Presence of fault breccia in the field represents

Another product of extreme crushing and differential movement along the fault is mylonite. A mylonite is a microbreccia that remained coherent during deformation and is characteristically a platy structure. Uncrushed fragments of the parent rock can be recognized under the microscope. When the crushing is so complete that no such fragments of the parent rock can be recognized, an ultra mylonite is formed.

8.4.4 Silicification and Mineralization

Faults, being extensive fractures, are often traversed by circulating solutions. These solutions may replace the countryrock with fine grained quartz or amorphous forms of silica, causing silicification. Mineralization is another important character of fault zones. Many mineral deposits, particularly those of copper, lead and zinc are found associated with faults.

8.4.5 Differences in Sedimentary Facies

Due to major faults with large horizontal displacements, different facies of sedimentary rocks of the same age may be brought to occur side by side. For example (Fig. 8.16) in a basin of sedimentation, sand stones are usually deposited near shore, shales away from the shore and limestones farthest from the shore, with gradual transitions from sandstone to shale and from shale to limestone. In the transitional zone the beds show considerable intergingering. Thus each region is characterised by certain facies of sedimentary rocks and in this case, nearer shore of a sand stone shale facies, a shale facies, a shale lime-stone facies and finally a limestone facies. If the sand stone facies, for example is found to occur in contact with the limestone facies, a large fault is indicated.



Fig. 8.16 Changes in sedimentary facies

- A. Sandstone facies
- B. Sandstone-shale facies
- C. Shale facies
- D. Shale-limestone facies
- E. Limestone facies

8.4.6. Physiographic Criteria

Offset ridges when subjected to differential erosion, resistant beds usually stand up as ridges. When a group of strata are displaced by a dip fault or a diagonal fault or a diagonal fault, the more resistant beds will occur as discontinuous ridges. Such ridges are called **offset ridges**.

Scarps: Scarps are relatively steep and straight slopes which may vary in height from a few metres to hundreds of metres or even more. Scarps may be produced in many ways.

Scarps produced by faults typically truncate topographic features such as ridges and valleys. Such of the scarps which are the direct results of movement along the fault are called fault scarps, while those which are formed due to differential erosion along a fault line are called fault-line scarps. Composite fault scarps are formed partly due to faulting and partly due to differential erosion. (Fig. 8.17)

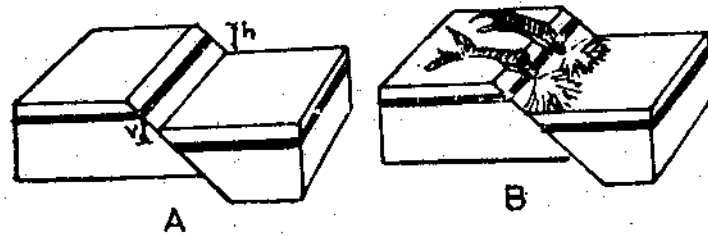


Fig. 8.17 Fault scarp A. Before erosion

B. After erosion - material from valleys in foot wall deposited as alluvian fans on the hanging wall.

Piedmont scarps or scarplets are of smaller size, upto a few meters in height. They are confined to areas of active faulting and are generally found near the foot of mountain ranges.

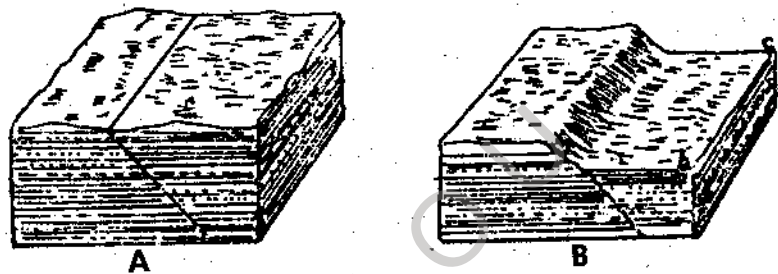


Fig. 8.18

A. Fault line B. Fault-line scarp

Triangular facets are found on some scarps resulting from normal faulting. There are produced by erosion of the fault scarp.

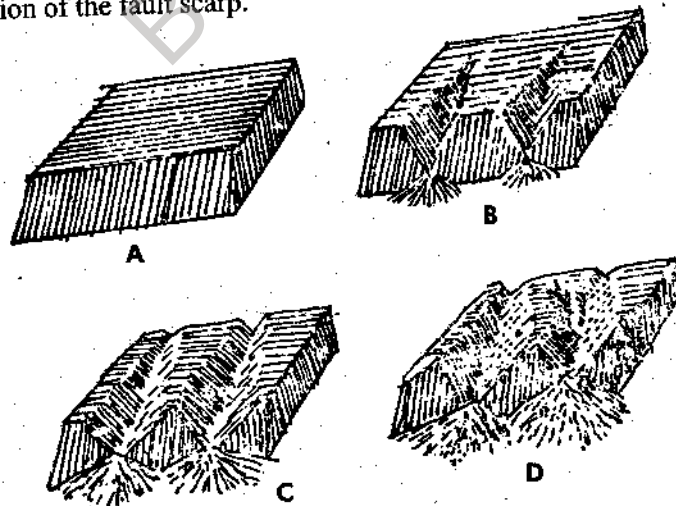


Fig. 8.19 Development of Triangular facets

A. Fault scarp before erosion.
B, C Gradual development of triangular facets.

Springs aligned along the foot of a mountain range, offset streams, breaks in stream profiles are also suggestive of faults. Slickenside, young breccia,

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.

8. Name the structure associated with physiographic criteria

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Faults Vs Unconformities

Faults may sometimes be confused with unconformities. It is easy to recognize dip faults, diagonal faults and transverse faults. But a contact at which the beds on both sides have the same strike as contact itself, may be either an unconformity or a fault. The following points will be helpful in such cases.

If the dip of the contact is parallel to the dip of the lowest bed in the sequence occurring above the contact then it is an unconformity. The more the dip of the contact differs from the dip of the bed referred to above, the more is the probability that the contact is a fault.

If the younger beds strike or dip into the contact, a fault is indicated.

The presence of pebbles of older formations in the formation above the contact indicates that the contact is an unconformity. However such a situation may be caused by a fault also.

In the case of an unconformity, small ridges of older rock may project into younger rocks. A conglomerate or sandstone with fragments of the older rock may be present above the contact. However slickensides, gouge and breccia are not found at an unconformity, but are likely to be present along a fault.

8.5 IMPORTANCE OF FAULTING

The study of fault is important for understanding the tectonic history of a region. Fault planes have been potential places for mineralisation and the occurrence of several mineral deposits is found to be controlled by faults. Hence a detailed study of faults is essential for the successful exploration and exploitation of mineral deposits. A thorough investigation of the faulted structures is very essential for engineering projects like dams, bridges and tunnels and even building construction because their safety is endangered by the presence of a fault in the region.

8.6 SUMMARY

Faults are fracture planes along which rocks have moved past each other and there is visible displacement. They show wide variations in size and displacement produced. The attitude of a fault is expressed in terms of its strike and dip. The parts of a fault include the fault plane, the hanging and footwalls. The displacement is called the net slip (with strike slip and net slip components). Throw, heave and rake are other measurable quantities related to net slip.

The movement along a fault may be translational or rotational. Faults are classified based on their geometry and on their genesis. Geometrical classifications are based on 1) The rake of net slip, 2) attitude of fault relative to the attitude of adjacent rocks, 3) Pattern of faults 4) dip angle of faults and 5) apparent movement of the fault. The above classifications recognize the following fault types; Strike slip fault, dip slip fault and diagonal slip-fault; strike fault, dip fault, bedding fault, longitudinal and transverse faults; parallel faults, step faults, en echelon faults, peripheral faults, normal and reverse faults. The genetic classifications are based on 1) relative movement and 2) absolute movement along the fault. The types of faults recognized on the above bases include gravity faults, thrust faults and overthrusts. Five alternatives are possible regarding the absolute movement along the fault. Upthrusts, underthrusts and overthrust terms are used for faults in which the active block is identified.

Fault may occur along tension or shear fractures. Gravity and compression are considered to be the main causes for faulting. Geological recognition is very essential in case of faults. The criteria for recognition is observation of continuity of structures, repetitions or omission of strata, minor structures like-slicken slide, gouge, breccia, silicification and mineralisation, changes in sedimentary facies and finally physiographic criteria like springs, etc. Study of faults is essential for understanding the tectonic history of a region, for the exploration and exploitation of mineral deposits and for planning engineering projects.

8.7 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Translation movement
2. Strike slip fault
3. Diagonal slip fault
4. Enechelon faults
5. High angle faults
6. The faults are classified based on the relative movements along the faults into two types. They are Gravity fault and Thrust fault.
7. Fault.
8. Scraps, triangular facts, springs etc.

8.8 MODEL EXAMINATION QUESTION

1. Answer the following questions in about 30 lines each
 1. What is fault? Describe the part of a fault with a neat sketch.
 2. Write down the classification of faults.
 3. Explain in detail the criteria used for the recognition of faults.
2. Answer the following questions in about 10 lines each
 1. Describe strike slip and dip slip
 2. What is normal fault ?
 3. What are Throw and Heave?
 4. Mention the features which distinguish a fault from an unconformity.
 5. Write down the importance of faults.

* * *

**BLOCK - III : ECONOMIC GEOLOGY -
ORE FORMATIONS**

BRAOU

UNIT - 9 SCOPE OF ECONOMIC GEOLOGY

Contents

- 9.0 Objectives
- 9.1 Introduction
- 9.2 Ore minerals
- 9.3 Gangue minerals
- 9.4 Ore
- 9.5 Summary
- 9.6 Check Your Progress - Model Answers
- 9.7 Model Examination Questions

9.0 OBJECTIVES

In this unit, we have given you necessary information regarding the scope of economic geology. By the end of the Unit, you should be able to

- * define economic geology
- * describe the scope of economic geology
- * define ore mineral, gangue mineral, ore and tenor

9.1 INTRODUCTION

Economic geology deals with the materials belonging to the mineral kingdom, which man derives from the mother earth for his needs and comforts. In search of such materials, man undertook voyages, successful findings of such materials made him commercially rich and his nation supreme. Nations which are having large amounts of materials, are considered to be economically superior. The more important substances of economic value derived from the rocks underneath the surface are iron for steel, water for drinking purposes. Fuel like coal and oil, building stones, lime and cement, clays for brick making and pottery. Road metals, ornamental stones, marbles, soils and last but not the least the precious and useful metals like gold and silver. In the search for these substances, knowledge of their distribution; character, occurrence and uses slowly and steadily got accumulated leading to the theories regarding their origin. Nations economy depends upon the mineral industry growth chiefly depending upon the knowledge derived from economic geology. Though knowledge of economic geology makes man perfect, so that, he will be able to guide people for continued supply of material needed for mineral industries. Consumption of economic mineral resources needs a discovery of new areas having economic minerals, so that the industries continue to get regular supply of the materials needed for mineral industries to grow.

Minerals which are of economic value are called economic minerals. The study related to economic minerals is called **economic geology**. The economic mineral has chemical composition and certain physical properties. The utility value of the economic mineral matter depends upon the physical properties rather than the chemical composition for example both Diamond and Graphite constitute carbon chemically, differ in their physical properties, making Diamond most precious gem and graphite as heat and chemical resistance substance. The study of occurrence of economic minerals in rock bodies is also comes under economic geology. Economic mineral deposits are geologic bodies which can be worked out for one or more metals or non metals.

The economic minerals are thus broadly classified into metals and non-metals.

Gold, Copper, Iron or Nickel etc. belong to metallic group where as Coal, Clay, Petroleum, Gem stones etc fall under nonmetallic, group. Everybody talks about politics, everybody wants money. There are very few, who really know very much about money and politics. Atleast it is clear that all money is based on something which the earth has provided out from its vast store house of treasures in the form of economic mineral material. The location, development and proper utilization of these natural resources have greatly influenced the course of civilisation.

The soils which result from the weathering of rocks are the basis of all agriculture operations. The fuels like coal and oil were formed through long and complicated geological processes.

The metals are likely to occur in complex geological settings, thus their discovery commonly requires detailed geological exploration. Economic geology is closely related to various desiplines; particular to various branches of geology like Mineralogy, Petrology, Structural geology, Geomorphology, Remotesensing etc.

Mineral deposits, whether they are metalliferous or non metalliferous are nothing but accumulations or concentrations of one or more useful substances which are scattered in the outer crust. The elements that enter into the materials of mineral deposits have been derived either from rocks of outer crust or from magmas, that have cooled to form igneous rocks. The minerals which constitute the earth's crust are very few in number. About 1600 mineral species are known. Out of which 50 are rock forming minerals and 200 are regarded as economic minerals.

Extreme concentrations of formerly diffused metal in rock are called metalliferous deposits. Close observation reveals that the desired metal is not seen independently but it is chemically bound with other elements: and is known as ore mineral. Ore minerals are found associated with other minerals or rock matter called gangue.

The combination of ore minerals and gangue minerals is called ore. Ore is found enclosed in the rocks.

9.2 ORE MINERALS

An **ore mineral** can be defined as a substance from which one or two metals can be extracted. A single metal can be extracted from different ore minerals. Chalcopyrite, Bornite, Chalcocite, Cuprite are all ore minerals from which Copper alone can be extracted. Therefore, chalcopyrite, chalcocite, cuprite and bornite are ore minerals of copper. Some ore minerals occur as native metals Ex. gold and platinum. But many ore minerals are found in combination with elements like silicon, oxygen and sulphur etc. Some times a single ore mineral provide more than one metal for example, Stannite ore mineral on extraction yields Copper and Tin.

Native metals like gold and platinum do not offer serious problems in extraction because admixed minerals can be easily separated and removed. The ore minerals of copper, lead, zinc, iron etc are found in combination either with silicon, oxygen, or with sulphur Ex. PbS (Galena): ZnS (Sphalerite) , Cu (Covellite) : Fe₂O₃ (Hematite). These are all simple combination of metals. In addition to this, there are more complex metallic combinations that yield considerable quantities of common metals. Ore minerals may be classified into primary and secondary ore minerals. Primary type are the ore minerals deposited during the original period of metallisation;; where as secondary type are the alteration products found at or near the surface. Some people called earlier formed ore minerals as primary ore minerals and later formed ore minerals in the same sequence as secondary ore minerals.

This has given rise to some confusion in differentiating primary ore minerals from secondary ore minerals. To avoid this confusion, terms hypogene ore minerals are those ore minerals which are formed by upcoming solution from depth or ascending solutions; where as supergene ore minerals are formed by down buckling solutions or descending solutions. Though, the terms hypogene ore minerals and primary ore minerals are considered synonymous, but they are to be used carefully. All hypogene ore minerals are necessarily primary but not all primary ore minerals are hypogene. An iron ore mineral like hematite of sedimentary origin is a primary ore mineral not to be termed as hypogene as it is not formed by ascending solution.

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. The combination of ore mineral and gangue mineral is called

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2. Define Ore mineral.

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9.3 GANGUE MINERALS

It has been stated that ore minerals occur in association with other minerals of uneconomic importance. Minerals of uneconomic importance associated with ore minerals in an ore deposit are called **gangue minerals**. Sometimes, discarded metallic substance like pyrite is also termed as a gangue mineral. Some of the gangue minerals are collected as by products and used, some of the gangue minerals like quartz, flourspar, pyrite, lime stones etc are used as abrasives, flux, for sulphur, for cement respectively. In short, gangue minerals are waste products, non economical materials found in ore deposits. Some of the worthless, less commercial and non economical gangue minerals of today may become valuable in future. Associated gangue minerals in ore deposits may be separated during extraction of metal and is treated involving expenditure. The expenditure varies depending upon the methods used and type of treatment ore receives. Thus, the gangue, therefore, determines the value of the ore. Depending upon the composition of the ore, the gangue minerals vary. In oxides common gangue minerals are quartz, garnet. In carbonates the gangue minerals are mostly calcite. In sulphides, barite and gypsum are common gangue minerals.

9.4 ORE

Ore is a mixture of ore mineral and gangue mineral and from which one or two metals can be extracted profitably. Therefore, to call material dugged out of the earth's surface, must be payable. This is ore must be payable. If it is to be payable, then, the cost of mining,

transportation of the material, must be less than the value of ore. If the cost involved in extraction is more than the value of the ore obtained from it then it is not a economic proportion. Suitable geographic location from where transporting facilities are available to the distribution centre is also one of the important factor which makes the ore profitable. Normally the proportion of ore minerals and gangue minerals varies and always gangue minerals will be more in proportions than the ore minerals. The ore will be more profitable when the part of the gangue mineral is less.

The metal content of an ore is called the **Tenor**. Tenor is always expressed in terms of percentages for ordinary metals like Copper, Iron, Manganese, Lead etc for precious metals like gold and platinum it is always expressed in ounces per ton. The tenor varies with the price of the metal, and cost of production higher the price of the metal, lower the metal content necessary to make it profitable. Tenor has no upper limit. Higher the tenor better it will be. But the lower limit of the tenor is fixed on various factors like size of the deposit, geographic location, price of the metal and cost of extraction.

The Economic mineral deposits have different modes of formation. Temperature, pressure and water play very importance role in the formation of mineral deposits.

Formation of mineral deposits may be related to magmatic processes or secondary processes or metamorphism. Due to igneous activity deposits of magmatic origin, metasomatic deposits, sublimates, pegmatitic and hydrothermal may result. Secondary processes give rise to sedimentary deposits, placers, residual deposits and deposits of formed by oxidation and sulphide enrichment. Some of the deposits may result from metamorphic processes. A given mineral deposit occurs either enclosed and in association with a rock formation. Such rock formation is called host rock. If the formation of mineral deposit and the host rock have taken place simultaneously, the deposit is called syngenetic mineral deposit. If the mineral deposit has formed later than the host rock it is called epigenetic deposit.

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 metal content of an ore is called

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4. What are syngenetic and epigenetic deposits?

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9.5 SUMMARY

Minerals which are of economic value are called economic minerals. The study related to economic minerals is called economic geology. Nations which are having large resources of such minerals are considered as economically superiors. The more important substances derived

from minerals are steel, water, coal, petroleum and other chemical elements. Mineral industries grows chiefly with the knowledge derived from economic geology. The economic minerals are classified as metals and non metals. So far about 1600 mineral species are identified, out of which 200 are economic minerals, useful for the better living condition of the society.

An ore mineral can be defined as a substance from which one or more metals can be extracted. A single metal may be extracted from different ore minerals. Some ore minerals occur as native metals Ex gold, but many are found in combination with elements like silica, Some times we may also get two metals from a single ore. Ore minerals are classified as primary and secondary ore minerals. Primary type are the ore minerals deposited during the period of metallisation, where as secondary type are the alteration products found at or near the surface. Ore minerals will occur in association with other minerals of uneconomic importance. Such uneconomic minerals are called as gangue minerals. Some of the worthless, less commercial value, non economical gangue minerals of today may become valuable in future. The percentage of gangue mineral determines the value of the ore.

Ore is a mixture of ore mineral and gangue minerals from which one or two metals can be extracted profitably. The ore will be more profitable when the part of the gangue mineral is less. The metal content of an ore is tenor. Tenor is always expressed in terms of percentage for metals and ounces for precious metals. Higher the tenor better it will be. Economic mineral deposits have different modes of formation. Temperature, pressure and water play very important role in the formation.

9.6 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Ore
2. An Ore mineral can be defined as a substance from which one or two metals can be extracted.
3. Tenor
4. If the formation of mineral deposit and host rock at a time, then such deposits are syngenetic deposits or if the mineral is formed later the host rock it is epigenetic deposit

9.7 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in about 30 lines
 1. What is economic geology? How is its study useful to the mankind?
- II. Answer the following questions in about 10 lines.
 1. Write notes on
 - a) Ore minerals
 - b) Gangue minerals
 - c) Ore
 - d) Primary and Secondary minerals
 2. Explain the relation of economic geology with other branches of geology?

* * *

UNIT - 10 IGNEOUS PROCESSES

Contents

- 10.0 Objectives
- 10.1 Introduction
- 10.2 Magmatic Process
 - 10.2.1 Early magmatic
 - 10.2.2 Late magmatic
 - 10.2.3 Nature of magmatic mineral deposits
- 10.3 Contact Metasomatic Process
 - 10.3.1 Mode of operation
 - 10.3.2 Requirements for contact metasomatic process
 - 10.3.3 Changes taking place between intrusive magma and contact rock
 - 10.3.4 Composition of the magma
 - 10.3.5 Characters of metasomatic deposits
- 10.4 Hydrothermal Process
 - 10.4.1 Cavity filling deposits
 - 10.4.2 Replacement deposits
- 10.5 Pegmatitic Process
- 10.6 Sublimation Process
- 10.7 Summary
- 10.8 Check Your Progress - Model Answers
- 10.9 Model Examination Questions
- 10.10 Glossary

10.0 OBJECTIVES

In this unit we have presented different processes of mineral formation with igneous activity

After completion, you should be able to

- * explain the magmatic concentration process and hydrothermal process
- * describe contact metasomatic process
- * define pegmatitic deposits and sublimates

10.1 INTRODUCTION

The formation of mineral deposits were discussed under four processes namely igneous processes, secondary processes, organic process and metamorphic process. In this unit, igneous processes are discussed. Due to igneous activity, the deposits of magmatic origin, matasomatic deposits, sublimates, Pegmatitic and hydrothermal deposits may be formed. The important igneous processes, such as magmatic process, contact metasomatic process, hydrothermal process, pegmatitic process and sublimation processes are discussed here.

10.2 MAGMATIC PROCESS

All igneous rocks are products of magma consolidation. These rocks are made up of two groups of minerals like essential minerals and accessory minerals. Minerals in rocks, whose presence and absence change the identity of rocks are called essential minerals: whereas minerals whose presence and absence have no effect on the identity of the rocks are termed as accessory minerals.

Take for example an igneous rock like granite which comprises of minerals such as quartz, feldspar, biotite, muscovite, chlorite, iron etc. Among these minerals quartz and feldspar are essential minerals; all other minerals like biotite, muscovite, chlorite, iron are accessory minerals. Iron will be of very small proportion and most uncommon constituent in granites. Such uncommon or accessory minerals formed from magma may get concentrated into bodies of sufficiently big size to form economic mineral deposits. Such valuable concentration mineral deposits of magmatic origin are called magmatic concentration deposits i.e., they are direct derivatives of magma. The process is called magmatic concentration process.

Magmatic concentration deposits are formed during differentiation of metal bearing magma directly from melts of an ultrabasic, basic or alkaline content. Magma which is hot molten rocky material slowly starts cooling with fall in temperature. Not only it cools, but also splits into different layers of different composition before getting consolidated. Most magmas are probably not homogeneous in composition, parts may be rich in ferromagnesian constituents, in silica, in sodium, in potassium compounds, in volatiles, or in other substances. When the composition magma cools. It crystallises and separates into fractions by the process of differentiation are termed as magmatic ore deposits. The most insoluble substances in magma crystallise first. During differentiation, the more mafic parts of the magma may be enriched in chromium, nickel, platinum, titanium and iron. Such products derived from magmatic fraction after the process of differentiation. In general uncommon, accessory mineral constituents like zircon, apatite, titanite, ilmenite, magnetite, chromite etc. are the minerals forming earlier than the rock forming silicates like olivine, augite, hornblende, orthoclase, mica and quartz. Their crystallisation from magma will be in a sequence having quartz as the last mineral to crystallise. This order of crystallisation of minerals in a sequence from magma is known as Bowen's discontinuous reaction series.

All economic minerals originated from magma during its course of crystallisation prior to the rock forming silicates are called Early magmatic mineral deposits. All economic minerals formed in the final stage of magmatic crystallisation are referred to as late magmatic mineral deposits.

Thus we have broadly two types of magmatic concentration deposits derived from magma. This clearly means that there can be more than one period of magmatic ore formation with the magmatic period and there may be one process of differentiation by which magmatic economic mineral deposits can be formed.

The early magmatic mineral deposits are the direct magmatic processes. These deposits form in three different ways such as:

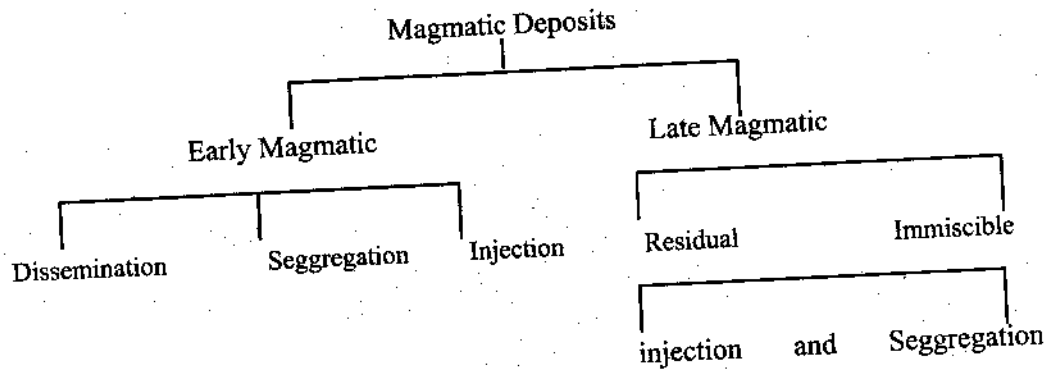
- i) Dissemination
- ii) Segregation
- iii) Injection

The late magmatic mineral deposits form towards the end of the magmatic period i.e., they are all later than the rock forming silicates. These deposits form in four different ways.

- i) Residual liquid segregation.
- ii) Residual liquid injection.

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- iii) Immiscible liquid segregation.
- iv) Immiscible liquid injection



10.2.1 Early Magmatic Mineral Deposits

These are the products derived from magma i.e. process prior to the rock forming silicates, these deposits are also known as orthomagmatic deposits. Early magmatic mineral deposits are the early differentiates that settled throughout the magma in response to gravity. Early magmatic ore deposits may form in three different ways such as i) Dissemination ii) Segregation iii) Injection.

- i) **Dissemination:** This is simple crystallisation of minerals of economic value from magma without getting concentrated in one place. Cooling of magma in deep seated condition yield a granular igneous mass in which economic minerals are found scattered throughout the rock mass. The best example of dissemination is diamonds in volcanic pipe or corundum in syenite rock.
- ii) **Segregation:** Segregation means sinking of early formed economic minerals in magmatic channel and getting accumulated. With fall in temperature, magma starts crystallising. On set of crystals so formed start sinking because of their high specific gravity. Such type of differentiation is known as gravitative crystallisation differentiation. Early magmatic economic mineral deposits may be due to segregation. Segregation means concentration of valuable constituents of magma by gravitative crystallisation differentiation process.

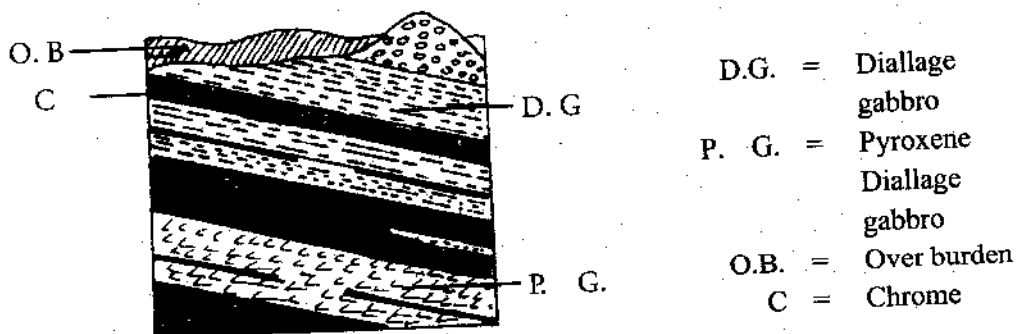


Fig.10.1 : Segregation deposits showing layers

For example chromite which crystallises early gets segregated or separated from other mineral constituents to form sufficiently rich and big deposits. Hence, economic minerals which are the products of gravitative crystallisation differentiation have been referred as early magmatic segregation deposits. All such deposits are generally lenticular and are of small size. They form layers in host rocks as shown in the (Fig. 10.1)

- iii) **Injection:** Ore minerals of magmatic origin in the early stage of magmatic process undergo gravitative crystallisation differentiation leading to the formation of segregated layers in magma, subsequently get injected into the surrounding rocks. Such deposits of economic minerals are known as magmatic injection deposits. Injection deposits have not remained at the place of original accumulation. Injection deposits cut across the rock into which they have been injected and occur as dykes or any other intrusive forms of igneous rocks.

10.2.2 Late Magmatic Mineral Deposits

Economic mineral deposits of magmatic origin formed towards the close of magmatic period are termed as late magmatic mineral deposits. They are all later than the rock forming silicates, hence, they cut across them, surround them, react with them giving rise to reaction rims. Late magmatic deposits are usually associated with basic igneous rocks. They may be due to crystallisation differentiation, or may be due to gravitative accumulation of residual liquid or it may be due to liquid immiscibility. Only certain types of magmas yield late magmatic deposits, it is generally seen that magmas undergoing the process of differentiation become progressively rich in silica, alkalies and water, but there are certain basic magmas like magma of anorthosite composition, which becomes progressively rich in Fe and Ti contents during the process of differentiation.

Late magmatic deposits may form in four (4) different ways such as i) Residual liquid segregation ii) Residual liquid injection iii) Immiscible liquid segregation iv) Immiscible liquid injection.

- i) **Residual Liquid segregation :** Magmas of anorthosite composition on cooling give rise to crystals of plagioclase in the beginning. The leftout magma or the residual magma may be rich in Fe content. This segregation of residual magma rich in iron content consolidates to form valuable mineral deposits of residual liquid segregation type. Fig. 10.2
- ii) **Residual Liquid Injection :** If the residual magma rich in iron content during the last phase of magmatic process after the crystallisation of plagioclase feldspars may get injected into the surrounding rock by filter press mechanism or by the influence of lateral pressure to form residual liquid injection deposits.
- iii) **Immiscible Liquid Segregation :** In certain basic magmas sulphides of nickel and iron and copper are found to the extent of 6 to 7% in soluble state. On cooling of such magma the sulphides of Ni, Cu and Fe form immiscible fraction. It continues to remain in liquid state till other silicates of magma crystallise, subsequently the segregated layer of Ni, Cu and Fe sulphides solidify to form immiscible liquid segregation deposits.
- iv) **Immiscible Liquid injection :** If the immiscible sulphides of Ni, Cu and Iron remain in liquid stage even after the silicates crystallise and get injected into the surrounding rocks, then such deposits are termed immiscible liquid injection deposits.

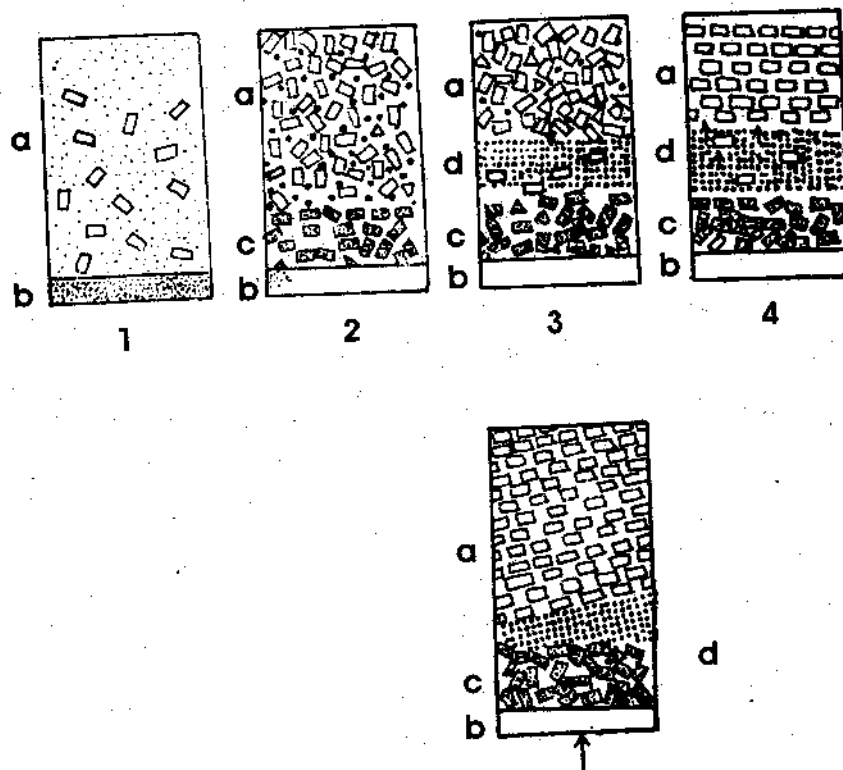


Fig : 10.2

Late gravitative liquid accumulation

- a Early stage of crystallisation
- b Chill zone
- c Layer of sunken early formed crystals rest on chill zone
- d Oxide rich residual liquid layer

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. The process in which mineral grains of greater density sink through the fluid magma during the crystallisation is known as

2. Give the best example of magmatic segregation
-
-
-
-

10.2.3. Nature of magmatic mineral deposits

Economic mineral deposits of magmatic origin have simple mineralogy and they are characterised by their close relationship with the intrusive igneous rocks. The most significant ore deposits of titanomagnetite, apatite-magnetite, and copper, nickel ores, chromites, diamonds, platinoids, apatite and graphite. The composition of the mineral deposits of magmatic origin is linked with that of the parent body. Chromites are associated with dunites; titanomagnetites with pyroxenites; diamonds with peridotites. The characteristic textures of the ores are massive banded, nodular, brecciated, and streaky, streaky-disseminated, while the typical structures are granular and prophyritic.

The surrounding rocks may show traces of the ore-forming processes in the form of serpentinisation, amphibolization, chloritisation, carbonisation, and taking from 1500°C as in the case of diamonds to 300°C. The drop in temperature between the beginning and the end of magmatic ore formation could have been very considerable ranging from 1500°C.

10.3 CONTACT META SOMATIC PROCESS

The process of formation of mineral deposits by contact metasomatism is related to magmatic activity. As crystallisation of magma progresses, the residual liquids tend to be rich in volatiles. During or shortly after the last stage of magmatic consolidations, the high temperature fluid emanations may escape into the surrounding rocks and produce pronounced effects upon them. These igneous emanations effect the surrounding rocks either by way of heat or high temperature fluid emanation. The processes of change caused in the surrounding host rocks by heat are referred as contact metamorphism while the change caused by high temperature fluid emanations are called contact metasomatism. The contact metamorphism may cause recrystallisation of the host rocks in the border zone of invading igneous body. Recrystallisation may be associated with textural and mineral changes. Quartzite may form from sandstone; Marble from limestone or dolomite, New minerals like wollastonite may form due to combination of calcium oxide; quartz and water, tremolite may develop from dolomite, quartz and water. However there will not be any addition of chemical constituents due to igneous intrusion.

In contrast to this, contact metasomatism is marked by recognisable formation of new minerals under conditions of high temperature and pressure conditions due to addition of new constituents from magma. The resulting mineralogy is thus more varied and complex than that by heat metamorphism alone. If the magmatic emanations are highly charged with the valuable mineral materials. Contact metasomatic deposits result particularly in the favourable environment of calcareous host rocks. Thus the contact metasomatic deposits are a class of highly characteristic deposits signifying their relationship with intrusive contacts and are recognisable by their distinctive assemblage of high-temperature minerals.

10.3.1 Mode of operation

The way of contact metasomatic process operative can best be visualised by comparing the volcanic explosion. It is known that where volcanoes explode from time to time, a vast volume of fluids are released.

These constituents originally were in solution in magma, and as long as the magma remained liquid and pressure unchanged, they remained in solution. With the release of pressure they escape. But most magmas, do not reach the surface but are enclosed in the earth's crust and their gaseous constituents do not directly reach the surface. However the fluid emanations may escape into the surrounding rocks. The emanations may carry the constituents of mineral deposits that replace the invaded rock to form metallic and non-metallic mineral deposits. These deposits are distributed sporadically in the surrounding rocks along the immediate contact of an intrusive, contact zone, wherein alteration of host rocks due to igneous emanations took place is called aureole. The shape and size of aureole varies according to the size and shape of the intrusive and the character and structure of the invaded rocks.

10.3.2 Requirements for Contact Metasomatic Deposits to form

Not all magmas which intrude into the rock yield contact metasomatic deposits. Only certain types of magmas are capable of yielding these deposits. The most important requirements are

- i) Suitable magmas capable of yielding contact metasomatic deposit
- ii) Magmas must contain necessary ingredients of economic mineral deposits.
- iii) The intrusion must take place at great depths.
- iv) The intrusive magma capable of yielding contact metasomatic deposits must come in contact with reactive rocks.
- v) Temperature range of formation is 400°C to 800°C.

10.3.3. Changes taking place between Intrusive Magma and Contact rock.

When intrusive magma comes in contact with the rock into which magma is entering certain changes take place such as, recrystallisation. Recombination and addition of new substances to the rock by magma i.e., accession. Certain minerals of rock under the influence of temperature recrystallise, calcite of limestones recrystallise to form marble.

Sometimes these limestones have impurities like carbon which goes to form graphite. Change of partner take place, which is termed as recombination. Recombination means interchange of ions. If original minerals in rock, are AB and CD there on recombination it becomes AC and BD, Further if intrusive magma adds some material after recombination which is known as accession, if material X is added to AC and material Y is added to BD, then, it becomes ACX and BDY where X and Y is termed as accession products of magma.

10.3.4 Composition of the Magma yielding Contact Metasomatic Deposits

Not all magmas of any composition yield contact metasomatic deposits. Only certain types of magmas which are silicic of intermediate nature such as quartz monzonite; monzonite Granodiorite or quartz diorite are capable of providing contact metasomatic deposits. Neither highly silicic magma of granite composition, nor basic composition magma of gabbroid composition yield such deposits because silicic magma has high percentage of water and basic magma is relatively dry where as silicic magma of intermediate composition has water content which is neither too high nor too less but just sufficient for collecting and transporting metal content of magma to the rock into which magma is intruding.

Contact metasomatic deposits are found associated with rocks, which have been formed at great depths under slow cooling and high pressure conditions.

If the intrusive magma containing economic minerals come in contact with impure calcareous rocks like silicious limestones or limestones with Aluminium impurities exhibit greater effects of contact metasomatism and yield contact metasomatic deposits.

10.3.5 Characters of Metasomatic Deposits

The shape of the deposits is generally fairly complicated and varied. They may be (1) bedded and stratified bodies (2) Lenticular bodies (3) Stocks (4) Pipes (5) Veins and vein-like bodies (6) vest and (7) Complex ranifying bodies.

Many metasomatic deposits have a zonal structure. Particularly distinct zoning is observed going away from the contact with the intrusive.

Metasomatic deposits are fairly diverse in their content of recoverable minerals. Almost all metals are known in them, with the exception of chromium, antimony and mercury. The most significant metasomatic deposits are those of iron, cobalt, copper, platinum, tungsten, molybdenum, lead, zinc, gold, tin, beryllium rare earths and uranium.

The most common feature that is observed in the mutual arrangement of minerals forming metasomatic deposits is the well-defined metasomatic characters of the mineral deposition, which often leads to pseudomorphs of various minerals and mineral complexes by minerals and aggregates deposited earlier. The grain size of minerals forming metasomatic deposits usually lies within limits of fractions of a millimetre and one or two centimetres; but individual crystals, may be as big as ten or fifteen centimetres.

10.4 HYDROTHERMAL PROCESS

The close of the magmatic phase, leaves behind liquid which is rich in economic mineral content originally present in the magma after the magma has undergone the process of differentiation. The end product of magmatic differentiation, rich in economic mineral content is known as hydrothermal solution. These hydrothermal solutions carry the economic minerals present in them through the opening like cracks and fissures and deposits the metal content to form valuable economic mineral deposits by hydrothermal solution is known as hydrothermal process;. These are strong evidence to believe that hot solutions or hydrothermal solutions are capable of forming economic mineral deposits. When the hydrothermal solutions travel through the rocks may deposit the metal content in the openings present in the rocks or it may get involved in chemical activity, replace the mineral constituents of the rock by the economic mineral carried. Thus we have two types of hydrothermal deposits like (A) **Cavity filling deposits** and (B) **Replacement deposits**. The hydrothermal solutions gradually lose heat with increased distance from the intrusive. Depending upon the temperature at which hydrothermal solution yield economic mineral deposits, are of three different categories such as hypothermal, mesothermal and epithermal.

High temperature, hydrothermal solution deposits near the intrusive is called hypothermal type. Slightly away from the intrusive with moderate temperature of hydrothermal deposits are called mesothermal type, where as the hydrothermal deposits far away the intrusive at low temperatures are called epithermal type. Replacement by hydrothermal solution will be dominant under high temperature condition near the intrusive where hypothermal deposits are formed; Where as cavity filling by hydrothermal solutions are dominant under low temperature condition away from the intrusive body where epithermal deposits are formed. In mesothermal the hydrothermal solutions can replace and fillup the cavities. Thus replacement deposits and cavity filling deposits may be formed in mesothermal conditions.

Essential requirements for hydrothermal deposits to form :

- i) Mineralising solutions or Hydrothermal solutions must be capable of dissolving and transporting mineral matter from original site to the place of deposition.
- ii) The Rock must have cracks, fissures or openings for allowing the hydrothermal solution to move through them.
- iii) The Rock through which hydrothermal solutions are travelling must have suitable places for deposition of economic mineral content.
- iv) Suitable chemical activity has to take place either to precipitate the metal content in the cavity or to replace the mineral constituents by economic mineral contents of hydrothermal solutions.
- v) The economic mineral thus deposited in the cavities of replacement of mineral constituents must get concentrated to form workable deposits.

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. Ore deposit one produced by the effect of high temperature solution known as

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4. Hydrothermal deposits formed at shallow depth (i.e. at low pressure) but at high temperature is known as

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Movement of Solution through rocks: The movement of hydrothermal solutions through rock appears to take place, where continuous opening like fissures or cracks are available in rocks. These opening in rocks are the main channels for the hydrothermal solutions, which supplies large amount of mineral matter, the small fractures, cleavages in the minerals serve as minor distributing centres by diffusion. Diffusion, though an important factor cannot act in large scale distribution but plays very important role in short instance transit of mineral matter brought by hydrothermal solutions. Diffusion replaces the ions in mineral matter. Thus diffusion is essential replacement, but it is not essential in cavity filling type because large volume of hydrothermal solutions can enter the openings, react with it chemically and deposit the metal content in the cavities.

There are two different kinds of cavities found in rocks namely original cavities like pore space crystal lattice, vesicles, bedding planes, cooling cracks and induced cavities like cavities or cracks formed by folding and faulting, solution cavities, rock alteration opening etc.

The hydrothermal solutions while passing through the rocks undergo chemical change by reaction. The most important factors in hydrothermal deposition are changes in temperature and pressure. In general, drop in temperature decreases the solubility leading to deposition of economic mineral content.

Replacement deposits by hydrothermal solutions where there is substitution of new minerals for older ones take place by reaction between hydrothermal solution and solid rock bodies through which it is passing.

Mineral deposits having magmatic affiliations show characteristically a sequence in their formation. The sequential arrangement of economic mineral formation is known as paragenesis. Hydrothermal deposits provide best example for the study of paragenesis.

10.4.1 Cavity Filling Deposits

The filling up of cavities with economic mineral content by hydrothermal solutions are called cavity filling deposits. In earlier days cavity filling by solutions was considered to be the only process by which all economic mineral deposits are formed. Cavity filling deposits are formed by hot, dilute magmatically related solutions. Cavity filling involves two separate processes (i) formation of opening (ii) deposition of economic minerals into the opening. Both these processes may take place simultaneously or it may be independent with a interval time in between cavity formation and economic mineral deposition in the cavity.

When the hydrothermal solution enters the cavity deposit the mineral content along the walls of the cavity and finally fills the cavity by economic mineral to form "Massive economic ore deposits" of cavity filling types. Some times we find layers of different economic minerals

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. List out process involved in cavity filling

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Formed one after the other in the cavity starting from the walls of the cavities, then, such layering of economic minerals in the cavities formed by hydrothermal solutions are termed as **Crustification**.

If prominent crystals project from the walls of the cavity then it is called **comb structure** Fig. 10.3. Crustification or layering in the cavities may be symmetrical or asymmetrical as shown in figure. Some times, the cavities will not be completely filled up the central portion remains vacant. The vacant portion of the cavity is called **Vug**. Some Vugs are large enough for a man to enter. Vugs are the places where one can expect beautiful and rare mineral crystals. Vugs are the treasure house for the mineral hunters.

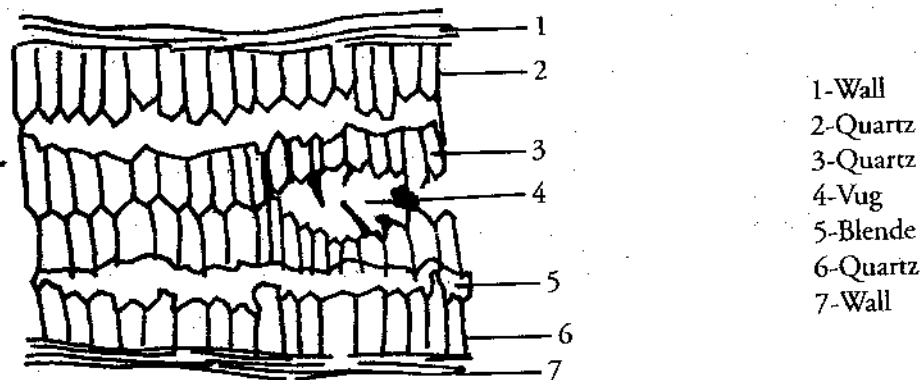


Fig.10.3 showing the formation of Comb & Vug Structure

There are different kinds of cavity filling deposits such as (i) Fissure veins (ii) Shear zone deposits (iii) Stock works (iv) Saddle reef (v) Ladder veins (vi) Pore space filling (vii) Vesicular filling (viii) Solution cavity filling (ix) Breccia filling (x) Foldcrack filling.

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.

6. In the cavity filled deposits, the ore is built up in successive layers are called

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i) **Fissure Vein deposits :-** It is most important and common type of cavity filling deposits. It is a tabular ore body having length greater than the width. Fissures are formed in the rocks due to stresses acting on them. If these fissures are deposited by the hydrothermal solution, then, it forms fissure vein deposits. There are many types fissure veins such as simple, composite, linked, sheeted, dilated and chambered as shown in Fig.10.4 Fissures rarely occur alone, they are always seen in groups. Number of fissures together is known as fissure system. Fissure system may have different patterns such as parallel system, Fan system, radial system, intersecting cognate, intersecting system and conjugated system.

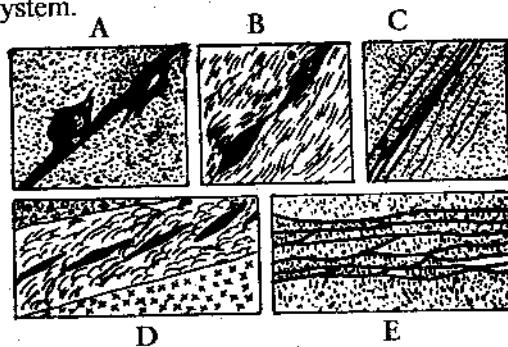


Fig. 10.4 Varieties of Fissure Veins

A Chambered vein
D Enechalon veins

B Dilution vein
E Linked vein

C Sheeted vein

- ii) **Shearzone deposits:-** are thin, sheet like connected opening of a shearzone, through which hydrothermal solutions pass and deposit the economic, mineral content.
- iii) **Stock Works :** It is a delicate, interlacking net work of small ore bearing veinlets inside the cavities of the rock.
- iv) **Saddle reef:** When the alternative layers of hard and soft rocks are closely folded, then cracks are formed at the crest of the fold. When hydrothermal solutions entering through such cracks deposits the economic mineral content to form saddle reef deposits Fig. 10.5
- v) **Ladder Veins:** When a country rock is intruded by a dyke and dyke develops cracks perpendicular to the length of the dyke, due to contraction while cooling. Subsequently, these transverse cracks deposits because if resemble the ladder.
- vi) **Pore space filling:-** The space in between the mineral grains of a sedimentary rock is called pore space. If these pore spaces are filled up the hydrothermal solution economic mineral content, then it is called pore space filling deposits.
- vii) **Vesicular filling:** Deposition of metal content by hydrothermal solutions into vesicles formed due to escapement of gases from the lava surfaces is known as vesicular filling deposits.

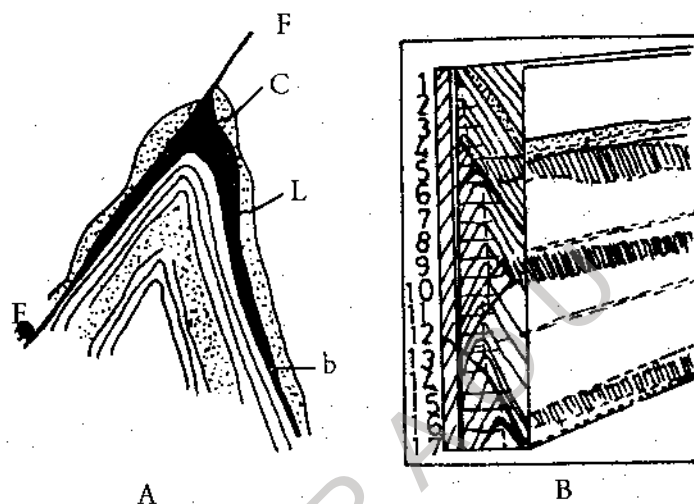


Fig 10.5

Showing A=Saddle reefs B= Three types of reefs

F=Fault C=Cap L=Leg b=Gold Quartz Ore

- viii) **Solution cavity filling:** In limestones, we find various types of solution opening into which hydrothermal solution deposits its mineral content.
- xi) **Breccia filling:** Irregular arrangement of angular to subangular fragments in breccia give rise to number of openings. The hydrothermal solution pass through and deposit the metal content to form breccia filling type of cavity filling deposits.
- x) **Fold crack filling:** Due to overlying burden, the lower part of the sedimentary beds bends developing gentle synclinal folds in some brittle rocks. It also develops connected tension cracks or opening known as pitches and flats. These cracks are the suitable sites for the deposition of metal content by hydrothermal solutions.

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.

7. Cavity filling deposits in which rock body is intercalated by a network of small closely spaced ore bearing veinlets is known as

10.4.2 Replacement Deposits

It is one of the types of hydrothermal deposits. It is a type of deposit commonly found in hydrothermal and mesothermal conditions. Replacement is a process in which there is capillary solution and deposition acting simultaneously. The replacing mineral is called metasome and it need not have common in with the replace substance. The replacing mineral is carried in solution and replaced mineral is also carried in solution hence, it is an open circuit.

If mineralising solutions encounter minerals that are unstable in their presence, then substitution may take place giving rise to replacement. The replacement process does not involve any change in shape and size of the rock material. Particle by particle replacement is carried or molecule by molecule. The mode of interchange can be shown with simple chemical equation such as



Replacement by hydrothermal solution is mainly due to diffusion. Movement of molecules or ions in a solution from point of supply to a point of deposition. There are three kinds of replacement deposits, they are i) Massive deposits ii) Replacement lode deposits iii) Disseminated replacement deposits.

- i) Massive deposits: are characterised by great variation in size and extremely irregular form. These deposits ramify into the rock after the replacement.
- ii) Replacement lode deposits: are found along the beds or fissures. Fig.10.6. They are very much resemble fissured vein deposits of cavity filling type. We find three differences between replacement lode and fissure vein deposits they are
 - a) They are wider than fissure vein.
 - b) The walls are generally wavy and irregular.
 - c) Replacement lode deposits show gradation into the country where as fissure veins do not show gradation with the rock.

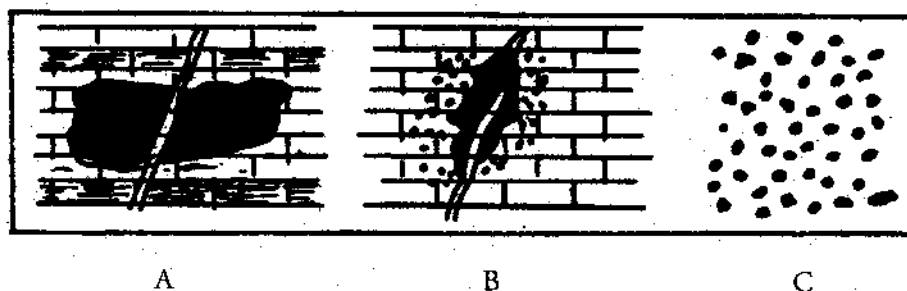


Fig. 10.6
Replacement Deposits

A. Massive

B. Disseminated

C. Multiple centre

- iii) **Disseminated replacement deposits:-** Replacement by hydrothermal solutions not in one place but scattered all through the rock body providing small proportion of the ore. The disseminated replacement deposits appears as if the economic minerals are scattered through the entire host rocks. They are generally huge but scattered which involve large scale mining operation and utilisation of low grade ores.

Oreshoots: Ore deposits are rarely found to be having same richness throughout. In some places it will be very rich and in some places it will be very poor. When primary ore minerals concentrate to a very great extent to form valuable economic mineral deposits, then such concentration is known as Oreshoots. The term ore shoot is primarily applied to economic minerals of hypogene type. The out line of the ore shoots may be irregular but generally they tend to be elongated bodies that extend in a vertical or highly inclined position up and down the fissure veins.

10.5 PEGMATITIC DEPOSITS

Pegmatites represent, the residual portion of the magma and in them are often concentrated valuable mineral which occur in rock. Pegmatite otherwise occur only in accessory amounts in the main body of the igneous represent aqueo-igneous stage and the richness in fluxes of the pegmatitic magma leads to the growth of minerals of large size. Pegmatite magma is very fluid, as such they are intruded as dykes and veins mainly around the borders of granite masses. Pegmatites are store house of many valuable minerals, and to mention a few are: mica, tourmaline, topaz, beryl etc.

Meaning of the Pegmatite Stage : When magma is undergoing the process of differentiation, it becomes progressively rich silica content with considerable amount of water and volatile like, Boron, Fluorine, Chlorine, Sulphur etc. These substance help crystallisation by decreasing the viscosity of the magma and by lowering the freezing point of the mineral. It is the stage in between igneous stage and hydrothermal stage. This aqueo igneous stage is known as **Pegmatitic stage**.

During the later stages of consolidation of magma, heated gases of great chemical activity stream into adjacent country rock and in this way pneumatolytic ore deposits are formed. This deposits usually accompany intrusions of granite and are associated with special set of minerals which form useful guide to the prospector.

10.6 SUBLIMATION PROCESS

When compounds which volatilised and redeposited from vapour at low temperature and pressure. Sublimation is a process in which solid material changes directly into gaseous state without becoming liquid or from gaseous state to solid state. Many compounds can not sublime under the presence of oxygen. Sublimation process is associated with volcanism and fumaroles. There are many sublimates deposited like sulphur, around volcanoes and fumaroles but the quantity is not much to form workable deposits of economic importance.

10.7 SUMMARY

Igneous processes include these deposits that have affinity in some way or other to igneous activity. These are (a) magmatic concentration process (b) hydrothermal process (c) contact metasomatic process, (d) pegmatitic deposits (e) sublimates

Magmatic concentration deposits are formed during differentiation of metal bearing magma directly from melts of an ultra basic, basic alkaline content magma which is hot molten rocky material slowly starts cooling with fall in temperature. All economic minerals originated

UNIT - 11 **SECONDARY PROCESSES**

Contents

- 11.0 Objectives
 - 11.1 Introduction
 - 11.2 Sedimentation Process
 - 11.3 Evaporation Process
 - 11.4 Residual and Mechanical Concentration Processes
 - 11.4.1 Residual concentration process
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 - 11.5.1 Oxidation process
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 - 11.6 Summary
 - 11.7 Check Your Progress - Model Answers
 - 11.8 Model Examination Questions
-

11.0 OBJECTIVES

In this unit we have discussed about secondary processes

After completion, you should be able to

- * explain sedimentation and evaporation processes
 - * describe residual and mechanical concentration processes
 - * explain oxidation and supergene enrichment processes
-

11.1 INTRODUCTION

Mineral deposits arising out of the processes of weathering and activities of several geological agents are called secondary mineral deposits and the processes associated with this are called secondary processes. The important processes are sedimentation, evaporation, residual and mechanical concentration, oxidation and supergene enrichment

11.2 SEDIMENTATION PROCESS

This class of deposits is formed by the process of sedimentation. When the pre-existing rocks are subjected to the process of weathering, the rocks are mechanically disintegrated and the mineral constituents are chemically decomposed. Broken and decomposed material will be carried away from the place of weathering by transporting agents like rivers, glaciers and wind to the site of deposition. Along with the rock materials some of the economic minerals found in traces are also carried and deposited to sedimentary economic mineral deposits. This process involving weathering, transportation and deposition of sediments and economic minerals into layers is known as sedimentary process. Some of the most important and world famous economic mineral deposits are formed by this process, such as iron, manganese, copper, phosphate, oil, coal and limestones. The sedimentary deposits are composed of both organic and inorganic materials.

Requirements for the formation of sedimentary deposits:

- The requirements are as follows: i) source material ii) gathering of the materials by solution iii) transporting of the material to the site of deposition and its accumulation.

Source Materials : The material forming the part of sedimentary deposits are derived from the pre-existing rocks after weathering. Some times weathering and oxidation of former mineral deposits also form source material for the sedimentary deposits. Igneous and metamorphic rocks may contain a number of mineral constituents. These mineral constituents may be iron, manganese, aluminium, barium, phosphorous bearing; such as pyroxenes, hornblende, rhodonite, celestine, apatite. Such igneous rocks, metamorphic rocks with these minerals on weathering provide source material for sedimentary deposits of iron, manganese, phosphorous and aluminium.

Solution and Transportation: These mineral constituents which are source materials for sedimentary deposits undergo chemical decomposition to form solution by the action of effective solvents like carbonated water, humic acids and other organic acids and sulphate solutions. These solvents dissolve Fe, Mn, P, Al and get mixed up with flowing water on the surface or through subsurface water. These sedimentary substances continue to remain in solution till the solution does not undergo any physical and chemical change.

Deposition of the solution containing the sedimentary material: Deposition of the sedimentary substances carried by transporting agencies may be mechanical, chemical or biochemical. The manner of deposition depends upon the nature of the solvents and place of deposition.

If the solution is in the form of bicarbonates of iron and manganese then the deposition may be due to loss of carbon dioxide; or it may be due to oxidation and hydrolysis or it may be due to bacteria, or it may be due to plants or it may be due to reaction with sea bottom colloidal silica. If the solution is in the form of sulphate of iron and manganese then the deposition may be due to reaction with calcium carbonate or it may be due to oxidation or hydrolysis.

If the solution is of organic nature with dissolved iron and manganese in it get deposited by oxidation of ferrous and manganese carbonate to ferric and manganese oxide or it may be due to bacterial action or it may be due to reaction with alkalies or it may be due to action of plants.

Bacterial action is considered to be of great importance in sedimentary deposits. Certain types of bacteria are responsible for the deposition of iron, manganese and even phosphorous. Bacteria are also effective in the deposition of sulphates and sulphur dioxide.

It has also been found that ordinary sea water electrolytes cause almost immediate precipitation of ferric oxide from colloidal iron solutions; so also the deposition of manganese.

The sedimentary iron and manganese ores are deposited in both fresh and salt water in bogs, swamps, marshes, lakes, lagoons and in the oceans. Phosphates and sulphur form under marine conditions.

Important deposits of iron, copper, manganese, vanadium, phosphorous, sulphur, limestone, clay are the products of sedimentary process.

11.3 EVAPORATION PROCESS

Evaporation is a common phenomena in nature. Many of the valuable non-metallic mineral deposits are formed by the process of evaporation. It is the most simple and familiar among all the processes involved in the formation of ore deposits. Evaporation process yields household materials used by the house holders, farmers, chemist, engineer, birds and plants. Salt mixed up in water, can be got by the process of evaporation.

Process of mineral formation by Evaporation:

This process of evaporation is very common in warm, dry, arid climate and also it is very active and effective in arid regions. The bodies of saline water have concentration of

various salts. The precipitation of salts occur when supersaturation of salt is reached. The precipitation, therefore, depends upon the solubility. Least soluble salts precipitate, in the early stage of evaporation itself; highly soluble salts are last to precipitate. Temperature and presence of other salts in solution also control the deposition by the process of evaporation.

In the formation of complex salts, time factor is also very important. Important salt deposits are formed by the process of evaporation. The term salts may mean chlorides, sulphides, carbonates, nitrates and borates of sodium and potassium; sulphates of calcium and magnesium. Large and important economic deposits of chlorides and sulphates are formed by the evaporation of water present in sea and salt lakes. The average salinity of the sea water is 35 parts per 1000 and the percentage composition of the salts is NaCl-77.76; $MgCl_2$ -10.88; $MgSO_4$ -4.74; $CaSO_4$ -3.60; K_2SO_4 -2.64; $CaCO_3$ -0.34 and $MgBr_2$ -0.22

Before these salts are deposited, water must become saturated with them and as sea water is not nearly saturated, special geological condition must play its part prior to their deposition. For example, Earth movement may cut off the part of the sea or by the shallowing of its concentration with the main body and if the climate is suitable deposition of salts occur by the process of evaporation. The salts are precipitated in a sequence during the process of evaporation. Calcium salts are first, followed by sodium salts, magnesium salts and finally the potassium salts. The salinity of sea water is due to salts brought by the rivers mainly; small amount of salts in sea is also contributed by volcanoes.

The salts are deposited mainly in marine and also in lacustrine environment. Calcium sulphates, common salt (Halite) Potassium salts, borates and bromides are some of the salts deposited in marine conditions by the process of evaporation. In lacustrine environment also the deposition of salts of saline lakes are more diverse than those of the salts formed in ocean. This is because, each lake is an individual unit with no outlet, collects into itself the soluble salts of its own drainage basin. With high rate of evaporation, characteristic of arid regions, deposition of salts take place. Lakes with sodium and potassium carbonates are called alkali lakes and lakes with sodium sulphate far greater in proportion than sodium carbonate and chlorides are called bitter lakes. Lakes with borates are known as borate lakes and lakes with nitrate are called nitrate lakes. These different types of lakes on evaporation yield different salt deposits.

Evaporation of underground water is universal but in humid regions these evaporates are mostly redissolved and carried away by rain water. The evaporation deposits get accumulated as long as the climate remains dry.

The ground water also contain salts in dissolved state like lakes and oceans. The concentration of these salts is generally low, the proportions of the individual salts vary with the character of the soil, bed rock, topography and climate of the area. Calcium carbonate is invariably present, magnesium, sodium, potassium, iron compounds are common. Silica, phosphorous, nitrates and borates are also found in very small proportion.

Deposition of salts by the process of evaporation occurs at or near the surface or in caves. Evaporation of ground water is very rapid when it is very close to the surface such as valley bottom, slope of the hill.

The deposits of economic importance formed by the evaporation of ground water are nitrate salts with iodine, some boron, calcium carbonate, sodium sulphate and sodium carbonate. The origin of these deposits is controversial. It is generally agreed that nitrates were transported by ground water and were deposited by this evaporation.

Natural brines result when sediments saturated with sea water are buried beneath the level of circulating ground water. These are called connate waters and become source of commercial salts on evaporation.

Calcium carbonate in solution in the ground water is also deposited by the process of evaporation at or near the surface.

The hot spring also contain salts in the dissolved state. These salts are deposited along the orifices of the spring by the process of evaporation. A few deposits formed by the evaporation process from hot spring have become commercially important. Chief substances deposited in this manner are calcium carbonate in the form of travertine; silica in the form of siliceous sinter or geyserite; iron oxide in the form of ocher, manganese dioxide in the form of wad. All such deposits around the orifices of hot springs are known as spring deposits formed by the process of evaporation.

11.4 RESIDUAL AND MECHANICAL CONCENTRATION PROCESSES

Rocks with economic mineral content in them after undergoing the process of weathering, will be mechanically broken down and chemicals decomposed. These loose fragments may be transported or stay at the site of weathering. If they stay at the place of weathering without undergoing transportation, and economic mineral also get concentrated, then such deposits are known as residual concentration deposits. If the weathered products undergo transportation by rivers or by wind, while getting transported there will be natural gravity separation. Minerals having high specific gravity will be separated from minerals having low specific gravity and get deposited at suitable site of deposition due to decrease in velocity of the transporting agents. Such deposits of economic minerals are termed as mechanical concentration deposits or placer deposits. By following the stream or rivers upstream, it is often possible to locate the original home of valuable economic minerals. Thus gold is traced to gold bearing quartz vein, platinum to ultrabasic igneous rocks and gems to metamorphic limestones.

Weathering is a slow, non stop destructive process whereby rocks get mechanically disintegrated and chemically decomposed. The minerals which are unstable under weathering conditions undergo chemical decay.

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. If the mineral deposit formed on the site of weathering, then the deposit is known as.....

.....

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.....

Soluble parts may removed and insoluble parts remain and get accumulated to form residual mineral deposits. Rocks contain, two types of minerals, stable minerals and unstable minerals. Stable minerals do not show any change chemically but they get freed from rocks by mechanical disintegration. Such stable minerals like quartz, gold, platinum, garnet etc., after getting freed from rocks accumulate in a place to form residual concentration deposits. If these stable minerals after getting freed undergo transportation and on the way getting separated as per their specific gravity from other minerals under transit to form mechanical concentration deposits.

Mechanical weathering or disintegration of parent rocks do not create new minerals but only reduces the particle size thereby increasing the specific area for chemical attack whereas chemical weathering or decomposition of rocks actually creates new minerals of which some minerals remain stable under surface conditions.

Thus the products of weathering fall into two groups such as i) Products staying at the place of weathering and ii) Products getting transported by water or air to the site of deposition after weathering.

11.4.1 Residual Concentration Process

If there are rich concentration of economic minerals derived from the weathering of rocks without getting transported, then such deposits are termed as residual concentration deposits.

Requirements for residual Concentration Deposits

In order to get residual concentration deposits, following requirements are absolutely needed. They are as follows

- i) Desired substances must be insoluble and undesired substances must be soluble under surface conditions.
- ii) Suitable climatic conditions are necessary for chemical decay. A rock containing Al, Fe and Si minerals may undergo weathering in different climatic conditions. Among these three constituents, silica is considered to be undesirable where as Al and Fe are of economic value.

If the rock containing Al, Fe and Si undergo weathering in temperate climate, silica is not completely removed but remains in the form of clay; whereas the same under tropical climate completely removes silica and we get concentration of Al or Fe to form bauxite and laterite deposits.

Therefore climate play an important role in **Residual concentration deposits**.

- iii) Relief should not be too great it must be moderate. Relief means the topography of the hill, which is undergoing the process of weathering. If the hill has steep slope, then, the loose fragments derived after weathering slide down rapidly and do to allow the material of economic importance to get concentrated at the site of weathering thereby, it becomes difficult to have residual concentration deposits.
- iv) The materials of economic importance should not get destroyed by the process of erosion. To withstand the erosion, the minerals must have long crystal stability.
- v) Of all the requirements mentioned above, the rocks undergoing the process of weathering must have economic mineral content present in them.

If these conditions are present, then, a limestone rock having iron impurity in the form of cementing material Ferrugeneous limestone on chemical decomposition dissolves calcium carbonate leaving behind iron oxide as residue. This iron getting concentrated yield residual concentration of iron.

Valuable deposits of iron, manganese, bauxite, laterite, tin, gold, kyanite, barite and clays are formed by residual concentration process.

11.4.2 Mechanical Concentration Process

It is a natural gravity separation of heavy minerals with the help of running water blowing wind, action of sea waves etc. When minerals of high specific gravity get concentrated deposited mechanically, such, valuable economic mineral deposits are called Mechanically

The mechanical concentration deposits form in two stages. In the first stage, weathering of the parent rock releasing the stable minerals from the rock matrix. The second stage is of concentration of stable economic minerals. The concentration will take place only when the economic minerals have three important characters, such as i) high specific gravity ii) chemical resistance to weathering iii) durability.

Gold, platinum, magnetite, chromite, rutile, copper, gemstones, zircon, have all the three important characters. Hence they form valuable economic mineral deposits by mechanical concentration process. Hence, these minerals are known as placer minerals.

The operation of mechanical concentration depends of few basic principles chiefly the specific gravity, size and shape of the particles. Mechanical concentration of placer minerals can take place if the velocity is favorable. If the velocity is less, separation of heavy minerals from lighter minerals do not take place. If it is a high velocity, then everything will be swept away together.

Regions of deep continued weathering of rocks containing economic minerals with steep slope are important for continuous supply to get concentrated and to form placer deposits.

Types of Placer Deposits : There are four types of Placer Deposits : they are (i) Eluvial placer (ii) Alluvial placer or stream placer (iii) Beach placer (iv) Eolian placer.

In all these four types of placer, we find natural gravity separation of heavy minerals from lighter minerals but the agents involved in separation are different.

- i) **Eluvial placer:** When a hill made up of rock material with economic mineral content, on weathering give loose particles of rock materials and economic mineral matter, these loose particles slide down the slope of the hill, in which heavy particles move down greater distance towards the bottom of the hill, whereas the lighter particles move little down the slope, thus bringing out the separation of heavy minerals from lighter ones. These heavy minerals which are chiefly economic minerals get accumulated at one place to form eluvial placer deposits. In this type the separation is mainly due to slope of the hill, eluvial placers are considered to be the initial stage in the formation of alluvial placers.
- ii) **Alluvial placer:** Among the four types of placer deposits, alluvial placer deposits are considered to be one of the most important type. It is also known as stream placers because the natural gravity separation is done with the help of flowing water. Water is considered to be natural vehicle of transportation and most effective separators. When the velocity of the stream decreases, the deposition of heavy minerals take place. Stream placer deposits are found along the banks of inland curves of meandering river or stream or places where river or stream cross highly inclined alternate hard and soft rocks, the harder rocks project in the form of ridge and soft rocks get eroded by stream action. So deposition of placer minerals can be found near the ridges so formed. Placer minerals are also found on the banks of the master stream which has tributary supply heavy minerals.
- iii) **Beach placer:** It is a kind of placer deposits in which natural gravity separation takes place with the help of the action of sea waves along the beach of the sea. Shore shift materials along shore, the lighter minerals are tossed farther away than the heavy minerals. Wave action also operates at the same time. These waves, throw up materials on the beach; subsequent concentration of economic minerals form beach placer deposits, ilmenite, rutile, monazite are some of the typical beach placer deposits.
- iv) **Eolian placer:** The blowing wind is also considered to be one of the effective sorter of heavy minerals from the lighter ones. The concentration of heavy economic minerals

by the action of wind is termed as Eolian placer deposits. Eolian placer deposits are found in the regions where wind is the sole geological agent; such regions are arid regions like desert. A sandstone containing gold particles in desert regions, under the action of wind get disintegrated into loose particles of sand and gold. Sand particles which are very light get blow by the wind action leaving behind gold particles. Such gold deposits are termed as eolian gold placer.

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. A placer deposits formed by the distruction of primary source by rise is

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3. A placer deposit in which the weathered and disintegrated material has shifted by wind is known as ...

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.....

.....

11.5 OXIDATION AND SUPERGENE SULPHIDE ENRICHMENT PROCESS

Like other rocks, ore deposits undergo weathering and decomposition at their outcrops, this weathered upper part of the deposit is called oxidised outcrop or gossan. Down beneath this gossan, the minerals have been altered into oxides. The process known as secondary enrichment is of great importance in silver, copper and other metals. The oxides and oxy salts are carried deeper on the primary ore body. Chemical action take place making already existing primary ore body into richer ore body. By this chemical concentration workable ore-bodies may result from rather low grade. Such process of enriching earlier ore body by down trickling solution in the form of sulphides is known as supergene sulphide enrichment.

Where ore deposit become exposed by erosion, they are subjected to weathering along with enclosing rocks. The surface waters oxidised many ores and yields solvents which can dissolve other minerals. Thus the ore body is oxidise and its valuable metal contents is leached down by the solvents and carry it down towards the water table and deposit the metal content in the form of oxides. If these solvents carrying leached metals cross the water table then, the deposits will be in the form of sulphides because below the water table, there is no available oxygen. Thereby already existing sulphides get enriched by supergene solutions. Therefore this phenomena is known as Supergene sulphide enrichment. The unaffected part of the ore

body is called Hypogene ore body or Primary ore body. Thus, we have different zones formed in the earlier ore body, such as i) Oxidised out crop or gossan ii) Leached zone iii) Oxidised ore zone iv) Sulphide enriched ore zone v) Primary zone or unaffected part of the ore body.

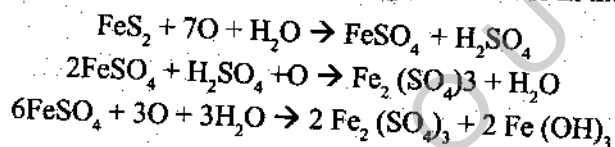
The zonal arrangement as described above is possible, only, when there is long continued weathering.

Requirements for Oxidation & Supergene Sulphide enrichment Process

- i) Long continued weathering is needed.
- ii) Geologically long time is required to yield desirable results.
- iii) Suitable climatic conditions are absolutely necessary.
- iv) Proper physiographic environment.
- v) Lastly the most important requirement for this process is presence of pyrite and amenable ores.

11.5.1 Oxidation Process

Oxidation and Enrichment by supergene solutions always go hand in hand. Without oxidation, there can be no supply of solvents. No solvents no down trick'ing of solutions and no formation of sulphide enrichment. The effect of oxidation on the ore body is of great importance. Minerals are changed and their structures get obliterated. Metallic substances are leached. Water with dissolved oxygen is the most powerful oxidising agent. Most metallic mineral deposits contain pyrite. The powerful oxidising agent attacks pyrite; which on chemical reaction yield powerful solvents capable of dissolving other matter in the ore body



The above equations explain the importance of the presence of pyrite in the ore body which gives rise to ferric sulphate, sulphuric acid, ferric hydroxides which are powerful solvents.

If pyrite is absent in deposits undergoing oxidation only small quantity of solvents are produced, thereby no or little enrichment of ferric sulphides can take place.

Factors which Control Oxidation

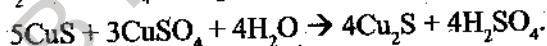
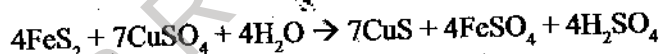
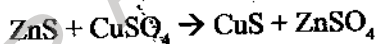
- i) The portion of water table is a deciding factor of oxidation. Above the water table only oxidation can take place because oxygen is freely available. Hence water table is the downward limit of oxidation. Since oxidation require oxygen, it stops where there is no supply of oxygen.
- ii) Rate of erosion must not be too high or too low the oxidation may not keep pace with erosion.
- iii) Suitable climate is of great importance of oxidation. High temperature accelerates oxidation, low temperature retards oxidation. Therefore, oxidation can take place brightly in warm climatic conditions than in cold climate.
- iv) Oxidation is relatively slow process and it requires considerable time geologically speaking. Many of the oxidised zones are atleast few million years old.
- v) The physical and chemical properties of enclosing rock affect oxidation of the ore body present in it. Oxidation is more effective in porous rocks, brittle rocks which can break or develop fracture easily. Oxidation is less effective in unfractured rocks.
- vi) Structural features greatly influence oxidation.

11.5.2 Supergene Sulphide Enrichment

The metals in solution that escape the capture in the oxidised zone trickle down to place of no available oxygen, that is below water table, deposit the metal content in the form of sulphides. The metals which are removed above are added to those existing below thereby enriching. This zone is called secondary enrichment or supergene sulphide zone. By this action of supergene solvent action rich ores are made richer, lean ores are made valuable, non commercial ore is converted into commercial ore body. There are certain requirements for supergene enrichment. They are i) Oxidation ii) Suitable Hypogene ore minerals iii) Permeability iv) Zone of no available oxygen v) Precipitants.

- i) Oxidation is the most important requirement for sulphide enrichment. Oxidation of ore deposits may take place without attendant sulphide enrichment but enrichment can not take place without accompanying oxidation.
- ii) Suitable hypogene ore minerals is absolutely needed otherwise it will not yield solvents. Iron sulphide i.e., pyrite is essential without which we can not expect supergene enrichment.
- iii) Permeability: The rocks must have the capacity to transmit solvent through them otherwise, the down trickling solutions can not penetrate beneath the zone of oxidation.
- iv) Zone of no available Oxygen : Supergene Sulphides can be deposited where there is no supply of oxygen which is generally below the water table.
- v) Precipitants: If the down trickling solutions do not encounter sulphides in zones lacking available oxygen, the sulphate become dissipated and no supergene sulphide enrichment occurs.

Supergene sulphide replacement is invariably volume for volume and is not molecular interchange between replacing and replaced substance.



Water level, primary ores, wall rocks, structure, topography, climate, erosion and time are the influencing factors for Sulphide enrichment.

Gossans: Oxidised out crops found on the top of the ore body undergoing the process of weathering are called Gossans. They are also known as Iron hats. Gossans are absent in glaciated regions. In all other areas the ore bodies are usually capped by gossans.

Gossans are considered to be important guides for locating hidden wealth. It is a cornish term for oxidised outcrop. Gossans attract the attention of the geologist and create interest in him, such that he makes a careful observation of the area. Locating a gossan means locating a hidden wealth i.e. a gossan is a sign board for a mineral deposit.

There are two types of gossans. a) True gossan b) False gossan. To distinguish between the two, it needs wide experience, thorough knowledge and careful observations.

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. In the Supergene sulphide enrichment the lower unaffected part of the ore body is the

5. Zone of oxidation in supergene sulphide enrichment process extends upto ...

11.6 SUMMARY

Mineral deposits formed with the processes of weathering and associated geological processes are called secondary deposits. The process of formation of secondary mineral deposits is called secondary processes. Secondary processes include Sedimentary, Evaporation, Residual Placer and Oxidation and Sulphide enrichment deposits. All these processes owe to weathering of pre-existing rocks and minerals. The Process involving weathering, transportation and deposition of economic mineral is called sedimentation process. This process yields valuable mineral deposits like iron, manganese, coal phosphates etc.

The process of evaporation is manifested by precipitation of salts under different solubility conditions governed by temperature and pressure. Residual processes yield deposits like Bauxite, Clay etc. as the products of weathering are subjected to differential solvent and leaching action. Placers are the deposits formed by the action of water, wind based on their physical properties and chemical stability. Deposits of oxidation and sulphide enrichment takes place at such sites where a ore body which is other wise subjected to weathering and solvent action under suitable physicochemical conditions.

11.7 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Residual concentration deposits
2. Alluvial Placer
3. Eolian Placer
4. Hypogene Zone
5. Water table

11.8 MODEL EXAMINATION QUESTIONS

I) Answer the following questions in about 30 lines each

- 1) Write an account of the ore deposits formed as a result of mechanical concentration
- 2) What do you understand by the term 'Oxidation' and "Secondary enrichment"? Briefly explain.
- 3) Briefly explain the evaporation process.

II) Answer the following questions in about 10 lines each

- 1) What are requirements for the formation of sedimentary deposits? explain.
- 2) Write an account of placer deposits.
- 3) Explain about metamorphic process.
- 4) What is oxidation process?

* * *

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II. Answer the following questions in about 10 lines each.

1. Explain in detail about the late magmatic deposits.
2. Write notes on the nature of magmatic mineral deposits.
3. What are the essential requirements for hydrothermal deposits to form.
4. Briefly explain the Pegmatitic deposits.
5. What is sublimation?

10.10 GLOSSARY

Contact Metamorphism	: Contact metamorphism is used for changes which take place in and surrounding intrusive rocks at lower temperature.
Pre-existing rock	: The parent rock present at the site of deposition.
Recrystallisation	: The process where by a mass of crystals passes through a solution phase in developing a new set of crystals.
Magma	: A molten rocky fluid formed within the crust or upper mantle of the earth.
Differentiation	: The separation of an igneous magma into two or more fraction, which on consolidate into different rock types.
Liquid Immiscibility	: The development of two liquids which do not mix, as oil and water behave.
Residual deposit	: Deposits formed from the left out magma.

* * *

UNIT - 11 SECONDARY PROCESSES

Contents

- 11.0 Objectives
- 11.1 Introduction
- 11.2 Sedimentation Process
- 11.3 Evaporation Process
- 11.4 Residual and Mechanical Concentration Processes
 - 11.4.1 Residual concentration process
 - 11.4.2 Mechanical concentration process
- 11.5 Oxidation and Supergene Enrichment Processes
 - 11.5.1 Oxidation process
 - 11.5.2 Supergene sulphide enrichment
- 11.6 Summary
- 11.7 Check Your Progress - Model Answers
- 11.8 Model Examination Questions

11.0 OBJECTIVES

In this unit we have discussed about secondary processes

After completion, you should be able to

- * explain sedimentation and evaporation processes
- * describe residual and mechanical concentration processes
- * explain oxidation and supergene enrichment processes

11.1 INTRODUCTION

Mineral deposits arising out of the processes of weathering and activities of several geological agents are called secondary mineral deposits and the processes associated with this are called secondary processes. The important processes are sedimentation, evaporation, residual and mechanical concentration, oxidation and supergene enrichment

11.2 SEDIMENTATION PROCESS

This class of deposits is formed by the process of sedimentation. When the pre-existing rocks are subjected to the process of weathering, the rocks are mechanically disintegrated and the mineral constituents are chemically decomposed. Broken and decomposed material will be carried away from the place of weathering by transporting agents like rivers, glaciers and wind to the site of deposition. Along with the rock materials some of the economic minerals found in traces are also carried and deposited to sedimentary economic mineral deposits. This process involving weathering, transportation and deposition of sediments and economic minerals into layers is known as sedimentary process. Some of the most important and world famous economic mineral deposits are formed by this process, such as iron, manganese, copper, phosphate, oil, coal and limestones. The sedimentary deposits are composed of both organic and inorganic materials.

Requirements for the formation of sedimentary deposits:

The requirements are as follows: i) source material ii) gathering of the materials by solution iii) transporting of the material to the site of deposition and its accumulation.

UNIT - 12 ORGANIC AND META MARPHIC PROCESSES

Contents

- 12.0 Objectives
- 12.1 Introduction
- 12.2 Organic Processes
 - 12.2.1 Calcareous deposits
 - 12.2.2 Phosphatic deposits
 - 12.2.3 Ferruginous deposits
 - 12.2.4 Silicious deposits
 - 12.2.5 Carbonaceous deposits
- 12.3 Metamorphic Processes
- 12.4 Summary
- 12.5 Check Your Progress - Model Answers
- 12.6 Model Examination Questions

12.0 OBJECTIVES

In this unit we have discussed about organic and Metamorphic process of ore formation. After completion of this unit, you should be able to

- * explain organic processes
- * describe calcareous, phosphatic, ferruginous, silicious and carbonaceous deposits
- * explain metamorphic processes

12.1 INTRODUCTION

In this earlier units the igneous and secondary processes of ore formation are discussed. In this unit emphasis is laid on organic process and metamorphic processes. In the organic processes there will be a direct or indirect activities of animals or plants are involved. The role of Biochemical process in the precipitation of ore deposits is getting attention by many geologists. Certain algae or Bacteria can cause the precipitation of oxide compounds by acting as catalyst for oxidation reactions. The anerabic Bacteria are able to reduce sulphates, producing H_2S which in turn may cause the precipitation of ore minerals.

The process of metamorphism by the action of pressure, temperature and solutions on pre-existing rocks also give rise to workable mineral deposits.

12.2 ORGANIC PROCESSES

Sedimentary processes are of two types, namely chemical precipitation and Biochemical precipitation. The Biochemical precipitation is the organic processes. The organic processes are also are of two categories i. Biochemical and ii. Bio-mechanical deposits. Bio Chemical deposits are formed due to the vital activities of organisms which accelerate the reaction and follow precipitation. These rocks are usually fine grained. Bio-mechanical deposits are formed due to the fragmentation of organisms like skeletons, shells etc. and their accumulation. The grain size depends upon the size of organism or fragments into which their hard parts break. To differentiate between biochemical and bio-mechanical it is very difficult, because the line of demarcation is very lazy and they grade into each other.

The effect of temperature, pressure and solutions make the mineral matter to change and to form economic minerals with metamorphism. Several kinds of non metalliferous deposits are formed such as graphite, talc, garnet, kyanite, andalusite, silliminite etc.

12.5 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Organic process is one in which organisms are involved directly or indirectly for the formation of ore deposits.
2. Coal, mainly lignite, Bituminous and Anthracite.
3. Kyanite, silliminite, andalusite, garnet etc. are the characteristic minerals of metamorphism

12.6 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each

1. Write an essay on organic processes.
2. Explain metamorphic processes.

II. Answer the following questions in about 10 lines each

1. Calcarious deposits.
2. Carbonaceous deposits.

* * *

BLOCK - IV : DESCRIPTION OF MINERAL DEPOSITS

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UNIT - 13 FERROUS AND FERROALLOY MINERALS

Contents

- 13.0 Objectives
 - 13.1 Introduction
 - 13.2 Iron
 - 13.2.1 Chief ores
 - 13.2.2 Process of formation
 - 13.2.3 Indian distribution
 - 13.3 Manganese
 - 13.3.1 Chief Ores
 - 13.3.2 Process of formation
 - 13.3.3 Indian distribution
 - 13.4 Chromium
 - 13.4.1 Chief Ores
 - 13.4.2 Process of formation
 - 13.4.3 Indian distribution
 - 13.5 Summary
 - 13.6 Check Your Progress - Model Answers
 - 13.7 Model Examination Questions
-

13.0 OBJECTIVES

In this unit, we have discussed about ferrous and ferroalloy minerals, after completion, you should be able to

- * explain the chief ores, formation process and distribution of iron.
 - * describe the ores, formation and distribution of manganese.
 - * explain the ores, formation processes and Indian distribution of chromium.
-

13.1 INTRODUCTION

Amongst the various ore minerals, the iron ores and the ores of ferroalloy metal ores are of unique importance. They constitute the basic raw materials for the iron and steel industries. Steel is synonymous with industrialisation and the per capital production / consumption of steel of any country is an index of degree of its industrial development. You will therefore find a ocean of difference between developed countries like U.S.A. and a developing country like our India. It is not enough to have Iron ore deposits. They should be mined and iron and steel should be produced. Here in this unit the important ores, formation process and Indian distribution of Iron, Manganese and Chromium are discussed.

13.2 IRON

Iron is most widely distributed and abundant metal round in rocks of the earth's crust. Iron constitutes about 45% of the earth's crust next to aluminium. Iron is the back bone of modern industry. Steel, cast iron, wrought iron and iron alloys have their particular sphere of use. Iron is unaffected by dry air but oxides are formed when it comes in contact with moist air. **109**

Pig Iron, from which all the various grades of iron and steel are obtained is produced in the blast furnace by the reduction of iron ore by coke. Strongly magnetic in character.

13.2.1 Chief Ores

ORE	COMPOSITION	TENOR PERCENTAGE
Magnetite	Fe_3O_4	72.4%
Haematite	Fe_2O_3	70.0%
Limonite	$2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$	60.0%
Siderite	FeCO_3	48.2%
Pyrite	FeS_2	46.2%

13.2.2 Process of formation

Various types of commercial deposits of iron ore are formed by magmatic segregation, by contact metasomatism, by sedimentary process, by residual concentration process. Limonites are found in the gossans of sulphide deposits. The sedimentary, magmatic and residual process give rise to the most important deposits. There are some iron deposits which are the products of two or more processes. For example, iron deposited by sedimentation process followed by residual enrichment subsequently metamorphosed.

13.2.3 Indian Distribution

The biggest iron ore deposits of India are situated in the Singhbhum district of Bihar and the adjoining districts of Keonjhar, Sundergarh and Mayurbhanj of Orissa. The important mining centres in Orissa and Bihar are Guva, Bonai, Barbil, Kiriburu, Sulupet, Gorumahisani, Noamundi, Barjamada etc. The other distribution is Bailadila hill ranges of Madhya Pradesh, Ratnagiri of Maharashtra, Bicholim - Pale in Goa, Bababudan hills and Kudremukh of Karnataka, Salem district of Tamilnadu, Cuddapah, Kurnool, Chittoor, Nellore, Anantapur and Adilabad districts of Andhra Pradesh, Iron ores are also occur in West Bengal and Assam.

Some Important Ores

Magnetite:- Chemical composition is Fe_3O_4 , Iron Black colour, Black Streak, Metallic to sub metallic luster, cubic system, sub conchoidal fracture, hardness 5.5 to 6.5, high specific gravity. Some magnetite varieties are using as natural magnets. Magnetite is useful in the manufacture of steels and in the heavy media coal washers.

Haematite :- Chemical composition is Fe_2O_3 , steel grey or iron black in colour, cherry red colour streak, metallic luster, Hexagonal crystal system, sub conchoidal fracture, hardness 5.5 to 6.5, high specific gravity. Useful in the manufacture of metallic iron and steel and soft variety is using in paint industry.

Pyrite: Chemical composition is FeS_2 , brange yellow in colour, greenish black streak, cubic crystal system, metallic luster, conchoidal or uneven fracture, hardness 6 to 6.5. It is useful in the manufacture of H_2SO_4 .

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.

- List out the two chief ores of iron with Tenor Content and Composition

13.3 MANGANESE

It is one of the most important ferro alloy metals. Manganese is alloyed with iron to produce special steels with specific properties. Not only manganese is used in making high manganese steels but it is absolutely essential for making all carbon steel. Manganese ore of high purity is used in glass industry, paints, pigments, dyes and in fertilisers. Manganese ore is generally hand sorted. It is then heated in furnace with iron ore to make ferromanganese. A little metallic manganese is made in electric furnace and by the thermal process.

13.3.1 Chief Ores

ORE	COMPOSITION	TENOR PERCENTAGE
Hausmanite	Mn_3O_4	72.4%
Braunite	Mn_2O_3	64.3%
Manganite	$MnO(OH)$	62.5%
Pyrolusite	MnO_2	63.0%
Psilomelane	Hydrate oxide of Mn with Ba and K	
Dialogite	$MnCo_2$	47.8%
Rhodonite	$MnSiO_3$	41.86%

13.3.2 Process of formation

Manganese deposits are formed either by hydrothermal solution or by the process of sedimentation or by residual concentration process. Some of the important deposits of manganese are from sedimentary and residual concentration processes. Weathering of manganese bearing minerals in schists, pegmatite, sedimentary beds, fissure veins have yielded valuable deposits of manganese. By metamorphism of sedimentary and residual deposits of manganese, we get rich valuable manganese ore deposits. Manganese gets precipitated in beds during the sedimentation process or layers of nodules along with iron in moderately deep water.

13.3.3. Indian Distribution

India is one of the largest producers of manganese in the world. The most important localities in India where manganese deposits are found in Balaghat, Chindwara, Jabalpur, Nagpur which yield 60% of the Indian output of high grade Mn ore all in Madhya Pradesh. Rich manganese deposits are present in Bellary, Chitaldurg, Shimoga and Belgaum districts of Karnataka, Srikakulam of Andhra Pradesh. Gondite and Kodurite are the chief sources of manganese in India of Dharwarian age. Workable deposits of manganese are also found in laterite like rocks in various parts of peninsular India. Dharwar rocks have been metasomatically replaced by underground water containing manganese solutions.

Psilomalene : Chemical composition is $Mn_2O_3 \cdot 2H_2O$, dark steel grey in colour, brownish black streak, submetallic luster, hardness 5 to 6, specific gravity is medium to high. It is one of the chief ores of manganese. High grade varieties are used in the manufacture of batteries. It is the chief raw material for the preparation of chemicals like $KMnO_4$.

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 are the uses of Manganese?

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13.4 CHROMIUM

Chromium like manganese is an important ferrous alloy metal. Chromite is the only ore mineral of chromium. Previously chromite was used chiefly in refractories. After the development of science and technology, chromium has become a prized steel alloy. Chromium imparts great strength to alloys and it increases the toughness, hardness, resistance to oxidation, abrasion, chemical attack, electricity and high temperature breakdown. As a refractory, the mineral chromite is widely used for furnace lining, and its chemical compounds are used in dyeing, bleaching, tanning and as oxidising agent. Chromite is a mixture of oxides of iron and chromium with 68%Cr₂O₃ and 32% FeO. Chrome is marketed as lump chromite after hand sorting.

13.4.1 Chief ores

The important ore of chromium is chromite Cr₂O₃, FeO

13.4.2 Process of formation

Chromite deposits are mostly formed by magmatic concentration process belonging to segregation and injection type. There has been considerable discussion as to the time of crystallisation of the chromite, whether early magmatic or late magmatic or even during hydrothermal stage.

Chromite mostly occurs in basic and ultrabasic igneous rocks like dunite, pyroxenite, peridotite. Small quantities of chromite are also found in detrital sedimentary deposits.

13.4.3 Indian Distribution

Chromite occurs in host rocks as masses, lenses and disseminations in various state of India like Orissa, Karnataka, Tamilnadu and Andhra Pradesh. Important localities where we get chromite deposits are Byrapur in Karnataka, Salem in Tamilnadu, Ratnagiri of Maharastra, Krishna district of Andhra Pradesh, Dhenkanal, Cuttack and Keonjhar of Orissa. The Orissa deposits are considered to be the biggest in India. Next comes Karnataka Tamilnadu and Maharastra. Tamilnadu and Singbhum deposits produce relatively small quantity.

Chromite : Chemical composition is Cr₂O₃, FeO, iron black colour, brown streak, sub metallic luster, cubic crystal system, uneven fracture, hardness 5.5, specific gravity medium to high, moderately magnetic. It is the only ore of chromium metal, it is a ferroalloy metal, useful in the manufacture of structural steels and stainless steels. It is useful as refractory, useful for the manufacture of paints, chrome nickel is useful in electricity.

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. Chromite occurs in

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13.5 SUMMARY

Ferrous and ferroalloy minerals were explained in this unit. Iron, manganese and chromium are the important ferrous and ferroalloy minerals. Iron is most widely distributed and abundant metal in rocks of the earth crust. Iron is the back bone of the modern industry. The chief ores of iron are the magnetite, hematite, limonite, siderite, pyrite etc. Iron ores are formed with magmatic segregation, by contact metasomatism, by sedimentary process, by residual concentration processes. Some ores are the products of two or more processes. The biggest iron ore deposits are situated in the Singhbhum district of Bihar and the adjoining districts of Orissa. Iron ore deposits are available in the states of Maharashtra, Madhya Pradesh, Karnataka, Goa, Tamil Nadu, Andhra Pradesh, West Bengal, Assam.

Manganese is the important ferroalloy metal. Manganese is alloyed with iron to produce special kinds of steel. It is also essential for making carbon steels. It is useful in glass industry, paints, pigments, dyes, fertiliser industries. The chief ores are hausmanite, braunite, manganite, pyrolusite, psilomalene, diallogite, rhodonite. Manganese deposits are formed either by hydrothermal solution or by the process of sedimentation or residual concentration processes. In India Manganese deposits are found at Balaghat, Chindwara, Jabalpur areas. Rich deposits are also found in Karnataka, Andhra Pradesh.

Chromite is the other important ferrous alloy metal. Chromium is the chief alloy of steel. Chromium imparts great strength to alloys and it increases toughness, hardness, resistance to oxidation, abrasion, chemical attack, electricity and high temperature breakdown. Chromite is the only important ore of chromium. Chromite deposits are formed by magmatic concentration process belonging to segregation, injection type. In India, chromite occurs at Sukinda (Orissa) Kondapalli (Andhra Pradesh) Byrapur (Karnataka) Salem (Tamilnadu).

13.6 CHECK YOUR PROGRESS - MODEL ANSWERS.

1.	Iron Ore	Composition	Tenor
	Magnetite	Fe_3O_4	72.4%
	Hematite	Fe_2O_3	70.0%
	Limonite	$2\text{Fe}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$	60.0%
	Siderite	FeCO_3	48.2%
	Pyrite	FeS_2	46.2%

2. Manganese is chief ferroalloy metal. It is useful in steel industry, glass, paints, pigments, fertiliser industries.
3. Chromite occurs in ultra basic rocks.

13.7 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each

1. Write a short essay about iron ores, formation and distribution.
2. Give an account of occurrence and origin of chromite deposits of India.

II. Answer the following questions in about 10 lines each

1. Uses of Manganese
2. Distribution of iron ores in India.

* * *

UNIT - 14 NON FERROUS MINERALS

Contents

- 14.0 Objectives
- 14.1 Introduction
- 14.2 Gold
 - 14.2.1 Chief Ores
 - 14.2.2 Process of formation
 - 14.2.3 Distribution in India
- 14.3 Copper
 - 14.3.1 Chief Ores
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- 14.4 Lead and Zinc
 - 14.4.1 Chief Ores
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- 14.5 Aluminium
 - 14.5.1 Chief Ores
 - 14.5.2 Processes of formation
 - 14.5.3 Distribution in India
- 14.6 Summary
- 14.7 Check Your Progress - Model Answers
- 14.8 Model Examination Questions

14.0 OBJECTIVES

In this unit, we have discussed about non ferrous metallic minerals.

After completion of this unit, you should be able to

- * explain about gold ores, formation and distribution.
- * describe the processes of formation of copper, lead, zinc, manganese and aluminium ores.
- * describe the Indian distribution of copper, lead, zinc, manganese and aluminium ores.

14.1 INTRODUCTION

The utility and applications of non-ferrous metals like copper, lead and zinc in industry as well as defence are quite vast. They play crucial role in the manufacture of alloy metals. The most important use of copper is in the electrical industry both as a conductor and for electrical machinery. All armatures of electric motors require copper wire. It is indispensable in telecommunications and telephone exchange where several kilometers length of copper wire is consumed. Copper extensively used in the manufacture of alloys, such as bronze, gun metal, bell-metal (copper and tin), brass (copper, nickel and zinc) and some others of technical importance, such as phosphorous and manganese bronzes, silicon bronze and novel metal etc. The use of copper for defence is still more important. About 400 Kg of copper is required to

build a tank, one ton for a large bomber and 1000 tonnes for a battle ship. Still larger amounts go into the making of ammunition. The most important use of lead and zinc is in the protective coating of steel sheets. Lead prevent gamma radiations and its painting on doors and windows protects people from radiation hazards of atom bombs.

14.2 GOLD

Gold is one of the precious metals like platinum and silver. Gold occurs in nature as native gold with a purity of nearly 99.8% gold when it is pure, it is more soft, ductile and malleable. The specific gravity is 19.3 and melts at 1060°C . Gold is known to man since antiquity. Mostly used in the preparation of ornaments. For over 2000 years, its value is generally increased and rarely decreased. International market is controlled by gold. India produces 7% of the world output South Africa produces nearly 35% of the world out put of the gold. Gold's purity is expressed in terms of carats. One carat means 1 part of gold in 24.

Gold forms natural amalgam with mercury and silver. Gold tellurides occur mainly in veins and replacement deposits in which they are associated with pyrite and other sulphides.

14.2.1 Chief ores

ORE	COMPOSITION	TENOR PERCENTAGE
Native Gold	Au	99.8%
Elements with other metallic Elements	Gold Amalgam (Au, Ag, Mg)	40.0%
Gold Tellurides	Sylvanite (Au, Ag) Te_2 Calaverite (Au, Ag) Te_2 Petzite (Ag, Au) $_2\text{Te}$	

14.2.2 Process of formation

Gold deposits are formed by various processes in nature such as magmatic concentration, contact metasomatism, replacement and cavity filling types by hydrothermal solutions. Gold deposits are also found as residual and mechanical concentration deposits or placer deposits.

14.2.3 Distribution in India

Gold occurs in India both as native gold associated with quartz-veins or reefs. It occurs in alluvial sands of large number of rivers. The main source of gold in India is in Quartz reefs traversing Dharwar rocks in Kolar district of Karnataka state: It is popularly known as Kolar Gold Fields (K.G.F.). It is one of the deepest mines. Presently the mining operation is taking place at a depth of 4000 meters. Next to Kolar, we get gold in Hutti area of Raichur district of Karnataka where gold occurs in Dharwar schist. Gold occurs in quartz reef traversing chloride schist of Dharwarian age at Ramgiri in Ananthapur district of Andhra Pradesh.

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. Kolar gold deposit is an example of

14.3 COPPER

It is one of the most important non-ferrous metals. Copper is widely distributed and abundant element in combination and is also found in native state. Copper is comparatively soft but it is tough, malleable and ductile with specific gravity of 8.9 and melts at 1100°C . It is best conductor of electricity. Copper is used extensively for the manufacture of alloys such as Bronze, Gun metal, Bell metal, Copper salts are used in various industries such as disinfectant, in printing and dyeing of textiles, for preserving timber and as fungicide.

14.3.1 Chief ores

ORE	COMPOSITION	TENOR PERCENTAGE
Native Copper	Cu	
Cuprite	Cu_2O	88.8%
Chalcopyrite	CuFeS_2	84.5%
Chalcocite	Cu_2S	79.8%
Covellite	CuS	66.4%
Malachite	$\text{CuCO}_3 \cdot \text{Cu(OH)}_2$	57.3%
Azurite	$2\text{CuCO}_3 \cdot \text{Cu(OH)}_2$	55.1%

14.3.2 Process of formation

Copper deposits are formed by various processes such as by magmatic concentration, by contact metasomatic process, by hydrothermal solution filling the cavities or by hydrothermal solutions replacing minerals of rocks through which it is passing. Supergene sulphide enrichment process has also yielded valuable copper deposits.

Most of the important and big deposits of copper have been formed by hydrothermal solutions with replacement dominant over cavity filling type. In unglaciated regions most copper deposits have undergone oxidation and supergene enrichment.

14.3.3 Distribution in India

Copper deposits are found in Singhbhum and Chota Nagpur in Bihar; Nellore and Krishna Districts of Andhra Pradesh; Ajmer, Khetri of Rajasthan. The Copper deposits of Sikkim are found in association with Bismuth, Antimony, Zinc and Lead. Agnigundala of Guntur district in Andhra Pradesh, Mylaram of Khammam district have yielded good deposits of copper. Rich copper deposits are being found in Malazkund, Bhandara Districts of Maharashtra. In most of the above deposits, the mode of origin of ore bodies is almost similar. They have resulted from the metasomatic replacement of the country rock by copper bearing solution derived from granitic and other intrusions in the Dharwarian rocks.

Chalcopyrite:- Chemical composition is CuFeS_2 , brass yellow in colour, greenish black streak, trigonal (Hexagonal) crystal system, uneven fracture, hardness 3.5 to 4, occurs mainly in hydrothermal deposits.

Malachite:- Chemical composition is $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$, bright green in colour, light green streak, Monoclinic crystal system, silky luster, cleavage present, hardness 3.5 to 4, occurs in the zone of weathering of oxidation.

Azurite:- Chemical composition is $2\text{CuCO}_3\cdot\text{Cu}(\text{OH})_2$, deep azure blue in colour; blue streak, monoclinic crystal system, vitreous luster, conchoidal fracture, hardness 3.5 to 3.8; occurs on the surface of copper deposits in the zones of oxidation and weathering.

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. Name the three chief ores of Copper with tenor content

14.4 LEAD AND ZINC

These two metals lead and zinc are usually considered together because of their natural associations. Though they are not chemically similar yet geological conditions favour their association. Throughout the world we find the sulphides of lead, zinc and copper occur forming one common deposit. They are most important metals of modern industry. They are essential nonferrous metals next to copper. Lead is used in cable covering, storage batteries, pipes, sheet lead and bearing metal, where as zinc finds its use in galvanizing, die casting, brass making, for precipitating gold, use in medicine and chemicals.

14.4.1 Chief ores

ORE	COMPOSITION	TENOR PERCENTAGE
Galena	PbS	86.6%
Cerrussite	PbCO_3	77.5%
Anglesite	PbSO_4	68.3%
Pyromorphite	3Pb_3	$\text{P}_2\text{O}_5, \text{PbCl}_2$
Zincite	ZnO	80.3%
Franklinite	(Fe, Zn, Mn)	$(\text{Fe, Mn})_2\text{O}_3$ 15-20%
Smithsonite	ZnCO_3	52.0%
Sphalerite	ZnS	67.0%

14.4.2 Process of formation

Most lead and zinc deposits occur as cavity fillings and replacement formed at low temperature by hydrothermal solutions. Lead and zinc deposits by contact metasomatic process and by oxidation in surface conditions.

14.4.3 Distribution in India.

Considerable lead, zinc deposits occur in the metamorphosed limestones belonging to Aravalli system near Udaipur in Rajasthan are known as Zawar lead and zinc deposits. This mineralisation of lead and zinc at Zawar is believed to be due to intrusion of Granite body beneath Aravalli Limestones during post Delhi Orogeny. The Zawar lead-zinc deposits belong, geologically to the class of metasomatic replacement. Lead-Zinc deposits associated with silver are found in number of places such as Himalayas, Tamilnadu, Bihar, Andhra Pradesh enclosed in crystalline schists or as veins or pockets in precambrian and Vindhyan limestones.

Galena:- Chemical composition is PbS , lead grey colour, lead grey streak, cubic crystal system, metallic luster, perfect cleavage, hardness 2.5, high specific gravity, occurs as hydrothermal and metasomatic replacement deposits.

Sphalerite:- Chemical composition is ZnS , black or brown in colour, white or reddish brown in streak, perfect cleavage, cubic crystal system, resinous luster, hardness 3.5 to 4.0. Occurs in hydrothermal deposits in association with galena.

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. Lead and Zinc deposits of Rajasthan State are confined to the rocks of
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14.5 ALUMINIUM

Aluminium (Al) is not found in a free state but in combination.

It constitutes nearly 8% of the earth's crust. Most abundant of all metals. Chief industrial sources of Aluminium is Bauxite.

14.5.1 Chief ores

The chief ore of aluminium is the Bauxite with chemical composition $Al_2O_3 \cdot 2H_2O$.

Aluminium metal is produced by electrolysis of alumina obtained from bauxite ($Al_2O_3 \cdot 2H_2O$). low specific gravity of 2.58, i.e. It forms alloy with most metals and some non metals. Chief uses of aluminium is in causing industry, household utensils, for wrapping material and foil. Now-a-days aluminium metals widely used in electrical industries in place of copper. It is essential constituent of clay mineral and large number of silicates such as feldspars, micas, sillimanite, kyanite, andalusite etc.

14.5.2 Process of formation

Bauxite results from the decay and weathering of Aluminium bearing rocks. Bauxite deposits are mostly due to residual concentration process. Bauxite is not mineral species but colloidal mixture of hydrated oxide of Al, Fe and water. Commercial bauxite is in three (3) forms pisolitic or oolitic, sponge ore and amorphous or clay ore.

All bauxite deposits result from residual concentration and occur as Blankets at or near surface or near surface or inter stratified deposits on unconformities or pocket deposits in limestones or as transported deposits. Four tons of bauxite yield two tons of pure alumina and one tone of metal.

14.5.3 Distribution in India

Rich deposit of bauxite are found located in maharastra, Karnataka, Madhyapradesh and Andhra pradesh. East Coast bauxite deposits considered to be one of the biggest and richest.

Bauxite :- Chemical composition $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$, dirty white, greyish or brown in colour, earthy streak, hardness 2.5 to 3.5. Lateritic bauxite deposits are formed as residual concentrations.

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. What is the chief ore of Aluminium?

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14.6 SUMMARY

Nonferrous metallic minerals are useful to the society in many ways. They play very important role in the manufacture of alloy metals. Copper and aluminium are very essential in electrical industry, lead and zinc are useful as a protective coating of steel sheets.

Gold is the most precious metal. Gold occurs as native gold. In our country, gold is useful in the preparation of ornaments. Gold deposits are formed by magmatic concentration, contact metasomatism replacement and cavity filling processes of hydrothermal solutions. Gold also found as placer deposits. In India Dharwar rocks in Kolar district of Karnataka and Anantapur district of Andhra Pradesh are the major mining centres.

Copper is the most important non-ferrous metal and is the best conductors of electricity. Copper occurs as native copper, cuprite, chalcopyrite, chalcocite, covellite, malachite, azurite. Copper deposits are formed by magmatic concentration, contact metasomatic process, by hydrothermal solutions and supergene sulphide enrichment processes. Copper occurs in Bihar, Rajasthan, Andhra Pradesh and Maharashtra.

Lead and zinc are usually considered together because of their natural association. These are essential non ferrous next to copper. Lead is used in cable covering, storage batteries pipes, sheets and bearing metal. Zinc is useful in galvanising, diecasting brass making, in medicines etc. The chief ore of lead is galena and zinc is sphalerite. Most lead and zinc deposits occurs as cavity filling deposits. Lead and zinc deposits occurs in Rajasthan, Tamilnadu Bihar and Andhra Pradesh.

Aluminium is not found in free state. It is the most abundant metal. The chief source of Aluminium is Bauxite. Bauxite deposits are mostly due to residual concentration process. Rich bauxite deposits occurs in the Easternghats region of Andhra Pradesh

14.7 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Fissure vein deposits
2. Cuprite, chalcopyrite, malachite
3. Aravalli group
4. Bauxite

14.8 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each

1. What are the chief ores of copper?
Write about the formation processes and distribution in India.
2. Write the chemical composition, processes of formation and distribution in India of lead and zinc.

II. Answer the following questions in about 10 lines each

- 1) Aluminium ores
- 2) Gold distribution in India.

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UNIT - 15 NON METALLIC MINERALS

Contents

- 15.0 Objectives
 - 15.1 Introduction
 - 15.2 Cement
 - 15.3 Refractories
 - 15.3.1 Acid Refractories
 - 15.3.2 Neutral Refractories
 - 15.3.3 Basic Refractories
 - 15.4 Abrasives
 - 15.5 Ceramics
 - 15.6 Paints and Pigments
 - 15.7 Precious and Semi Precious Minerals
 - 15.8 Summary
 - 15.9 Check Your Progress - Model Answers
 - 15.10 Model Examination Questions
-

15.0 OBJECTIVES

In this unit the non metallic minerals used in the industries of Cement, Refractories, Abrasives, Ceramics, Paints and Pigments are discussed. After completion, you should be able to

- * describe non metallic minerals and industrial needs
 - * describe raw materials. needs for manufacturing
 - * describe precious and semi precious minerals
 - * explain the uses of non metallic minerals
-

15.1 INTRODUCTION

The non metallic minerals includes a wide variety of minerals and are useful for different industries. These are also called as industrial minerals. These non metallic minerals are classified on the basis of their utility and purpose for which the minerals are used. The application is quite wide and all most all industries require these minerals. If some as basic raw materials, others at some stage or other. There is no industry which does not use minerals. In this unit, the minerals used in cement industry, abrasives, refractories, paints and pigments, ceramics, precious and semi precious stones are discussed.

15.2 CEMENT

The word cement is used both colloquially as well as technically. In engineering it is referred to the product which has hydraulic property i.e., The property of hardening under water.

Romans made cement by mixing slacked lime with volcanic ash called it pozzuolane cement. It was not until 1824 that portland cement was made. A brick layer by name Aspidin mixed lime and clay with certain proportion and burned the mixer in a kiln. The resulting product was pulverized and used in the manufacture of concrete. This concrete resembled in

appearance the stone that was being quarried in the Isle of Portland as such Aspidin, gave this base material the name as Portland cement. The portland cement of today does not however have the same composition as that prepared by the Aspidin in 1824. The other types of cement are a) White cement b) Alumina cement c) Natural cement d) Pozzoualane cement and e) Slaged cement. Its more restricted sense the word cement practically always mean portland cement which is by far the most important cement used for constructional purposes at the present time.

Portland cement is an active combination of silicates, aluminates and ferro-aluminates of lime. The most combination of silicates, aluminates in portland cement is tri-calcium silicate, 3CaOSiO_2 which is supposed to give hydraulic property. The white cement is made of clay that burned to find white colour and used for decoration. Alumina cement is made up of lime, bauxite and coke. This has property of very quick setting and resistant to the action of sea water. The natural cement is made by calcination at high temperature either clay limestone or argillaceous limestone.

Pozzoualane cement is made from lime and volcanic ash, while for the manufacture of slag cement blast furnace slag is being used. The chief raw materials for portland cement should constitute three parts of limestone and one part of clay.

The following is the composition of the mix.

CaCO_3	75%
$\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$	20%
$\text{MgO} + \text{Alkalies}$	5 %
Gypsum	3%

Gypsum is being added as retarder.

Besides the above chemical constitution the limestone should be physically sound to yield firm crushed kiln feed without fine i.e. it should be hard and fine grained. Most cement requirement is that the limestone must not contain more than 3% MgO or 5% MgCO_3 . These should not be any free silica or sulphur occurrences. The chief raw material required for cement industry is limestone. Limestone is available in different parts of the country, particularly from Vindhyan rocks and their equivalents. Such limestones are abundantly available in Andhra Pradesh. The principal localities are in Palanad, Kareemnagar, Adilabad and Nalgonda districts. Elsewhere in Ratnagiri, Chanda in Maharashtra, Raipur, Baster, Jabbalpur in Madhya Pradesh. In all most the states of India, suitable deposits of limestone are available for manufacture of cement.

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 the Composition of Portland cement mix ?

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15.3 REFRACTORIES

A group of minerals are commonly used metallurgical industry as refractory materials for furnace lining to other metallurgical purpose must withstand high temperatures i.e. above 1500°C.

The group includes Graphite, Kyanite, Chromite, Magnesite, Bauxite etc. The basic requirements for refractories are :

- a) They should not react with materials being melted.
- b) They should be strong enough to withstand the weight and wear of molten metals and slag.
- c) They should resist cooking and spalling under temperature changes.
- d) They should be moulded in bricks or other forms.

The refractories used in large quantities are classified into:

- (i) Acidic refractory minerals are fire clay, sandstone, Bauxite (Siliceous material).
- (ii) Neutral refractory minerals are graphite, chromite, sillimanite and kyanite
- (iii) Basic refractories minerals are dolomite, magnesite, serpentine

15.3.1 Acid refractories

The bulk of the modern refractories are grouped under fire clays and silica refractories. The fire clay refractories are used for furnace linings, boilers etc. The silica refractories common forms are quartzite and crushed quartz. They are used in many metallurgical processes like smelting.

The sand stone and quartzite of suitable refractory grade are available in the different parts of India from Vindhya and their equivalents, Cuddapah and their equivalents. A few occurrences are also available from intrusive quartz veins and different river sand.

15.3.2 Neutral refractories

Graphite required for the industry is of flaky or lumpy or amorphous variety. Usually 80-85% carbon content graphite is used as refractory.

The graphite deposits of India are confined to precambrian metamorphic formation. The principal source of supply of graphite is from Orissa-Bolangir, Kalhandi, Koraput, Dhenkanal and Sambalpur districts. In Andhra Pradesh, graphite occurs in the districts of Vishakapatnam, East Godavari, Khammam and West Godavari.

Chromite : Chromite required for refractory industry should have very low silica and too high iron content. Usually hard lumps of chromite with Cr_2O_3 ranging from 38-48% is being preferred. Chromite is being mined at Chaibasa, Singhbhum districts of Bihar, Cuttack, Dhenkanal districts of Orissa, Mysore, Hassan, Chikamngalur, Shimoga of Karnataka and Ratnagiri of Maharashtra. Occurrences of Chromite has been reported from the districts of Khammam, Krishna and West Godavari of Andhra Pradesh.

Sillimanite & Kyanite : Richest and unique deposits of sillimanite are available in Khasi hills at Sonapahar of Assam. These deposits supply 80% of world requirements. Similarly India possesses world's richest deposit of kyanite occurring at Rajkharshwar, Singhbhum districts of Bihar. Minor occurrences at Nellore of Andhra Pradesh and Hassan and Chikmangalur

15.3.3 Basic refractories

Magnesite occurs at chalkhills in Salem district of Tamilnadu. This is being worked in two lenses. Dolomite of refractory grade occurs in various states in Cuddaph formation and their equivalents. Serpentine occurs as an altered product at the contact of ultrabasic intrusives and in the Cuddaph formations, particularly limestone formations.

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 are the three groups of refractories?

15.4 ABRASIVES

Many minerals and rocks of diverse composition by with one thing common, "hardness" are employed as natural abrasives. Abrasives have wide application in all phases of industries. The abrasive such as industrial diamonds. The Abrasive are used as either in natural form like sand, pumice are after shaping like mill stones or after being ground and made up into wheels or paper. Natural material used as abrasives are divided into three groups as follows:

a) High grade	b) Siliceous	c) Miscellaneous
Diamond	Sandstone	Bauxite
Corundum	Sand	Magnesite
Emery	Quartz, Flint	Chalk
Garnet	Chert, Quartzite	Oxides of Fe,Cr,Mn
	Diatomite, tripoly Pumice	

Diamond being the hardest mineral known to the world, finds widest application in industry and is of immense value. Without it the defence programmes effect every country producing its own arms. There could be not jet engines, no arms piercing shells, no highly intricate instruments requiring microscopic fine fire, that can be drawn only through diamond made dies. Industrial diamond is known as bort and carbonado. The diamonds from Borenevo (Indonesia) Australia, Kimberlite are world famous for the supply of industrial diamonds.

Occurrence of diamonds in India predates the birth of Christ by several thousand years. Till 17th century India has flourishing diamond trade. The discovery of Brazilian fields in 1725 dealt a death blow to the diamond fields of India. The diamond occurrence of India is of three types 1) Pipe type panna Diamond fields Madhya Pradesh, Wajrakarur of Ananthapur district, Andhra Pradesh.

2) **Conglomerates** : Banganapalle, Kurnool district and at certain parts of Madhya Pradesh where Vindhayan conglomerates are available.

3) **Placers** : River born sediments at certain places contain diamonds of not only precious type, but also industrial varieties Ex:- In Paritala, Krishna district. Corundum is a natu-

rally occurring Al oxide. Corundum having a bright and glassy luster splentry and devoid of cleavage planes grains in optical grinding, on paper and cloth, in the form of abrasive wheels and in for grinding different parts in automobile industry. Corundum is found as a product of early crystal satin in rock containing a high percentage of alkalis, deficit in silica and excess of alumina. Such rocks are nepheline syenite, anorthosite and peridotite. Corundum occurs as either irregular massive bands or as bedded deposits or irregular lenses and pockets.

The best known corundum deposits are those of Tamilnadu-Salem and Coimbatore districts. Madhya Pradesh-Sindhi district and Assam Khasi & Jaintia hills. Minor occurrences are reported from Karnataka, Andhra Pradesh (Khammam) and Maharashtra.

Emery:- is a natural mixers of corundum, magnetite and some hematite. It is named from cape emery, Greece. It is a very tough rock with hardness of 7.25. It is used extensively as abrasive paper and grinding wheels. There are no known occurrences of Emery in India.

Garnet : Garnet comprises of orthosilicate minerals of divalent and trivalent elements of general chemical formula $3R^{+2}O_2 \cdot 3SiO_2$. There are six minerals commonly regarded to belong to this family. There are

- 1) Grossularite
- 2) Pyrope
- 3) Almandite
- 4) Spesartite
- 5) Andradite
- 6) Uvaravite

Only iron garnet, almandite, and to less extent grossularite are used in the manufacture of abrasives. Garnet tending to break into small pieces with sharp angular uneven faces is considered as a good abrasives. These are used in the manufacture of coated garnet paper cloth & discs gluded with sodium silicate to polish wood and optical glass. Garnet occurs as a common mineral of metamorphic rocks such as gneiss and schist, and pegmatites. It occurs as a irregular massive bands or in lensoidal forms. Resources in India are mainly in Rajasthan - Ajmer, Bhilwara, Jaipur, Karnataka-Hassan, Kolar and Mysore. Minor occurrence are in Nellore and Khammam district of Andhra Pradesh.

Siliceous : These varieties of abrasives are available in sedimentary formation of Cuddapah, Vindhya and their equivalents, either as quartzites or sandstone. Quartz vein transversing precambrian crystalline formation also yield abrasive quartz.

Tripoli is a siliceous bed found near Tripoli, Libya and it is formed due to alternation of siliceous limestone.

Diatomite is micro amorphous silica formed from deposition of microscopic flowerless plants called diatoms.

Pumice is a volcanic rock.

Tripoli, Diatomite and Pumice are not reported to occur in India.

Miscellaneous Abrasives : A variety of mineral and mineral powder are also being used as abrasive. The occurrences of those minerals are presented in earlier chapters.

Glass :- The chief constituent in glass is silica. The composition and specification of silica required for glass sands are as follows.

SiO_2 - 95 - 99.8%

126 Al_2O_3 - Should be less than 4%

For optical glass less than 0.1%

Fe_2O_3 , - Upto 1% or even less.

CaO, MgO & Alkalies are desirable

Grain size - should be even and fine.

Much of the glass sand are available as consolidated deposits like sandstone beds and unconsolidated deposits of river born sediments.

Quartz veins traversing precambrian crystalline formation are also found to be useful for manufacture of glass. Such vein quartz is mined in Ranga Reddy, Mahaboobnagar, Medak and Nizamabad districts. Glass sands is extensively mined in Uttar Pradesh, Rajasthan and Gujarat. The important sources of glass sand in the country are in Shankargarh Lohagarah in Allahabad, Jabalpur district, Madhya Pradesh. quartz of special purity is mined from veins in Sambalpur and Koraphut districts of Orissa.

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. Name any three abrasive minerals

15.5 CERAMICS

The chief raw material of ceramic industry is clay. The other substance that are required are feldspar & quartz for certain white porcelains andalusite & kyanite for certain highly refractory substances. However the backbone for ceramic industries is clay.

Clay is one of the most wide spread and earliest mineral substance utilized by man as evident from inscriptions upon tablets, brick building monuments and pottery. The term "clay" is applied to the substances consisting chiefly of hydrous aluminium silicates with colloidal material and specks of rock fragments.

The clay becomes plastic when wet and hardens like a stone under fire. These properties make clays to be used in any form by moulding into desired shapes. Clay is not a mineral, as it contains as aggregate of minerals and colloidal substance. The different clay variates are Ball clay, China clay, Fire clay, and Bleaching clays (Betonite & Fuller's earth). The first three varieties predominately contain kaolinite group and the last variety montmorillonite group of hydrous alumina silicate.

Important clay deposits are available in Sambalpur, Puri, Cuttack, Saundargh, Dhenkanal of Orissa and West Godavari, (Dwaraka Tirumala) East Godavari, Near Rajahmundry, Adilabad (Asifabad). Ranga Reddy district (Vikarabad) and at few other places in Andhra Pradesh.

Clays are also available in other parts of India.

15.6 PAINTS AND PIGMENTS

Mineral pigments are utilized directly as paints or to give colour, or opacity to paints, plaster, linoleum, rubber, plastics or other materials.

There are three classes

- a) natural mineral pigments
- b) Pigments made by burning natural minerals
- c) Manufacture paints.

The natural mineral pigments are ochres. Ochres are mixers of hematite, limonite and clay. These are formed mostly by residual weathering.

The manufacture pigments are made from lead, zinc, titanium, barium, chromium and carbon. The corresponding minerals galena, sphalerite, hematite, barite, chromite and graphite and the corresponding chemical paints are white lead, and zinc oxide, lithopone, titanium white paints, chromium green or brown, black of carbon. Besides these there are several other minerals. Elements which are used as pigment minerals. Ex:-Cobalt - Cobalt blue, Mercury-Vermilion Cadmium-Calcium red.

India has sufficient reserves of ochres (coloured earth's) barytes, chromite etc., to meet the domestic requirements of paint industry.

15.7 PRECIOUS AND SEMIPRECIOUS MINERALS

Gemstones or precious stones are regarded as flowers of the mineral kingdom. Precious stones are known from ancient times, dating back 100,00000-75000 B.C. There are many circumstances that point to India as their birth place. Gem mining is probably the oldest form of mining.

Primitive man is said to have known 18 Gems and decorative stones before he knows of any metals. They are minerals with few exception such as pearls, corals, and ivory which are animal product, amber and jet are of vegetable origin.

The gem materials are precious stones and are minerals distinguished by their hardness which enable them to be worn as personal ornaments without deviation, and by their colour and lustre which render them attractive. These qualities might be had in several minerals, some of which could not be called precious, but may be called semiprecious. Precious stones are those that are really rare and hard to get. This is only arbitrary definition Ruby and Emerald are now difficult to obtain and hence regarded precious. If any large deposits of these minerals are discovered they become semiprecious. If Amethyst become rare, it becomes, precious stone. But Diamond is always regarded as precious, because of its properties irrespective of its abundance.

There are 1600 mineral species so far known and about 50 of them have been cut and polished as gemstones. The rare gems are treated as precious stones and more common ones as semiprecious. To qualify as a gemstone, the mineral should satisfy to have the following.

- a) Colour, Lusture, Play of colours and brilliance.
- b) Durability.
- c) Rarity
- d) Fashion

A Gemstone may not posses all the qualities listed above, but the diamond satisfies all the conditions and is highly esteemed as a gem.

The common Gem stones that are available in India are Diamonds, Ruby, Zircon, Topaz, Emerald, Sapphire, Amethyst etc.

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. What are the common gem stones ?

5.8 SUMMARY

Different industries need, minerals as essential raw materials. They are a) Cement b) Refractories c) Abrasives d) Glass e) Ceramic and Paints & Pigments. Besides these some minerals are also used as precious and semiprecious.

The essential raw material for manufacture of cement is limestone. Some amount of laterite or clay are also being used in the industry. Gypsum acts as retarder.

The number of minerals are used as refractories. These minerals should withstand, high temperature and must be chemically inert.

Many minerals or rocks of diverse composition, but one thing in common namely hardness are used as abrasives.

Quartz and feldspar of specified physical and chemical characters are the principal source for the manufacture of different types of glass.

Since time in memorial different types of ceramic products ranging from simple pot to glazed tiles are being manufactured, using natural clay as the chief raw material.

Naturally occurring rock and a variety of minerals are being the chief source for making paints.

Diamond, corundum, garnet, emerald, ruby are some of the minerals, which are used as precious and semiprecious stones.

15.9 CHECK YOUR PROGRESS - MODEL ANSWERS

1. CaCO_3 - 70%
 $\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$ - 20%
 $\text{MgO} + \text{Alkalis}$ - 5%
Gypsum - 3% are the major composition of portland cement mix
2. Acid refractories, neutral refractories and basic refractories are the three groups of refractories
3. Diamond, corundum, garnet
4. Diamond, Ruby, Zircon, Topaz, Emerald etc are the common gem stones.

15.9 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write essay on Refractories and Ceramics
2. Explain briefly the term "cement" and different types.

II Answer the following questions in about 10 lines each

1. Minerals of paints industry
2. Abrasives
3. Precious stones or gemstones.

* * *

BRAOU

UNIT - 16 FUELS AND RADIO - ACTIVE MINERALS

Contents

- 16.0 Objectives
- 16.1 Introduction
- 16.2 Coal
 - 16.2.1 Formation of coal
 - 16.2.2 Characters and ranks of coal
 - 16.2.3 Origin, occurrence and age of coal
 - 16.2.4 Distribution of coal in India
- 16.3 Petroleum
 - 16.3.1 Geologic and Geographic distribution
 - 16.3.2 Origin
 - 16.3.3 Formation of oil pool
 - 16.3.4 Important oil bearing rocks in India
- 16.4 Radio - Active minerals
 - 16.4.1 Some radio active minerals
 - 16.4.2 Formation processes
 - 16.4.3 Distribution in India
- 16.5 Summary
- 16.6 Check Your Progress - Model Answers
- 16.7 Model Examination Questions

16.0 OBJECTIVES

In this unit we have discussed about fuels and radio-active minerals. After completion, you should be able to

- * explain the formation, origin, occurrence and distribution of coal.
- * describe the origin, formation of oil pools, important oil bearing formations in India
- * define radio-active minerals

16.1 INTRODUCTION

Energy is derived predominantly from fossil fuels that include coal, petroleum, natural gas etc. The natural fuels are coal and petroleum. Coal is widely distributed, and reserves are sufficient to last hundred of years. It has long been the back bone of industrial life. Petroleum has been known to the ancients, for it has been used for a very long time for embalming bodies, and for medical purposes. Petroleum is essential compound of carbon and hydrogen or rather mixture of such compounds in a bewildering variety. Radio-active minerals have been utilised for multifarious purposes. Radium is used for curing diseases, uranium is used for the production of electricity and in the preparation of war ammunition.

16.2 COAL

Among the different kinds of utilizable energy like coal, petroleum, atomic energy, solar energy, natural gas etc., Coal is most important source of energy. Coal is the backbone of industrial life. Countries having vast reserves of coal have grown in importance commercially and politically.

Petroleum is composed of many hydrocarbons i.e., compounds of carbon and hydrogen with minor oxygen, nitrogen and sulphur.

16.3.1 Geologic and Geographic distribution of petroleum

Petroleum occurs in sedimentary rocks, very rarely it moves into adjacent rocks of igneous and metamorphic rock types. Igneous and metamorphic terrains can be easily eliminated for prospecting of petroleum. The most common rock types in which we get petroleum are sands; sand stone, conglomerates, porous limestones, dolomites etc. Petroleum rocks range in age cambrian to pliocene. Of all rocks, rocks belonging to sedimentary group of tertiary age are prolific petroleum yielding rocks.

16.3.2. Origin of petroleum

There are two theories regarding the origin of petroleum. Some believe that petroleum is of inorganic origin, which involve, the reaction of carbides within the earth to form acetylene and subsequently changing over to hydrocarbons. It is now accepted that origin of petroleum is of organic nature. Organic material buried in marine sediments underwent changes to produce natural hydrocarbons, such hydrocarbons subsequently moved into porous sedimentary rocks known as reservoir rocks and got accumulated to form commercial oil pools. Oil pools are nothing else but mere accumulation of oil in large quantities in porous sedimentary rocks. Slow oxygen fire decomposition of remains of plants and animals of microscopic nature is considered to be the original source of petroleum. Higher forms of life which grow and live on land surface are unimportant, but the lower forms of life such as planktonic organisms, such as algae are considered to be the most probable and important source materials. Conversion of organic matter into petroleum hydrocarbons is mainly due to bacteria which thrive in the upper mud of the sea floor.

16.3.3 Formation of oil pool

Oil pools as explained earlier is nothing but mere accumulation of drops of oil scattered in the reservoir rock. When these oil drops accumulate in a place, then it forms a oil pool. For the formation of oil pool certain conditions are necessary. They are as follows.

- (i) Migration and Accumulation
- (ii) Suitable reservoir rocks
- (iii) Suitable traps
- (iv) Retention

Migration and accumulation of drops of oil formed in the source mud by the bacterial action slowly gets migrated into the adjacent sands. There are forces which help in migration of oil drop. Such as compaction of muds, capillary action, gravity, currents and buoyancy.

Accumulation take place only in porous and permeable rocks. A rock like clay has high porosity but low permeability and hence it is not a reservoir rock but only a cap rock. The most suitable reservoir rocks are loose, unconsolidated sands and porous sand stones.

There are two types of traps which hold the oil accumulation from getting away from the place of accumulation. They are (i) Structural traps (ii) Stratigraphic traps. Some of the most important structural traps are anticline, dome, monocline, faults, fissures and salt domes, whereas some of the important stratigraphical traps are, unconformities, sandstones lenses, buried coral reefs; over laps etc.

16.3.4 Important oil bearing rocks in India

In India important oil occurring places are in Assam, Punjab, Gujarat, Andhra Pradesh.

134 The petroleum bearing rocks are confined to narrow belt of tertiary strata. There are only three

areas within this belt which have so far been found to bear petroleum on a commercial scale. There are

- (i) Punjab Sind Gujarat Gulf (Cutch cambay area)
- (ii) Assam Gulf (Digboi, Naharkatiya)
- (iii) Bombay high

Apart from these prominent areas Oil and Natural Gas Commission has carried out exploration work in Godavari, Krishna and Covery basin. Results are encouraging. Bombay High where oil has struck in Miocene rocks having Anticlinal structure has proved to be of great commercial importance.

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 major oil production centres of India are confined to formation.

16.4 RADIO - ACTIVE MINERALS

Radio - active minerals usually decay and emit α , β , γ rays. The α ray particles are the nuclei of helium atoms, β -rays are high speed electrons and the γ -rays are the high frequency radiations, similar to x-rays. All the uranium and thorium minerals usually contain certain percentage of their decay products. The decay of radio - active minerals results in its transformation into another element. The radio - active chain ultimately produces a stable non-radio-active element. The radio - active isotope of radium is the most useful radio, isotope used for therapeutic purpose. It is also used as a tracer in bio-chemical reactions and in the study of hydrology. Uranium, Plutonium are the sources of energy. About half a kilogram of uranium is equivalent to 1,300 tons of good coal for the purpose of generating thermal energy.

16.4.1 Some Radio-active minerals

Pitch blend	- UO_2 and UO_3
Uraninite	- UO_2
Monozone	- (ce, y, La, Th) PO_4

16.4.2 Formation processes

Radio active minerals mainly the uranium and thorium minerals are deposited under three categories pegmatitic, hydrothermal, secondary. Some divided these deposits are formed in three distinct phases which grade into one another. The first phase is the igneous processes and metamorphic processes, schists etc. Those formed by secondary sedimentary processes such as shale, phosphorites, sand stones etc. The third is deposits formed by weathering as tracers.

BRAOU

BLOCK - V : INDIAN GEOLOGY - I

BRAOU

UNIT - 17 PRINCIPLES OF STRATIGRAPHY AND CORRELATION

Contents

- 17.0 Objectives
- 17.1 Introduction
- 17.2 Principles of Stratigraphy
 - 17.2.1 Order of Super position
 - 17.2.2. Lithological Character
 - 17.2.3 Structure and Tectonics
 - 17.2.4 Fossil Records
 - 17.2.5 Geophysical Methods
 - 17.2.6 Correlation
- 17.3 Standard Stratigraphic Units
- 17.4 Geological Time Scale
- 17.5 Absolute Age of Rocks
- 17.6 Summary
- 17.7 Check Your Progress - Model Answers
- 17.8 Model Examination Questions

17.0 OBJECTIVES

After Studying this unit you should be able to

- * describe the principle of Stratigraphy
- * correlate the rock formations
- * explain the stratigraphic units
- * define the geological time scale

17.1 INTRODUCTION

The Earth crust is mainly occupied by three types of rocks namely Igneous, Sedimentary and Metamorphic. The surface of Earth crust has undergone continuous geological changes producing enormous quantities of sediments resulting in formation of sedimentary rocks occupying more than three fourth of earth surface. These sedimentary rocks are characterized by the presence of bedding or stratification which result from the deposition of sediments in essential horizontal layers. The igneous and metamorphic rocks seldom show bedding. The study of layered or stratified rocks (sedimentary and volcanic), especially their sequence in time, character and correlation in different regions is known as Stratigraphy or Historical Geology.

17.2 PRINCIPLES OF STRATIGRAPHY

The main aim of the Stratigraphy is the sequential arrangement of layer of rocks according to the time of their formation on the surface of the earth. The chronological sequence of rock formations established in terms of their relative ages is graphically represented in vertical columns. The older formations are shown below the younger ones. The rocks that deposited later will lie over the ones deposited earlier. Generally the younger formations preserve advanced

forms of organisms. The study of these organisms or fossils helps in determining the relative ages of the fossiliferous rock formations. However, many rock formations especially those deposited more than 570 million years ago, are general devoid of any fossil record. For determining the relative age of fossiliferous as well as unfossiliferous rocks, certain set of principles are used. These principles are known as Principles of Stratigraphy.

17.2.1 Order of Super Position

Every geological formation rests on another and is superposed by a third. The formation at the bottom is naturally older than the one at the top. Each overlying bed is younger than the underlying bed under the normal conditions of stratification. This principle or ordering is known as Law of Superposition. Based on this principle, we can determine the relative ages of sedimentary and volcanic rocks having simple structures (Fig. 17.1). In the case of disturbed rocks, the top and bottom of beds at the time of their deposition are determined with the help of sedimentary structures like current bedding, graded bedding and ripple marks (Fig. 17.2).

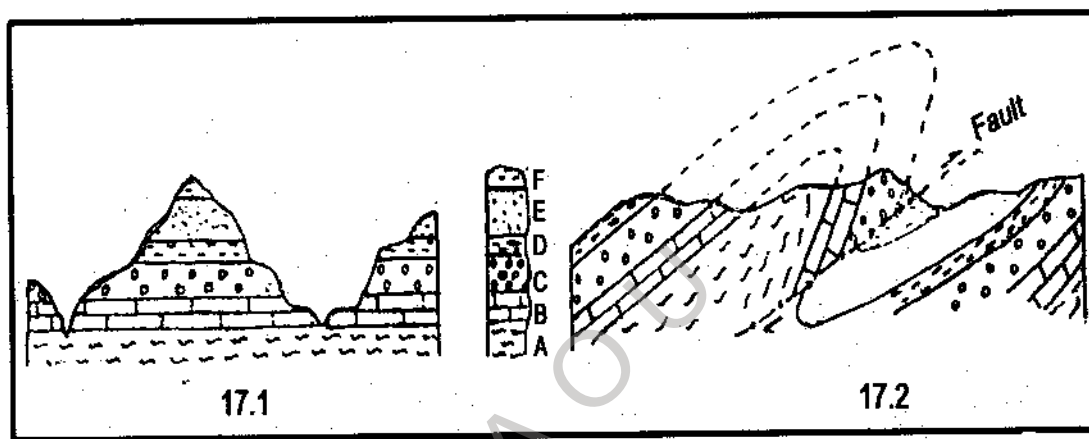


Fig. 17.1 Geological cross section of horizontally bedded formation

Fig. 17.2 Geological cross section of disturbed formation.

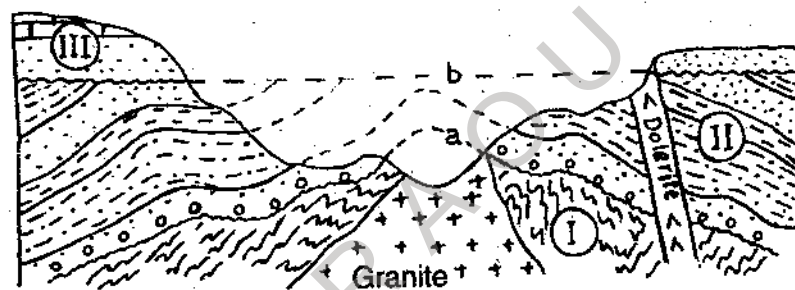
17.2.2 Lithological Character

The study of lithological characters of rocks help in dividing the rock sequences into formations. Each lithological unit may consists a number of individual beds having more or less the same characters when it is called as a Formation and given a local or specific name of distinguish it from a similar formation of different age or belonging to another area. We have thus the Barakar Sandstone, Kamthi Sandstone, Cumbum Slate, Vempalle Limestone etc. Correlation of rock formations of two areas is often carried out by comparing the lithological characters of their formations. The correlation is done by tracing the distinct characters of the beds in the formations. Such beds are called as marker beds. The rock formation that occur between two marker beds in the neighbouring areas are considered to be of the same age. The baraker sandstone of lower Gondwana which mainly exposed in Jharia Coal fields consists of weathered feldspar bearing sandstone, grits and occasionally associated with conglomerates and shales. The same type of rock formation occurs in Raniganj, Darjling, Assam, Sikkim and

Rock formations of the same age but deposited in different sedimentary basins may differ from one another in their lithological characters. For example, the Permian rock formation of the Salt Range (Productus Limestone) is lithologically different from that of Spiti area (Productus Shale).

17.2.3 Structure and tectonics

The sediments deposited in various sedimentary basins are uplifted above the surface of water at different times in the earth's history. Such movements are called tectonic movements which deform resulting in various structures in the rocks. Then there will be gap in the deposition. Such gap is known as period of non-deposition. The later deposited sediments in the basin are not conformable with earlier developed sediments. The surface separating these two successions of the rock formations is known as surface of unconformity (Fig. 17.3). It is either a surface of erosion or non-deposition. A sequence of rock formation of an area can be divided into major rock groups separated from one another by such surface of unconformity. In the field, an unconformity is commonly evidenced by the presence of a conglomerate. If there is no visible break and the formation show complete parallelism in spite of a gap in sedimentation is called as disconformity. Formations lying between the two successive surfaces of unconformity in neighbouring area are considered to be of the same age. Tectonic movements are also recorded within a single group of rock succession in the form of rhythmicity of different lithological types.



Surfaces of unconformity : a - Post Granite
b - post dolerite (I) - Lower Group,
(II) Middle Group (III) Upper Group

Fig. 17.3 Surface of Unconformity separating of the rock formations

The basin of deposition may undergo successive phases of deepening or shallowing which are reflected from deposition of sediments alternatively in the basin. The presence of sandstone indicates shallow water deposition and that of shale the deep-water deposition.

17.2.4 Fossil Records

Organic remains preserved in rocks, has been most widely used for determining the relative age of rock formations deposited during the last 570 million years. The types of organic remains preserved in rocks indicate the kind of life that existed on the earth at the time of formation of these rocks. Such fossil records are more reliable for determining the relative age of rock formations and their correlation over large areas. This method is based on that the given faunal or floral assemblage is never repeated again in the geological time and the organisms continuously undergo changes in their morphology. The biological evolution reveals that the organisms cannot evolve to a preceding form even if they find themselves in exactly similar

17.3 STANDARD STRATIGRAPHIC UNITS

The earth scientists opined that the earth was born before 4.6 billion years ago, since then experienced several geological events. These events are recorded in rock formations as the pages of the Earth's history. The rock sequence which were deposited during the certain duration of geological and which contain characteristic fossils constitute duration of geological time and which contain characteristic fossils constitute chronostratigraphic or time stratigraphic units. Thus, the chronostratigraphic unit represents a certain course in earth's history and for each chronostratigraphic unit there is a corresponding geological time unit or time unit.

The chronostratigraphic unit is divided into systems, systems into series, series into stages and stage into zones. Likewise the geological time unit is divided into periods, period into epochs, epoch into ages and age into phases. The standard chronostratigraphic scale is not suitable for stratigraphic divisions of unfossiliferous strata. In view of these limitations, a new scheme of classification of rock succession proposed known as Lithostratigraphic unit or rock stratigraphic unit. This type of classification also follows the same basic principles of stratigraphic classification and correlation. In this classification group is the broadest unit and consists of thick succession of rock formation spread over a large area. A group is divided into more than one formation, formation into member and member into bed. An association of mutually related groups is known as supergroup is divided into more than one formation, formation into member and member into bed. An association of mutually related groups is known as supergroup.

The chronostratigraphic units, time units and lithostratigraphic units have separate sets of terminology as given in table 17.1

TABLE 17.1 TERMINOLOGY OF STRATIGRAPHIC UNITS

Geological Time Units		Chronostratigraphic Units		Lithostratigraphic Unit	
Unit	Example	Unit	Example	Unit	Example
Era	Cenozoic Era	Erathem	-----		
Period	Tertiary period	System	Tertiary System	Group	Semri group (Vindyan System)
Epoch	Miocene epoch	Series	Mocene series	Formation	Rohtas formation
Age	Panonian Age	Stage	Panonian stage	Member	Suket shales
Phase	Globorotalia	Zone	Globorotalia	Bed	Obotellas shale bed
	Tumida		Tumida Fflexuosa		
	fluxuosa phase		Zone,		

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. Name the lithostratigraphic units

.....

.....

.....

.....

17.4 GEOLOGICAL TIME SCALE

Successive arrangement of standard stratigraphic and time unit as standard reference for world wide correlation is known as Standard Stratigraphic Scale and Geological Time Scale. The wider stratigraphic unit i.e., Erathems, Systems and series are readily recognised in most parts of the world and hence a single set of nomenclature for these units is used by the stratigraphers all over the world.

An Erathem, represented by a succession of rock formation deposited during an Era is a record of the broadest division in the Earth's history. An earthem is generally made up three or more systems. A system constitutes a part of an erathem and it is represented by a succession of rocks which were deposited during a period. In Phanerozoic rock formation, a system is characterised by a typical fossil assemblage. The successive systems are demarcated on the basis of substantial renewal of fauna and flora. The boundaries of the system are also demarcated by sudden change in sedimentary facies or the presence of unconformity. System is made up of two or three series of rock formation. Thus all the rock successions of the earth were divided into five broad chronostratigraphic units with reference to the type of life that existed on the surface of the earth. The palaeozoic, mesozoic and cainozoic succession contain fossils of past-life because the organism living during those eras developed hard parts. The group of these three eras is referred to as Phanerozoic indicate the presence of forms of life with preservable hard parts. The primitive life of Archeozic and Proterozoic Eras did not contain hard parts and therefore the rocks deposited during this time are generally unfossiliferous. These two eras combined into one unit and named as Precambrian Era. The Precambrian era is divided into three units, the lower unit corresponds to the Archeans or Archeozoic, and middle and upper to the Proterozoic. These rocks were earlier referred to as Azoic means absence of life. Sub divisions in Phanerozoic have been given suitable names for international correlation. Subdivisions of Archean successions have been given based on local or regional significance. The names of five erathems have been derived from Greek words. Thus 'Archeoes' means oldest, 'Proter's' older, 'Paleo' early, 'Meso' intermediate, 'Cainos' new and the ending of each name zoicos means life.

Table 17.2 : Major divisions of Geological Time Scale and Chief Fossils / Events

Era / Erathem	Period / Systems	Epochs / Series	Approx. Time in 10⁶ years	Chief Fossils / Events
CENOZOIC	Quaternary	Holocene (Recent)	1.6	Living animals
		Pleistocene		Man appears, Many mammals die off during glacial periods
	Tertiary	Pliocene	2.6	Large Carnivores
		Miocene		Mammals, Molluscs
		Oligocene	64 - 65	Flowering plants dominant
		Eocene		Whales, Apes
MESOZOIC	Cretaceous	Late (senonian)	136	First Placental Mammals
		Early (neocomian)		Last of Dinosaurs, Last of Ammonites, Rise of flowering plants
	Jurassic	Late	190-195	First Birds, Flowering plants, Flying reptiles, Rise of Dinosaurs
		Middle		
		Early		
	Triassic	Late	230	Ammonites, Reptiles and Amphibians abundant
		Middle		
		Early		
PALAEOZOIC	Permian	Late	280	Primitive reptiles, Last of Trilobites
		Middle		
		Early		
	Carboniferous	Late (Pennsylvanian)	320	Many non-flowering plants Glossopteris flora dominant
		Early (Mississippian)	345	
	Devonian	Late	395	Abundant of corals, brachiopods, appearance of land plants, Earliest known amphibians
		Middle		
		Early		
	Silurian		430-440	Graptolites disappear, first fish
	Ordovician	Late	500	Abundance of Trilobites, Graptolites, Rise of Cephalopods
		Early		
	Cambrian	Late	570	Many kinds of shelled invertebrates, Abundance of trilobites
		Middle		
		Early		
PRECAMBRIAN ARCHAEOZOIC PROTEROZOIC (ARCHAEANS)	Upper Middle		1000	First microscopic algae, marine algae Oxygen Atmosphere
			1600	
			2000	
			2500	
	Lower		3200	First Stromatolites Anaerobic bacteria
			3500	First Sedimentary rocks Formation of the Oceans and Continents
			4000	
	Formation of the Crust Formation of the Earth		4600	

17.5 ABSOLUTE AGE OF ROCKS

Absolute age of the earth and its rock formations are determined by various methods, such as the rate of sedimentation, rate of increase in the salinity of the sea and rate of biological evolution. The above methods do not give satisfactory results as the natural processes are not constant and work different rates throughout the earth's history. Recently, a reliable and widely used method has been developed on the basis of radioactive decay. The science which measures the age of rocks, minerals, water and biological materials based primarily on the radioactive decay is called as geochronology. The radioactive elements constantly undergo a process of decay to the formation of stable isotopes is known as daughter element and original element called mother element. The process of radioactive decay is spontaneous and not affected by any physical parameters like temperature and pressure. The each radioactive element reduces half of the quantity by decay at a period of time is known as half-life period of the element. The half-life period of each radioactive element can be measured in the laboratory with sophisticated instruments.

Radioactive elements with long period of half-life (million years) used in geochronology of Precambrian rocks. The most commonly used elements for dating of Precambrian rocks are Uranium (U), Thorium (Th), Rubidium (Rb) and Potassium (K). Uranium and Thorium decay to form stable isotope lead and alpha particles. Minerals having more than 1% U and Th, such as Uranite, Monazite, Zircon and Allanite are used in dating. The Potassium-Argon isotope method is a very significant one which can be used to many igneous, metamorphic and sedimentary rocks. Sedimentary rocks containing glauconite, illite etc. and igneous rocks having Potash feldspar and mica are suitable minerals for dating of rocks. Rubidium-Strontium method is also widely used because rubidium occurs as trace element in alkali feldspars and mica. Carbon dating is a very important method applicable to younger rock formations. Its ratios are calculated from the plant remains enclosed in younger sedimentary deposits.

The Radiometric methods of dating the rocks have become essential tool in Precambrian stratigraphy. The Precambrian rocks are generally affected by repeated cycle of tectonism and metamorphism. Such rocks containing radioactive elements may disperse or migrate into distant areas. In view of that the Samarium (Sm) and its daughter element Neodymium (Nd) isotopes are used for determining the absolute ages of very old rocks. The Sm and Nd elements are not affected by the metamorphic process.

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 geological time scale is divided into eras

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17.6 SUMMARY

The earth crust is occupied by three types of rocks namely igneous, sedimentary and metamorphic. The igneous and metamorphic rocks rarely show bedding but sedimentary rocks are characterized by bedding or stratification.

Stratigraphy - main aim is sequential arrangement of layered rocks as per their relative age. While representing the sequence in vertical column the older rocks are always shown below the younger ones. Determining the relative ages of rock formation, fossiliferous as well as unfossiliferous strata are based on certain principles of stratigraphy. Such as order of superposition, lithological character, structure and tectonics and fossil records. The precise absolute age of the rocks are determined by the radiometric methods. The lithological characters of rocks, help in dividing rock sequences into formations. Correlation of rock formation of two areas is often carried out by comparing lithological characters of their formation. Rock formations of the same age but deposited in different sedimentary basins many differ from one another in their lithological character. In sedimentary formations, any break or gap in the deposition is marked by a surface known as unconformity. Unconformities are structural features, which separate the older formations from younger ones. Geophysical methods such as electrical and gamma logging, seismic wave reflections and palaeomagnetism can be used in determining the order of superposition of rock formations. Study of fossil record (index fossils, fossil assemblages and micro organisms) help in determining the relative ages of rocks and for correlation of different regions. Correlation is an important principle of stratigraphy. It aims at matching the rock formations of different regions. For world wide correlation of rock formations, a standard stratigraphic scale is devised and known as geological time scale. This is developed based on standard stratigraphic units. Absolute age of the Earth and its rock formations are determined by various methods. But a reliable method recently developed is radiometric dating. The usually adopted methods are Uranium (U) - Lead (Pb) method, Rubidium (Rb) - Strontium (Sr) method, Potassium (K) - Argon (Ar) method, Samarium (Sm) - Neodymium (Nd) method etc.

17.7 CHECK YOUR PROGRESS - MODEL ANSWERS

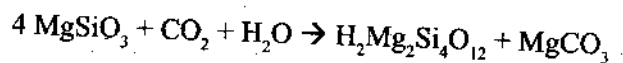
1. Lithological characters, Order of Superposition, Structure and Tectonics, Fossil record, Geophysical methods.
2. Unconformity.
3. Group, Formation, Member, Bed.
4. Precambrian, Palaeozoic, Mesozoic and Cainozoic.

17.8 MODEL EXAMINATION QUESTIONS

- I. **Answer the following questions in about 30 lines each**
 1. Describe the Principles of Stratigraphy and Correlation.
 2. Describe in detail the Geological Time Scale
 3. Explain the Stratigraphic Units.
- II. **Answer the following questions in about 10 lines each.**
 1. Describe in detail the Correlation of rocks
 2. Write briefly about the Order of Superposition.
 3. What are index fossils? Discuss their use in Stratigraphy.

* * *

aided by dynamic metamorphism. Formation of talc may be due alteration of any Mg amphibole or Mg Pyroxene in presence of CO_2 and H_2O .



Kyanite, sillimanite, andalusite and garnets are all characteristic minerals found in metamorphic rocks, which are due to the effect of dynamothermal and regional metamorphism of aluminium silicate rocks.

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 charecteristic minerals of metamorphic rocks?

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12.4 SUMMARY

Organic processes will occur with direct or indirect activities of animals. Biochemical process of precipitation plays important role. Certain algae or Bacteria can cause the precipitation of oxide compounds by acting as catalyst for oxidation reactions. The organic processes are the two types, Biochemical and Biomechanical. The ores produced with biochemical process are having fine grained texture. Bio-mechanical deposits are formed due to the fragmentation of organisms like shells, skeletons, crinoids etc. To differentiate these two it is very difficult because the line of demarcation is hazy, on the basis of chemical composition organic deposits were classified as calcarious, phosphatic, ferruginous, siliceous and carbonaceous deposits.

The calcarious deposits are mainly limestones and dolomites. The bio-mechanical limestone are frequently heterogeneous consists of cheefly calcite and hard parts of animals. These are also known as fossiliferous limestones. Shelly limestone, coral limestones, algae limestones, crinoidal limestones, chalk are such deposits. Phosphate is known to be extracted from sea water by living organisms and concentrated with in their hard parts. Such hard parts may produce phosphatic rich beds. Gueno is another phosphatic deposit formed due to the accumulation of excrement of fish eating sea birds.

Some types of Bacteria are known to precipitate iron. Bog iron ore and some iron sulphides are the products of sulphate reducing Bacteria. Clay iron stone is also produced due to organisms.

The remains of radiolarians, diatoms and siliceous sponge spicules are common in silicious deposits. The siliceous frame work of shells can sink to grater depths where they mingle with red clay and produce silicious deposits.

Carbonacious deposits are rich in carbon content, and are formed by the burrial of ancient plants. The lignite, bituminous and anthracite are such deposits.

The effect of temperature, pressure and solutions make the mineral matter to change and to form economic minerals with metamorphism. Several kinds of non metalliferous deposits are formed such as graphite, talc, garnet, kyanite, andalusite, silliminite etc.

12.5 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Organic process is one in which organisms are involved directly or indirectly for the formation of ore deposits.
2. Coal, mainly lignite, Bituminous and Anthracite.
3. Kyanite, silliminite, andalusite, garnet etc. are the characteristic minerals of metamorphism

12.6 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in about 30 lines each
 1. Write an essay on organic processes.
 2. Explain metamorphic processes.
- II. Answer the following questions in about 10 lines each
 1. Calcarious deposits.
 2. Carbonacious deposits.

* * *

16.6 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Khammam, Karimnagar, Adilabad and Warangal districts of Andhra Pradesh
 2. Original plant, degree of its decay, heat, pressure and degree of alteration.
 3. Tertiary formation
 4. Pitch blend, monozite
-

16.7 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each

1. Write briefly, the mode of formation, types and distribution of coal in India.
2. Discuss, in brief the mode of formation of oil pool, origin of petroleum and important oil bearing rocks in India.

II. Answer the following questions in about 10 lines each

1. Radio - active minerals.
2. Origin of petroleum.

* * *

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the changes in the physical properties of the rocks. Using recorded data, logging diagrams are prepared showing the sequential change of physical properties observed along depth of rock formation. Therefore, these logging diagrams can be used for correlation of neighbouring areas. Seismic geophysical method known as seismic stratigraphy is used widely in stratigraphy and exploration of hidden mineral deposits. In this method the data of seismic waves recorded using sensitive instrument called geophones. The seismic waves, while traversing through the subsurface rocks, are reflected and refracted from different interfaces of rock sequences. The changes in rock types produce changes in their reflectivity which observed in the seismic data. Thus rock type change indicates the stratigraphic changes. The most commonly used data in seismic method is p-wave reflections.

Paleomagnetism is an important tool for stratigraphic correlation of Cenozoic rock formations. It is known that the position of the earth's magnetism has been changing its polarity over a period of geological time. Magnetic minerals in both igneous and sedimentary rocks retain a record of the magnetic field prevailing at the time and place of their formation. Such rock samples polarity is recorded in terms of normal or reversal with respect to the present pole orientation of the earth magnetism. For example, in a succession of Deccan volcanic rocks four successive magnetic normals and reversals have been recorded.

17.2.6 Correlation

Correlation is an important aspect in Stratigraphy. It aims at matching the rock formations of different areas deposited at the same stage of the earth's evolutionary history. Such two formations deposited at the same time are referred as homotaxial. If two formations are not formed at same time, indicated that they may not synchronous in their origin. A standard stratigraphic scale (geological time scale) has been established for correlation of rock successions of different regions.

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. The Chief Principles of Stratigraphy are

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2. The period of non deposition of erosion indicates

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17.3 STANDARD STRATIGRAPHIC UNITS

The earth scientists opined that the earth was born before 4.6 billion years ago, since then experienced several geological events. These events are recorded in rock formations as the pages of the Earth's history. The rock sequence which were deposited during the certain duration of geological and which contain characteristic fossils constitute duration of geological time and which contain characteristic fossils constitute chronostratigraphic or time stratigraphic units. Thus, the chronostratigraphic unit represents a certain course in earth's history and for each chronostratigraphic unit there is a corresponding geological time unit or time unit.

The chronostratigraphic unit is divided into systems, systems into series, series into stages and stage into zones. Likewise the geological time unit is divided into periods, period into epochs, epoch into ages and age into phases. The standard chronostratigraphic scale is not suitable for stratigraphic divisions of unfossiliferous strata. In view of these limitations, a new scheme of classification of rock succession proposed known as Lithostratigraphic unit or rock stratigraphic unit. This type of classification also follows the same basic principles of stratigraphic classification and correlation. In this classification group is the broadest unit and consists of thick succession of rock formation spread over a large area. A group is divided into more than one formation, formation into member and member into bed. An association of mutually related groups is known as supergroup is divided into more than one formation, formation into member and member into bed. An association of mutually related groups is known as supergroup.

The chronostratigraphic units, time units and lithostratigraphic units have separate sets of terminology as given in table 17.1

TABLE 17.1 TERMINOLOGY OF STRATIGRAPHIC UNITS

Geological Time Units		Chronostratigraphic Units		Lithostratigraphic Unit	
Unit	Example	Unit	Example	Unit	Example
Era	Cenozoic Era	Era	-----		
Period	Tertiary period	System	Tertiary System	Group	Semri group (Vindyan System)
Epoch	Miocene epoch	Series	Miocene series	Formation	Rohtas formation
Age	Panonian Age	Stage	Panonian stage	Member	Suket shales
Phase	Globorotalia	Zone	Globorotalia	Bed	Obotellas shale bed
	Tumida		Tumida Fflexuosa		
	fluxuosa phase		Zone,		

17.5 ABSOLUTE AGE OF ROCKS

Absolute age of the earth and its rock formations are determined by various methods, such as the rate of sedimentation, rate of increase in the salinity of the sea and rate of biological evolution. The above methods do not give satisfactory results as the natural processes are not constant and work different rates throughout the earth's history. Recently, a reliable and widely used method has been developed on the basis of radioactive decay. The science which measures the age of rocks, minerals water and biological materials based primarily on the radioactive decay is called as geochronology. The radioactive elements constantly undergo a process of decay to the formation of stable isotopes is known as daughter element and original element called mother element. The process of radioactive decay is spontaneous and not affected by any physical parameters like temperature and pressure. The each radioactive element reduce half of the quantity by decay at a period of time is known as half-life period of the element. The half-life period of each radioactive element can be measured in the laboratory with sophisticated instruments.

Radioactive elements with long period of half-life (million years) used in geochronology of precambrian rocks. The most commonly used elements for dating of precambrian rocks are Uranium (U), Thorium (Th), Rubidium (Rb) and Potassium (K). Uranium and Thorium decay to form stable isotope lead and alpha particles. Minerals having more than 1% U and Th, such as Uranite, Monazite, Zircon and Allanite are used in dating. The Potassium-Argon isotope method is a very significant one which can be used to many igneous, metamorphic and sedimentary rocks. Sedimentary rocks containing glauconite, illite etc. and igneous rocks having Potash feldspar and mica are suitable minerals for dating of rocks. Rubidium-Strontium method is also widely used because rubidium occurs as trace element in alkali feld spars and mica. Carbon dating is very important method applicable to younger rock formations. Its ratios are calculated from the plant remains enclosed in younger sedimentary deposits.

The Radiometric methods of dating the rocks have become essential tool in precambrian stratigraphy. The Precambrian rocks are generally affected by repeated cycle of tectonism and metamorphism. Such rocks containing radioactive elements may disperse or migrate into distant areas. In view of that the Samarium (Sm) and its daughter element Neodymium (Nd) isotopes are used for determining the absolute ages of very old rocks. The Sm and Nd elements are not affected by the metamorphic process.

Check your progress

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

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4. The geological time scale is divided into eras

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17.6 SUMMARY

The earth crust is occupied by three types of rocks namely igneous, sedimentary and metamorphic. The igneous and metamorphic rocks rarely show bedding but sedimentary rocks are characterized by bedding or stratification.

Stratigraphy - main aim is sequential arrangement of layered rocks as per their relative age. While representing the sequence in vertical column the older rocks are always shown below the younger ones. Determining the relative ages of rock formation, fossiliferous as well as unfossiliferous strata are based on certain principles of stratigraphy. Such as order of superposition, lithological character, structure and tectonics and fossil records. The precise absolute age of the rocks are determined by the radiometric methods. The lithological characters of rocks, help in dividing rock sequences into formations. Correlation of rock formation of two areas is often carried out by comparing lithological characters of their formation. Rock formations of the same age but deposited in different sedimentary basins many differ from one another in their lithological character. In sedimentary formations, any break or gap in the deposition is marked by a surface known as unconformity. Unconformities are structural features, which separate the older formations from younger ones. Geophysical methods such as electrical and gamma logging, seismic wave reflections and palaeomagnetism can be used in determining the order of superposition of rock formations. Study of fossil record (index fossils, fossil assemblages and micro organisms) help in determining the relative ages of rocks and for correlation of different regions. Correlation is an important principle of stratigraphy. It aims at matching the rock formations of different regions. For world wide correlation of rock formations, a standard stratigraphic scale is devised and known as geological time scale. This is developed based on standard stratigraphic units. Absolute age of the Earth and its rock formations are determined by various methods. But a reliable method recently developed is radiometric dating. The usually adopted methods are Uranium (U) - Lead (Pb) method, Rubidium (Rb) - Strontium (Sr) method, Potassium (K) - Argon (Ar) method, Samarium (Sm) - Neodymium (Nd) method etc.

17.7 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Lithological characters, Order of Superposition, Structure and Tectonics, Fossil record, Geophysical methods.
2. Unconformity.
3. Group, Formation, Member, Bed.
4. Precambrian, Palaeozoic, Mesozoic and Cainozoic.

17.8 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in about 30 lines each
 1. Describe the Principles of Stratigraphy and Correlation.
 2. Describe in detail the Geological Time Scale
 3. Explain the Stratigraphic Units.
- II. Answer the following questions in about 10 lines each.
 1. Describe in detail the Correlation of rocks
 2. Write briefly about the Order of Superposition.
 3. What are index fossils? Discuss their use in Stratigraphy.

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UNIT - 18 PHYSICAL AND STRATIGRAPHIC DIVISIONS OF INDIA

Contents

- 18.0 Objectives
- 18.1 Introduction
- 18.2 Peninsular India
 - 18.2.1 The Western Ghats
 - 18.2.2 The Eastern Ghats
 - 18.2.3 The Vindyan Mountains
- 18.3 Extra-peninsular India-The Himalayas
- 18.4 Indo-Gangetic Plain
- 18.5 Stratigraphic Divisions of India
- 18.6 Summary
- 18.7 Check Your Progress - Model Answers
- 18.8 Model Examination Questions

18.0 OBJECTIVES

After studying this unit you should be able to

- * describe the mountains of Peninsular India - Western ghats, Eastern ghats and Vindhyan mountains.
- * explain the Himalayan mountains.
- * define the stratigraphic divisions of India.

18.1 INTRODUCTION

Physiography of India is almost an expression of its geological structure and lithology. The Indian sub-continent is broadly divided into three well defined regions. They are

1. The triangular plateau of the peninsular India.
2. The mountainous regions of the Himalayas, known as the Extra-peninsular India.
3. The Indo-Gangetic alluvial plains.

The Peninsular India has rocks covering the older to the younger. It is an ancient plateau exposed for a long time to denudation resulting in peneplanation. Its mountains are of the relict type. Its rivers traverse for the most part, a comparatively flat country with low gradients and have built of shallow broad valleys. The Extra-Peninsular India constitute part of the Alpine Himalyan Tertiary mountain belt. It is a region of folded and over thrust mountain chains, of geologically recent origin. Its rivers are youthful and are actively eroding the beds in their courses and causing out deep and steep sided gorges. The Indo-Gangetic plains are broad, monotonous, level expanses build up of recent alluvium through which the rivers flow sluggishly towards the seas. The plains were originally a great trough between peninsular and extra-peninsular regions. Its origin and structure are closely related to the raise of Himalayas.

18.2 THE PENINSULAR INDIA

The Peninsular Shield is characterized by varied physiography-complex association of plateau mountains with widely distributed drainage, peneplained ancient folded mountains, batholiths, graben like valleys and coastal plains. The Peninsula exposed in four regions have distinctly different structural-geomorphological trends-the southern part of Western Ghats with NNW-SSE trend, Eastern Ghats with NE-SW, Satpura and Mahadeva ranges in Central India with E-W trend and Aravalli ranges of northwestern Peninsula with NE-SW trend. The chief mountains of peninsular India are the Eastern and the Western ghats, Vindhyans, Satpuras, Aravallis, (Fig.18.1). Elongated graben like valleys in Peninsula-Narmada-Sone-Damodar valleys trending E-W and Mahanandi and Godavari valleys with NW-SE trend.

18.2.1 The Eastern Ghats

The Eastern Ghats forms a series of rather detached hill ranges of heterogeneous composition and extend from the border of Orissa through the coastal regions of Andhra Pradesh to join the Nilgiris in Tamil Nadu. The average elevation is about 800 meters but at places like Mahendragiri, Shevaroy in Salem and Nimaygiri in Koraput it rises to 1500 meters, 1650 meters and 1550 meters respectively. The Eastern Ghats meet Western Ghats at Dodabetta in Nilgiri hills. The Eastern Ghats are mainly consists of Khondalites, Charnockites and Migmatized gneisses.

18.2.2 The Western Ghats

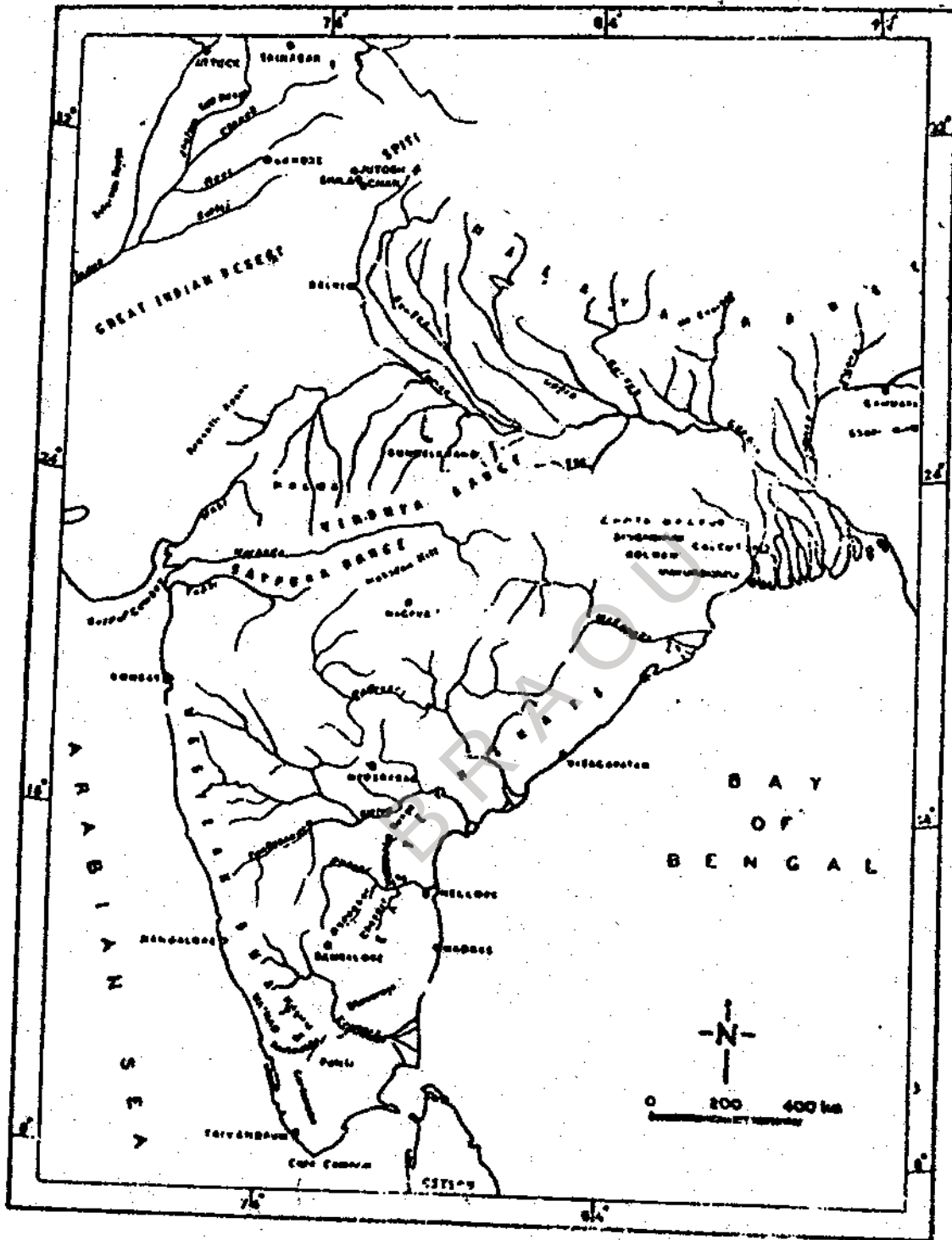
The Western Ghats constitute the ranges of mountains called the Sahyadri, extending almost north-south and parallel to the west coast of India. These mountains, running from the Tapti valley in the north down south to Cape-Camorian. They are about 1600 km in length and the average elevation ranges between 1000 and 1300 meters. The Nilgiri hills (2336 m), Makurthi (2554 m) and Annaimudi in Anna Malai (2693 m) are the highest peaks in the Western Ghats. The western slopes are steeper and often precipitous and the water of Konkan rivers flow into the Arabian sea. The northern part, down to Dharwar in Karnataka and Ratnagiri in Mumbai is composed of Deccan traps, while the southern part consists of Archean gneisses, schists and charnockites. The western ghats form the real watershed of the Peninsula. All the important peninsular rivers-- the Godavari, the Krishna, the Kaveri and their important tributaries originated in the Western Ghats and flow eastwards into the Bay of Bengal. Some of the hills like Trimbakeshwar and Mahabaleswar in Maharashtra are well known as places of Pilgrimage and hill stations are also situated in Western Ghats.

18.2.3 The Vindyan Mountains

The Vindyan mountains separate southern India from northern India and form continuous group of hill ranges extending from Jobat in Gujarat to Sasaram in Bihar. The mountains have a general elevation of 450 to 600 meters. The Majority of ranges are composed of sandstones and quartzites. The Vindyan mountains form the watershed of Central India from which rise the Narmada, Chambal, Betwa, Ton, Ken and Sone streams. Some of streams flow into the Ganga and other into the Godavari and the Mahanandi.

The Satpura mountains separate the Narmada and Tapti rivers. The Aravalli mountains cross the Rajasthan from northeast to southwest which separate the arid and semi-desert of the Bikanar, Jodhpur and Jaisalmer area on west from the more fertile region of Udaipur and Jaipur on east. They are composed of rocks of the Aravallies, Delhi and Vindyan Supergroups.

Figure 18.1



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 are the rock types of Eastern ghats?

18.3 EXTRA-PENINSULAR INDIA - THE HIMALAYAS

The Extra-Peninsular India is composed of the Himalayan Mountain ranges in the north and the Arakan-Yoma ranges in the East and extend up to Andaman Nicobar Islands. The Himalaya, stretching 2400 km from Nanga Parbat (8126 m) in the west to the Namche Barwa (7756 m) in the east forms a arcuate mountain belt and a rampart for the Indian subcontinent along its northern margin. Its southern margin is demarcated by the Sindhu (Indus) - Ganga alluvial belt and the northern margin by the Indus Suture zone. The width of the belt varies from 230 to 320 km, average being 275 km. The average height of the southern margin of the belt is 100 m and northern margin 4500 m. This orogenic edifice is young in age also though the rocks composing it have a long history ranging from the Proterozoic to the quaternary. Geographically the Himalaya covers the states of Jammu-Kashmir, Himachal Pradesh, Garhwal-Kumaon of Uttar Pradesh, Sikkim-Darjeeling and Arunachal Pradesh in India, the Hazare and Northwest Frontier Province in Pakistan, Nepal, Bhutan and South Tibet.

The Himalayas are broadly classified into three parallel or longitudinal zones differing from one another into well marked geographical features. The Great Himalayas are Central Himalayas comprising the zone of high snow-capped peaks which are about 140 km from the edge of the plains. This zone shows both sedimentary and older metamorphic rocks which have been intruded by large masses of granite.

The Lesser Himalayas form an intricate system and have an average width of 80 km. This consists of parallel ranges in Nepal and Punjab but of scattered mountains in Kumaon.

The Outer Himalayas intervene between the Lesser Himalayas and the Plains. The width varies from 8 to 50 km. They form a system of foot hills, often referred as Siwalik ranges.

The Great Himalayan zone is composed of a continuous series of highly fossiliferous marine sedimentary rocks. The Central Himalayan zone comprising the Lesser or Middle Himalaya together with the Great Himalayas which is composed of metamorphic rocks - gneisses and schists with unfossiliferous sedimentary Purana and Mesozoic deposits. The outer or sub Himalayan zone is mainly composed of upper tertiary sedimentary river deposits.

18.4 INDO-GANGETIC PLAIN

The Indo-Gangetic Plain is a deep crustal trough filled with quaternary sediments and covering an area of 8,50,000 sq. km. It encompasses the states of Assam, West Bengal, Bihar, Uttar Pradesh, Haryana and Punjab. Its origin and structure are closely related with the rise of the Himalayas and give rise to occasional earthquakes in northern India. The Plain is divided into four shelf-areas separated from one another by three transverse 'high' - The Highs, from west to east as Delhi-Haridwar Ridge, Faizabad Ridge and Monghyr-Saharsa Ridge. The four shelves

are Punjab shelf, West Uttar Pradesh shelf, East Uttar Pradesh Shelf and West Bengal Shelf. The Shelves mainly consists of Gondwana, Palaeogene, Neogene and Quarternary sediments. The maximum thickness of 6000 m of the Plain is encountered along its northern fringes near Shiwalik Hills. The basin sediments also contain animal fossils like Rhinoceras, Hippopotamus and elephas etc.

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. Term Peninsula stands for

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3. The chief mountains of Peninsular India are

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18.5 STRATIGRAPHIC DIVISION OF INDIA

More than half of the Indian Peninsula is occupied by gneissic and schistose rocks of the Archean and Proterozoic ages. The Archean basement is beset with extremely complex geological history. It is known as the Peninsular Indian Shield. The shield has remained relatively stable since its formation over 2500 million years ago. It is bounded on the west, south and east by the present day coast line and Phanerozoic to Recent cover. These rocks are the main source of metallic deposits of India. Lying over the Archean gneisses and schists are Purana basins of Cuddapah, Kaldgi, Bhima, Vindyan, Phakal (Pranhita-Godavari), Bastar and others. These Basins are covered by sedimentary rocks of middle and late Proterozoic. These are separated from Archeans by an unconformity called ~~Epa~~ Archean Unconformity. These rocks are exposed in (a) the Cuddapah basin of Andhra Pradesh (d) the Vindyan basin in Madhya Pradesh, Bihar, Uttar Pradesh and Rajasthan, (e) Pakhal basin in Maharashtra, Madhya Pradesh and Andhra Pradesh, (f) Chattisgarh basin in Madhya Pradesh and Orissa and (g) Bastar basin in Madhya Pradesh.

The Gondwana were initiated by continental ice sheets which covered large parts of the Southern hemisphere. The formation of thick coal seams during this period is indicative of the disappearance of the glacial conditions and improved condition of climate. The major exposures are found in large faulted troughs along the Son-Mahanandi basin, Pranhita-Godavari basin, Koel-Damodar basin, Satpura basin and Rajmahal basin. The deccan traps occupy the rest of the area in peninsula.

In the extra-peninsula, marine sedimentary systems of mesozoic and tertiary groups predominate, though parts of the sub-Himalayas and the main axis of the Himalayas are occupied by ancient metamorphic rocks and intrusive igneous rocks.

TABLE 18.1

Major Stratigraphical divisions of India

Recent	Recent alluvium, Sand dunes, Soils
Pleistocene	Older Alluvial, Karewas of Kashmir, River Terraces etc.
Mio-Pliocene	Siwalik Group, Cuddalore, Warkalli and Rajahmundry Formation
Oligo-Miocene	Murree Group, Nari and Gaj Formations
Eocene	Murree Group, Nari and Gaj Formations
Upper Cretaceous to	Deccan traps and Inter trappeans
Lower Eocene	
Cretaceous	Lameta, Bagh, Umia Beds, Trichinopoly Formations
Jurassic	Kioto Limestone and Spiti Shales, Jurassic of Kutch
Triassic	Mahadeva and Panchet Groups
Permian	Zewan Formation and Lower Gondwanas
Carboniferous	Lipak and Po Formations, Talchir Group
Devonian	Muth Quartzite
Silurian	Silurian of Himalayas
Ordovician	Ordovician of Himalayas
Cambrian	Haimanta Group
Middle to Upper Proterozoic	Upper Vindhyans, Kurnools, Bhimas, Chattisgarh
Middle Proterozoic	Cuddapahs, Delhi Supergroup, Lower Vindhyans
Late Archean to Early Proterozoic	Eastern Ghats
Late Archean	Dharwars, Singhbhum group, Aravallis
Middle Archean	Older Supra Crustals (Sarguru Group)

18.6 SUMMARY

Physiographically India is divided into three distinct regions -- Peninsular, Extra-Peninsular and Indo-Gangetic plain. The chief mountains of peninsular India are the Eastern and Western Ghats, Vindhyans, Satpuras and the Aravallis. These are of relict type. The Extra-Peninsular is characterised by the tectonic mountains of the Himalayas and is composed of a series of highly fossiliferous marine sedimentary rocks. The Indo-Gangetic plains are broad, monotonous level expanses build up of quaternary alluvium sediments in between the Peninsular and Extra-Peninsular regions.

The major stratigraphic divisions in Peninsular region are of Archean and Proterozoic rocks. The mesozoic and Tertiary Groups predominate in the Extra-Peninsular region.

18.7 CHECK YOUR PROGRESS - MODEL ANSWERS

1. The rock types of Eastern ghats are Khondalites, Charnockites and migmatised gneisses.
2. Tectonically stable area, covered mostly by metamorphic and Igneous rocks and area is surrounded on its three sides by sea.
3. Eastern Ghats, Western Ghats, Vindhyan, Satpuras and Aravallis.

18.8 MODEL EXAMINATION QUESTIONS

I **Answers the following questions in about 30 lines each**

1. Describe the Physiographic divisions of India.
2. Indicate the important mountains and rivers of Peninsular India.
3. Write in brief about the Himalayan mountains.
4. Give an account of the major stratigraphical divisions of India.

II **Answer the following questions in about 10 lines each.**

1. Write briefly about the mountains of Peninsular India.
2. What is the physiographic and stratigraphic set up of Peninsular India.
3. Describe the Indo-Gangetic plains.

* * *

UNIT - 19 ARCHEAN GROUP

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 - 19.1 Introduction
 - 19.2 Dharwar Province
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 - 19.7 Mineral Wealth of Archean
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19.0 OBJECTIVES

After studying this unit you should be able to

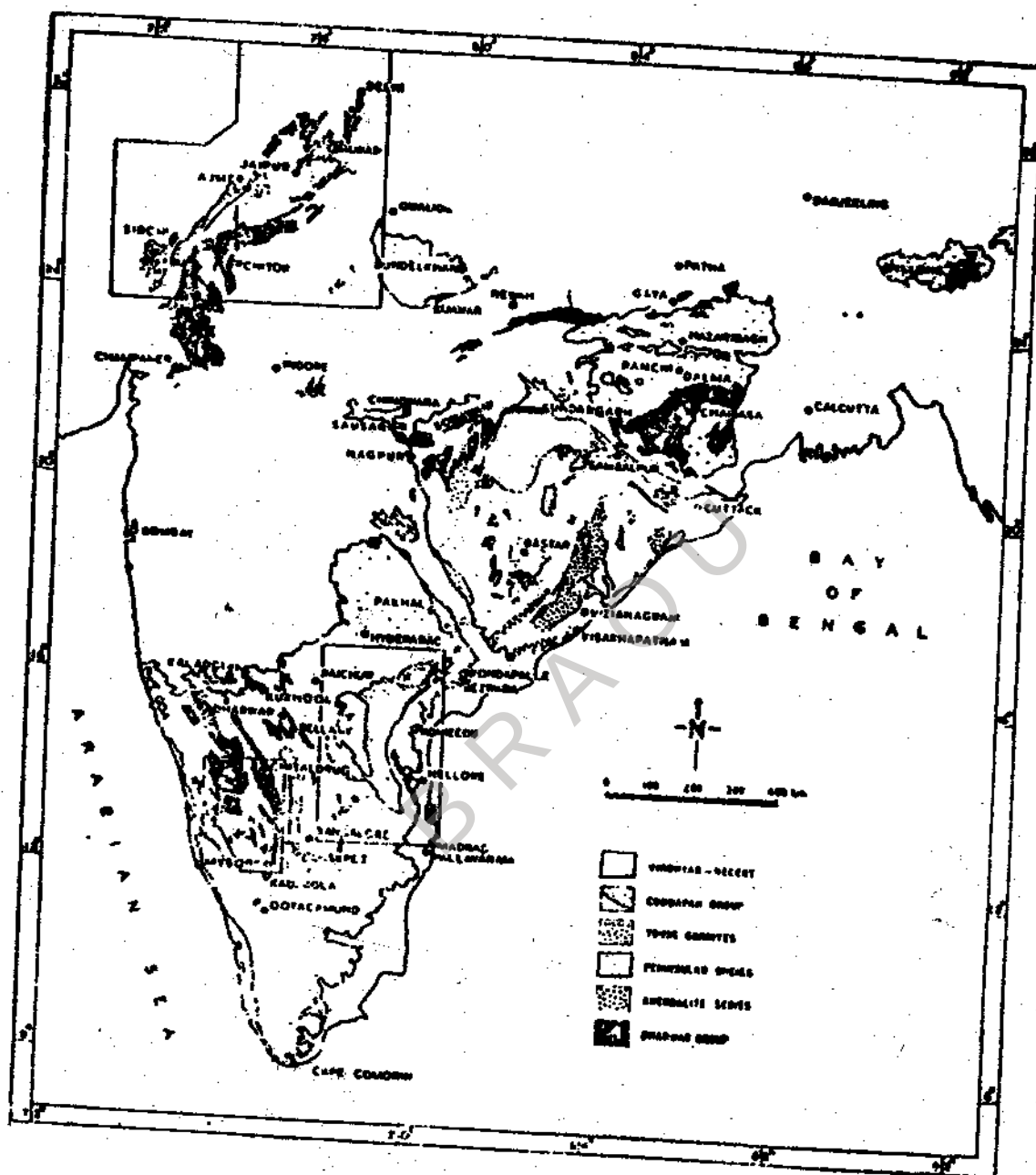
- * explain the five Archean Provinces - Dharwar, Eastern Ghats, Central India, Aravallis and Singhbhum-Orissa
 - * explain the Dharwar succession in Karnataka
 - * describe the Mineral Wealth of Archeans
-

19.1 INTRODUCTION

The term archean was introduced by **J.D.Dana**, for the ancient rock succession of the Canadian Shield. This succession is divided into two units based on geological and geochronological data. The lower unit consisting of highly deformed and metamorphosed rocks is termed as the Archean Group and the upper unit of less deformed and metamorphosed rocks as the Proterozoic Group. Recent studies indicated that during the early archean, the land surface was presumably covered by shallow seas. Sediments were deposited in these shallow volcanically active basins in an evaporate environment. So far the oldest rocks dated by isotopic method is a sediment from Greenland which gave the age of 3800 million years, and orthogneiss from Slave Province of Canada gave the age of about 3960 million years. As per the above data the Archean Era extends from 4000-2500 million years ago spanning very large interval of time. The upper unit of Proterozoic comprises relatively less metamorphosed sandstones, shales and limestones with intercalations of volcanic rocks and were deposited in distinct sedimentary basins of large aerial extent in a time span of 2500-900 million years.

The earliest phase of earth history representing the Archean era is preserved in the form of rock sequence at the surface of the earth over a inferred or unrecognizable basement. The Archean rocks show various proportions of volcanic and sedimentary assemblages. These assemblages occurs as linear belts of various dimensions, and as inclusions, enclaves etc. in vast gneissic terrain. These schist belts are variously referred as the "supracrustals", "supracrustal

associations', 'schist belts', 'greenstone belts', 'older metamorphosed' etc. Based on the data obtained from petrological, geochemical, structural and geochronological investigations the Indian Peninsula is recognised having five Archean provinces (Fig. 19.1).



(Fig. 19.1).

19.2 DHARWAR PROVINCE

Robert Bruce Foote introduced the term Dharwar System for the Archean rocks - granites and schists of this Dharwar Province in Karnataka. Later **Pichamuthu** named the entire Dharwar province as Dharwar Craton (Small Shield). It extends over an area of over 3,50,000 sq.km. in Southern Indian Shield. The Dharwar rocks occur in several NNW-SSE trending belts. The granitic gneisses contain enclaves of amphibolites and schists which are regarded as relict of the host rocks in a large granitic intrusion. Recent observations indicate that the schist inclusions or enclaves within the gneisses represent basic igneous rocks and primitive sedimentary rocks older than the Dharwars in age. The older schists show a relatively high degree of deformation and metamorphism known as "Ancient supracrustal enclaves" (Sargur type) or Sargur schist complex or Sargur Group. The Sargur equivalent rocks occur at Sargur, Krishnarajpet, Nugglihalli, Kalyadi, Nagamangala, Ghattihosa halli, Aladahalli, Holenarsipur in Karnataka.

The schist belts of Kolar and Hutti in Karnataka containing gold belong to the older greenstone belts and occur in the eastern part of Dharwar Craton. The high grade schists were intruded further by the Peninsular gneissic complex and together they form the basement for the deposition of volcanosedimentary assemblages belonging to younger greenstone belts known as Dharwar Supergroup (Table 19.1). Angular unconformity is recognised between Sargurs and Dharwars. The Dharwar type schist belts are Shimoga, Bababudan, Kudremukh, Chitradurg, Sandur etc. Sargur schist belts can be correlated with the Keewatins of Canada and other similar greenstone belts elsewhere. Granitic rocks are extensively developed in the eastern part of Dharwar Craton in a time span of 2700-2500 million years. Recently a name proposed for this group of rocks as "Dharwar Batholith".

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. The Dharwarian rocks have a regional strike of

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19.3 EASTERN GHATS PROVINCE

The Eastern Ghat Province is characteristic of high grade metamorphism and is mainly composed of Khondalites, Charnockites and Migmatitic gneisses. These are distributed mainly in two distinct belts. The first belt align the east coast of Andhra Pradesh and Orissa over a distance of 900 k.m. They extend from south of Ongole to Brahmani river in Orissa. The second belt extends from Chennai to the southern part of Cape Comorin and also western part of Tamil Nadu up to adjoining Kerala and Karnataka. The Eastern Ghats and the Western Ghats ranges coalesce in the Nilgiri hills.

Table 19.1 Precambrians of Karnataka

Approximate Age in million years	Super group	Group	Formation / Lithounits
2500		Closepet Granite Chitradurg granite Granulite	Isolated Stock like plutons of pink granites, prophyritic type Charnockites, pyroxene granulites, pink migmatites, fenitised charnockites.
2600 - 2500		Younger gneissic Complex	Kamba gneiss, patna gneiss, Dod gneiss, Dosagneiss of Kolar schist belt
2700 - 2600	Kolar type auriferous schist belts (Older greenstone belts)	Kolar, Hutti-Mski, Pennar-Hagari, Mangalur, Hungund-Kushtagi, Raichur - Deodurg belts	Volcano clastic sediments, acidic volcanics, polymict conglomerate, banded iron formations, cherts, banded quartzites, schistose amphibolites and metabasalts.
2900 - 2600	Dharwar Supergroup	Chitradurga	Hariyur Graywacke-argillite suite with volcanics, pyroclastic schists, polymict conglomerate. Ingaldhal Basic volcanics and pyroclastic acid volcanic cherts and sulphide iron formation Vaniyilas Iron and Manganese formations, limestones dolomites, phyllites and quartzites.
		Badabudan	Mullaingiri Volcanic and clastic sediments mainly iron formations and graphite schists Santveri Basic to intermediate volcanics, acid volcanics and cross bedded quartzites. Alampur Cross bedded quartzites, meta pyroxenites and meta gabbro. Kalsapura Metabasic rocks, quartz pebble conglomerate, quartz, quartzite, iron bedded volcanics.
3000		Older gneissic Complex	
More than 3000	Ancient supra crustal enclaves (Sargur Group)	Sargur, Krishnarajpet Nuggihalli, Kalyadi, Alladahalli, Holinarsipur schist belts	High grade schists comprising garnet, staurolite, kyanite, sillimnite, schists. Calc-silicate rocks, crystalline limestone, banded iron formations, fuchsite quartzite, amphibolite, ultra mafic flows and chromitiferous anorthosites

The Eastern Ghats is considered to be a classic example of a Precambrian Mobile Belt in the Peninsular Indian Shield. Recently it is also named as the Eastern Ghats Mobile Belts or Middle Proterozoic Mobile Belt. Structurally the rocks of Eastern Ghats are marked by intense folding and accompanying shearing and faulting. The regional trend of banding and foliation is generally NE-SW direction which in the western part of Tamil Nadu and adjoining Kerala, swerved to NNW-SSE to NW-SE.

The eastern ghat mobile belt is divided into three longitudinal zones-the western Charnockite zone, the central Khondalite zone and eastern Migmatite zone. Their proportions in the belt are 30%, 25% and 45% respectively. The Western zone consists of charnockite and basic granulite with minor banded iron formations. The Central zone is essential of garnet-sillimnite-graphite gneiss (khondalite), quartzite, calc-Silicate rocks, crystalline limestone, manganese silicate-carbonate rocks and cordierite-sapphirn-granulitic rocks. The Eastern Migmatite zone is composed of garnet bearing granitic rocks, migmatites of various types including leptynites and porphyritic-hypersthene gneiss.

Khondalites : Khondalites are named after the khonds of Andhra Pradesh and Orissa. These are essentially, garnet-sillimanite schists and gneisses containing quartz, feldspar and graphite. Graphite is of economic importance. Khondalites have altered into bauxite deposits at places. Other varieties of rocks associated with the Khondalite Group include quartzites, garnet-biotite gneisses, cordierite gneisses, crystalline limestones, calc-granulites and sapphirine bearing sillimnite gneisses. The Khondalite are derived from rather high alumina clays which were also fairly rich in iron. Kodurites are manganese rich gneisses often associated with the Khondalite Group. They are composed of potash feldspar, apatite, manganese pyroxene and spessartite and andradite rich garnet.

Charnockites : The name 'Charnockite' was suggested by Holland for the Hypersthene granite, in honour of Job Charnock, the founder of Kolkata, whose Tombstone was made up of this rock. Charnockites range in composition from ultra basic, basic to acidic varieties. The acidic charnockite are of two types, the granulitic (tonalitic composition) and granitic (granodiorite composition). The granulitic type is considered to have formed from acid, volcanic and igneous rocks by high grade metamorphism and structurally emplaced further into the Khondalites. The granitic type is formed much later due to palaeogenetic fusion and metasomatism. The granite gneiss transforms into charnockite is known as 'charnockite-making' and the charnockite is changed into granite gneiss is called 'charnockite-breaking'. These features are recently observed at Kabaldurga in Karnataka.

19.4 CENTRAL INDIA PROVINCE

The Precambrian rocks exposed in triangular belt of Nagpur, Bhandara, Chandrapur and Gad Chiroli districts in Central India are referred as Sakoli Group. The Sakoli schist belt is bordered on the north and northwest by ENE trending Sausar Group and the southeast by NNE trending Dongargarh belt comprising a succession of Amagaon, Nandagaon and Khairagarh Groups.

Sakoli Group

The Sakoli Group is considered as Proterozoic Supracrustal belt, covering an area of over 3500 sq.km in the eastern Maharashtra State. The group comprises predominantly of meta pelitic rocks with minor quartzites, conglomerates banded iron formations and metavolcanics including meta basalt, meta rhyolite, tuffs and epiclastic rocks. The phyllites in the belt show different colours -- green, brown and gray. The presence of the minerals like chlorite, biotite, almandine and staurolite indicate the Sakoli Group rocks which have undergone progressive regional metamorphism. This Group exhibits three different tectonic trends -- NNE-SSW to

NE-SW, ENE-WSW and NNW-SSE to NW-SE. The Group has undergone three phases of folding and regional metamorphism and referred as Sakoli fold belt. (refer Table 19.2)

Sausar Group :

The Sausar Group rocks are exposed in Chindwara and Balghat districts of Madhya Pradesh and Nagpur and Bhandara districts of Maharashtra. The rocks were first studied by Fennell in 1909. The Group consists of granulites, clastic-silicate rocks, mica schists, marbles, gneisses, quartzites and conglomerates. In Sausar group the most prominent formations are Mansar, Lohangi and Bichua. The Mansar formations contain richest manganese deposits of India while the Lohangi and Bichua formations have marble deposits. The Sausars are highly deformed characterised by the southern belt of overturned isoclinal folds and the northern belt of recumbent folds and nappes. Recent studies based on lithology, structure and geochronology indicate that Sakoli Group is older than the Sausar Group (Table 19.3).

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. The trend of Sausar Group

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3. The Mansar formation consists richest economic metallic mineral.

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19.5 SINGHBHUM - ORISSA PROVINCE

The Singbhum region of the southern Bihar and adjoining Orissa (parts of Mayurbhanj, Dhenkanal, Bonai and Keonjhar districts) are known for their rich deposits of iron and copper. It is also designated as the 'Archean Cratonic Core Region'. The Singbhum shear zone separates a northern terrain of more highly metamorphosed rocks and southern terrain of relatively less metamorphosed rocks. The formations north of the Singbhum shear zone and south of the Chota Nagpur granite gneissic complex are now recognised as the 'North Singbhum Mobile Belt' and also called an 'Orogen' which evolved in the Proterozoic. The Shear zone hosts large deposits of copper and uranium with associated gold, molybdenum, nickel, selenium and apatite-magnetite bodies. The oldest rocks so far dated from Bihar and Orissa are the 'Older Metamorphic Group' found as enclaves to several hundred sq.kms. in size in a vast mass of granitic rocks, named as the Singbhum Granite. This granite varies in composition from tonalite to granodiorite / granite and emplaced in three major phases. The youngest Precambrian basic

Table 19.2 Classification of Sakoli Group

Formation	Principal Lithology
Pawni Bhiwapur Dhabetekri Gaikhuri	Slate, phyllite, conglomerate, quartzite Metapelitic rocks (chloritoid+ andalusite+Staurolite) with interbands of Metavolcanic mainly rhyolite, dacite, tuffs, breccia, epiclastic rocks and minor basic rocks. Meta exhalites-Cu-Zn mineralisation and also gold and tungsten mineralisation. Metabasalts with minor meta pelites, chert bands and meta ultra mafic rocks. Conglomerates, gritty quartzite, meta arkose, minor carbonaceous phyllites, ferruginous quartzites and banded iron formations
Tectonised unconformity	
Amgaon gneissic complex	

Table 19.3 Litho-stratigraphic succession of Sausar Group

Formation	Principal Lithology
Bichua Junewani Chorbaoli Mansar	Dolomitic marble, Calc-gneisses and schists Mica schist and quartzites, granulites and biotite gneisses Quartzite, feldspathic schists, gneisses, autoclastic conglomerates Mica schist and gneisses, graphite schist, phyllites and quartzites, manganese ore deposits and gondites
Lohangi Lohangi member Utekata member Kadbikhere member Sitasaongi	Three calcareous members showing gradational contacts with one another Pink and white calcite and dolomitic marble Calc-silicate granulite and gneisses, epidote quartzites and manganese deposits Quartz-biotite schist, granulite, schists and gneisses. Quartz-mica schists, feldspathic schists, mica gneisses, quartzites and conglomerates
Disconformity	
Tirodi gneiss	Biotite gneiss with amphibolites, calc-silicate gneiss, granulites, and feldspathic mica schist
Unconformity	
Older metamorphics	Charnockite, orthogneiss, hornblende gneiss, amphibolites and calc-granulites

19.4 Precambrian formations of Singhbhum - Orissa

Approximate age in million years	Group	Formation
1600-950 2100	Newer Dolerites Mayurbhanj Granite Gabbro-anorthosite-ultramafics	
2200-2100	Kolhan	Jetia Shale Jhikpani Limestone Mungra Sandstone
Unconformity		
2300	Dhanjori	Jagannathapur Lava Dhanjori-Simlipal Lava Mungra Sandstone
2400-2300	Singhbhum	Dhalbhum Chaibasa
3100	Singhbhum granite (phase III) Iron Ore Group	Mafic lava, tuff, acid volcanics, Banded hematites, Jasper and banded quartzites, with iron ore Ferruginous cherts, local dolomite Quartzitic sandstone
3300 3500 - 3400	Singhbhum granite (Phase I & II) Folding and metamorphism of older metamorphic group-Older metamorphic tonalite gneiss	
3800 4000	Older Metamorphic Tonalite Group Older Metamorphic Group	

intrusives of the Singhbhum region are a group of dyke swarms predominantly developed in the NE and NW trends. These dyke swarms are designated as 'Newer Dolerites' and seem to have been emplaced in middle Proterozoic (Table 19.4).

19.6 ARAVALLI PROVINCE

The Aravalli hill ranges form a stretch from north Gujarat to South Haryana across Rajasthan. It is also known as 'Aravalli Fold Belt' or 'Proterozoic Fold Belt'. The Precambrian formation of this region is made of banded gneissic complex and a volcano-sedimentary succession comprising the Aravalli Supergroup (Table 19.5). The Aravalli Supergroup overlies the basement gneisses with significant erosional unconformity. The Aravalli Supergroup overlies the basement gneisses with significant erosional unconformity. The Aravalli sequence dominantly consists of argillaceous rocks and impure calcareous rocks with subordinate amount of conglomerates, meta volcanics and quartzites. Aravalli succession intruded by granites and ultra mafic rocks. The Aravalli sequence of Rajasthan along with the Champaners of Gujarat and Bijawars of Central India are considered as equivalents of the Dharwars of south India and Sausar and Sakoli groups of Central India. The exact relation between the Banded gneissic complex of Rajasthan and the Bundelkhand granite of Central India is uncertain.

19.7 MINERAL WEALTH OF ARCHEANS

Archeans are the repository of a number of economically valuable mineral deposits of iron, manganese, chromium, gold, copper, lead and zinc, tungsten, uranium, nickel etc. Most of the deposits are associated with schistose and granitic rocks.

Table 19.5 Precambrian Sequence of Rajasthan

Geological time scale	Supergroup	Group	Formation / Lithounit
Lower to Middle Proterozoic (2500 - 1800 million years)	Aravalli Supergroup	Delhi Supergroup Dharwar / Anjana granite	
		Jharol	Rakhadev-Serpentinite, talc-tremolite schist Jharol-Phyllite with thin bands of quartzites Iswal-Conglomerate, Quartzites
		Unconformity Leucogranite Intrusion	
		Debari	Zawar / Jahazpur Lead and Zinc bearing dolomites Sawar Rampura- Agucha, PurBaner Udaipur Graywacke, phyllite Umra Carbon phyllite Jamarkotra Phosphorite bearing dolomite Debari/Jaisalmand Conglomerate, quartzite, arkose
		Unconformity Pink Granite Intrusion	
		Delwara	Negaria Basic volcanics, quartzites, dolomites
		Unconformity	
Archean	Banded Gneissic Complex (Basement Complex)	Bereach granite (2500 million years) Untala, Gingla granite (2800 million years)	
		Bilwara Super Group	Hindoli Mangalwar Complex Sandmata Complex

Iron Ore : Archean sediments contain some of the richest and largest iron ore deposits in the world. Rich accumulation of iron ore are found forming the Baba budan, Kudremukh, Kodachadri and Sandur hill ranges in Karnataka, Singhbhum of Bihar, Keonjhar and Bonai districts of Orissa, Bastar, Chanda and Drug districts of Madhya Pradesh, Chandrapur, Bandra and Sindhurg districts of Maharashtra. There are some iron ores containing of titanium and vanadium minerals in economical viable concentration.

Manganese Ore : Manganese ore occurs as metamorphosed manganiferous sediments like Gondites and Kodurites. The Gondite type of manganese deposit is found in Chindwara and Balghat districts of Madhya Pradesh and Nagpur and Bhandara districts of Maharashtra. The Kodurite type manganese deposits occur in the Eastern Ghats associated with Khondalites. The Laterite type of manganese deposit occur in Karnataka, Bihar, Goa and Orissa.

Chromite Ore : Chromite ore occurs in ultra basic rocks like dunites, saxonites, pyroxenites and norites. The production comes from Keonjhar, Cuttack and Dhenkanal districts of Orissa, Singhbhum district of Bihar, Sittampundi complex in Tamil Nadu. Hussan ultra mafic complex in Karnataka etc.

Gold : Gold is mainly confined to Archean older greenstone belt like Kolar, Hutti in Karnataka and Ramgiri and Chigurugunta in Andhra Pradesh. Gold is also a by product in copper ores, iron ores and uranium minerals.

Copper : The main copper deposits are found in Singhbhum and Manbhum districts of Bihar, Malanjkhand in Madhya Pradesh and Chitradurg district in Karnataka.

Lead and Zinc : Zawar lead and zinc belt in Udaipur district of Rajasthan is the main significant deposit in India. There are also several small occurrences in Bihar, Orissa and Madhya Pradesh.

Tungsten : Tungsten ore minerals like Scheelite and Wolframite associated with Cassiterite deposits. Small deposits occur in Degana in Rajasthan, Bankura in West Bengal, Agargaon in Nagpur district of Maharashtra and Kolar and Hutti gold field in Karnataka.

Uranium : The only uranium mine is situated in Jaduguda in Singhbhum district of Bihar. Disseminations of uraninite, torbernite and other uranium minerals have been found in the copper belt of Singhbhum. Other uranium bearing minerals like allanite, columbite-tantalite, samarskite are occasionally found in pegmatites in various parts of India.

Nickel : Economically important occurrence of Nickel have not come to light so far. The ultra mafic lenses in the older greenstone belt show little concentration of nickel sulphide. The valuable non-metallic deposits like apatite, asbestos, magnesite, beryl, graphite, corundum and ornamental stones also occur in Archean group of rocks.

19.8 SUMMARY

Five Archean provinces: Dharwars, Eastern Ghats, Central India, Singhbhum-Orissa, 166 and Aravallis are recognised in Indian Peninsula. Dharwars of Karnataka consists of volcano-

sedimentary assemblages mainly gneisses and schists. They are divided based on special features into Sargur group and Dharwar Super group. Eastern Ghats extends from south of Ongole to Brahmini river in Orissa and Chennai to Cape Comorin and also western part of Tamil Nadu finally coalesce with Western Ghats at Dodabetta in Nilgiri hills. They mainly comprise Khondalite, Charnockite and Migmatite which are highly deformed and metamorphosed.

The Central Indian province is characterised by Sakoli and Sausar group of rocks, the later rocks rich in manganese deposits. The Singhbhum-Orissa province is known for Iron and Copper deposits. The Singhbhum shear zone separates the northern terrain and southern terrain. The northern part of the shear zone and south of Chota Nagpur gneissic complex are referred to as North Singhbhum Mobile Belt. The shear zone hosts large deposits of copper, uranium, molybdenum, nickel and apatite, magnetite bodies. The Aravalli province forms a hill ranges from north Gujarat to south Haryana across Rajasthan. It contains banded gneissic complex and volcano-sedimentary succession grouped as Aravalli Supergroup. The Aravalli succession broadly compared with the Dharwar of Karnataka. Archeans are the repository of a number of economically valuable metallic and non-metallic minerals occurring in granitic and schistose rocks.

19.9 CHECK YOUR PROGRESS - MODEL ANSWERS

1. NNW-SSE.
2. NNE-SSW.
3. Manganese.

19.10 MODEL EXAMINATION QUESTIONS

I Answer the following questions in about 30 lines each

1. Describe the Dharwar Supergroup of rocks in Karnataka
2. What are Archeans and how many archean provinces are recognised in India.
3. Explain the rock types in the Eastern Ghats.
4. Give an account of geology of Iron and Manganese rich provinces in India.

II Answer the following questions in about 10 lines each

1. Write an essay on mineral wealth of Archeans.
2. What are Sausars.
3. Discuss Singhbhum Shear Zone.
4. Write about Precambrian rocks of Rajasthan.

19.11 GLOSSARY

Shield : It is a stable part of earth's crust which group has not been disturbed since Precambrian times. Ex: Peninsular Indian Shield, Canadian Shield (North America) etc.

Craton : It is part of the earth's continental crust which has attained stability and was least affected by deformations during later periods.

Mobile Belt : It is a linear belt, characterised by intense deformation and metamorphism, surrounding a stable craton.

Terrane : It is a term used to describe a distinct litho-tectonic unit of regional extent usually fault bounded, juxtaposed and sutured together with another discrete litho-tectonic unit.

Schist : A regionally metamorphosed rock characterised by foliation and at time by lineation, which is coarser than slate and phyllite.

Gneiss : A coarse grained banded quartzo-feldspathic rocks with discontinuous foliation.

Green stone belt : The term first originated in Canada and later spread other parts of the world. The belt consists of lower ultra-mafic group comprising cyclic ultra mafic and mafic volcanics and pyroclastic rocks with minor sedimentary components.

Ancient Supracrustals : Highly deformed and metamorphosed volcano-sedimentary assemblages occurs as enclaves in older gneissic rocks.

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UNIT - 20 CUDDAPAH AND VINDHYAN GROUPS

Contents

- 20.0 Objectives
- 20.1 Introduction
- 20.2 Cuddapahs
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 - 20.2.2 Structure and Igneous activity
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20.0 OBJECTIVES

After studying this unit you should be able to

- * explain the Cuddapah Supergroup
- * describe the economic minerals of Cuddapah
- * describe the Vindhyan Supergroup
- * explain the economic minerals of Vindhyan

20.1 INTRODUCTION

After a prolonged period of denudation parts of the Archean Craton sank below shallow basins (called as Purana basins) and were covered by the Cuddapah deposits. They are dominantly composed of argillaceous and arenaceous rocks with subordinate calcareous rocks. There is a sharp contrast between the Archeans and the Cuddapahs, and Cuddapahs overlie the Archeans with a profound unconformity known as the "Eo-Archean Unconformity". This unconformity is well exposed on Tirumala Hills near Tirupati between the Archean granitic rocks and the Bairenkonda (Nagari) quartzites of Cuddapah Supergroup. It is marked by a conglomerate bed which is preserved as a National Geological Monument by the Geological Survey of India. Mafic igneous intrusions are plentiful in some of the Cuddapah formations (Fig. 20.1).

The Cuddapahs were followed by the Vindhyan after a time interval marked by earth movements and erosion. The Vindhyan Supergroup derives its name from the great vindhyan mountains developed in the Central India. Oldham (1895) designated great sandstone formations of the Bundelkhand and the Malwa as the 'Vindhyan System'. It covers a large part of

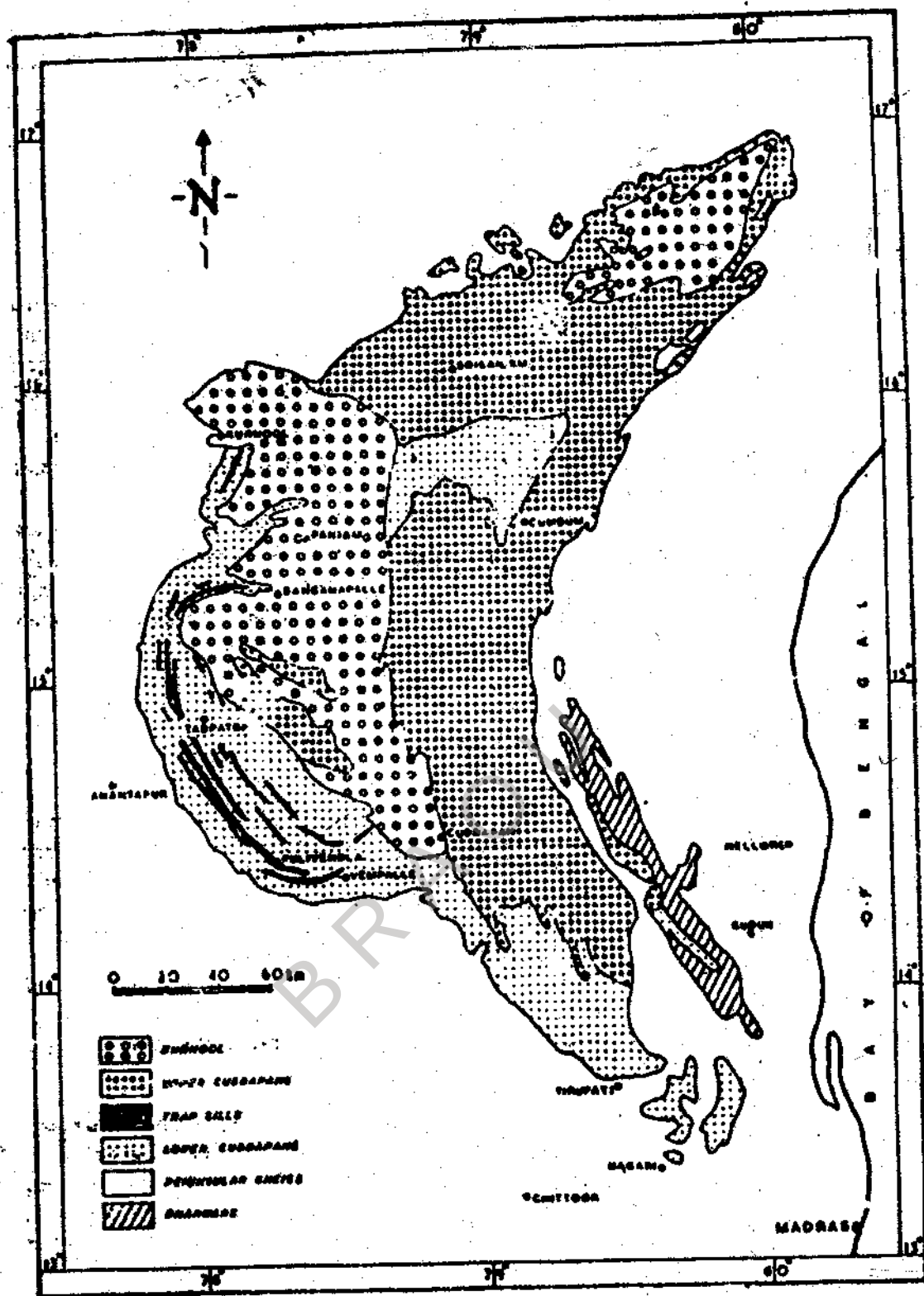


Fig. 20.1

Cuddapah basin in Andhra Pradesh

Peninsular India spreading over more than 1,00,000 sq.km in parts of Madhya Pradesh, Bihar, Uttar Pradesh and Rajasthan. An Area of about 78,000 sq.km of Vindhya Basin concealed under the Deccan Traps and alluvium of the Indo-Gangetic plains. Vindhyan Supergroup is comprised of vast stratified formations of sandstones shales and limestones attaining an average thickness of 4200 m. It occupies a large basin extending from Agra to Chattisgarh in west, Harda to Houshangabad in south and up to Sasaram in the east.

20.2 CUDDAPAHS

The rocks of Cuddapah Supergroup formed in crescent shaped Cuddapah Basin in south central part of Andhra Pradesh occupying an area of 44,500 sq.km. and distributed in parts of Chittoor, Anantapur, Cuddapah, Kurnool, Mahaboobnagar, Nalgonda, Guntur, Nellore, Prakasam and Krishna districts. It consists of 12 km thick sediments with minor volcanics formed as several discrete basins. The Cuddapah Supergroup and Delhi Supergroup are believed to be contemporaneous. The available geochronological data indicate that the oldest rocks in the basin are about 1750 million years which would assign them the Middle Proterozoic or Purana age.

20.2.1 Stratigraphic Succession

W.King (1872) first time described the rock formations of the Cuddapah Basin more than a century ago. The rock sequences are divided into lower and upper Cuddapahs comprising Papagni, Cheyyair, Nallamalai and Krishna series. Each of the major divisions of Cuddapah Supergroup is marked by an unconformity but major one occurs at the base of Nallamalai series. Recently the Geological Survey of India remapped the entire basin and given revised classification. The rock sequences have been divided into Papagni, Chitravati and Nallamalai Groups. The lithostratigraphy of the Cuddapah Supergroup together with the estimated thickness of each unit is given in Table 20.1.

Table 20.1 Classification of Cuddapah Supergroup

	Group	Formation	Lithology	Thickness (in m)
C U D D A P A H S U P E R G R O U P	Kurnool Group			
	Unconformity			
		Srisailem quartzite	Quartzite and Shale	300
	Unconformity			
	Nallamalai	Cumbum (Pullampet)	Phyllite, slate, quartzite, dolomite (Kimberlite), Lamprophyre, syenite, pullampet shale (volcanic tuffs), dolomite, quartzite. Bairenkonda quartzite, shale, Nagari conglomerate, quartzite and shale with intrusives	2000
		Bairenkonda (Nagari) Quartzite		4000
	Angular Unconformity			
	Chitravati	Gandikota Quartzite	quartzite, shale, (sills)	300
		Tadpatri	shale, volcanic tuffs, quartzite, dolomite with intrusives (flows, sills, tuff)	4600
		Pulivendla quartzite	Conglomerate	1 - 75
	Disconformity			
	Papagni	Vempalle	Stromalitic limestone, dolomite, mudstone, chert, breccia, quartzite with basic flows and intrusives.	1900
		Gulcheru Quartzite	Conglomerate, sandstone, quartzite and shale.	28-210
	Eaparaichean Unconformity			
	Archean gneisses / schist belts			

The cuddapahs are essentially a succession of an alternate sequences of quartzites or quartzite sandstones and shales or slates with associated bands of limestones, with conglomerates at the base of the quartzitic beds at places. The actual extent of the Papaghni, Chitravati and Nallamalai Groups is variable, probably because of the shape and depth of the basin changed from time to time. It is remarkable that each alternate sequence in the cuddapah succession begins with quartzites and ends with a shale unit representing cyclic repetition of quartzite-shale sequence reflecting successive transgressions in the basin indicating that the basin becomes shallow and gradually became deeper. The scarce occurrence of discoid tabular or column forms known as Stromatolites, marine algae remains in limestones belonging to various horizons support the gradual deepening of the basin.

20.2.2 Structure and Igneous Activity

Structure : According to King (1872) the Cuddapah Basin was a broad trough on the Archean basement, of which the western side has remained comparatively stationery while the middle and northern parts of the eastern half had been crushed and folded, and also faulted along the eastern margin. The main structural element of the Cuddapah basin is a north plunging, low amplitude, asymmetrical, synclorium made up of gentle dipping western limb, and an intensely folded, over folded and thrust eastern limb. Recently Geological Survey of India recognised the four morphological divisions in Cuddapah Basin. They are Western sub-basin, Nallamalai sub-basin, Srisailem sub-basin and the Kurnool/Palnad sub-basin. The Papaghni and Chitravati Groups are exposed in the Western sub-basin, while all other formations are restricted to their respective sub-basins. The rock in the Western sub-basin and Srisailem sub-basin display minimal deformation with sub-horizontal or gentle dips of beds. The rocks in the Nallamalai sub-basin are intensely folded, and the intensity of folding increases from west to east. This easterly more deformed sub-basin is also called the Nallamalai fold belt. A number of doubly plunging folds and domal structures are associated with Nallamalai Group. The N-S elongated Iswarakuppam dome is an important structural feature in the Nallamalai sub-basin. The Ramallokota-Gani-Kalva fault trending ENE-WSW cuts across the Cuddapah and Kurnool formations. A similar trending Karkambadi fault near Tirupati cuts across the Cuddapah rocks in southern most part of basin. The eastern margin of the Cuddapah Basin is intensely faulted and affected by thrusts.

Igneous Activity : The igneous activity in the southern part of the western margin, mainly with Vempalle and Tadipatri formation occurs in the form of volcanic flows, sills and dykes. It is marked by the occurrence of dolerite, picrite and gabbro sills, basaltic flows, ignimbrites and ash fall tuffs. Nagari quartzites, pullampet and cumbum formations are traversed by dolerite sills. Kimberlite and syenite intrusives are found in the cumbum formations at Chelima - Giddalur area. Large domal structures of granitic rocks are also found in cumbum formations. The basic flows and sills in the Vempalle and Tadipatri formation have arcuate shape, and truncation in the western margin is remarkable or striking. The recent geophysical studies have revealed a fault along the Cuddapah-Kurnool contacts, which obviously might have been resulted into the discontinuity of the original ring structure. The overall shape and revival of basic igneous activity in the form of flows and intrusions suggest the presence of cone sheet structure within the basin and having their counterparts represented by radial dykes outside the basin. The sills and flows show flow-banding and are at places porphyritic. The basic rocks are mainly consists of plagioclase, clinopyroxene and olivine. Geochemically they are quartz as well as olivine normative and rarely nepheline normative with a tholeiitic trend, and differentiation of primary picrite magma having mantle source.

20.2.3 Cuddapah Equivalents

Sedimentary basins of the Cuddapah age (Purna age) are found in parts of Maharashtra (Kaladgi basin) Andhra Pradesh (Pakhali basin), Orissa and Madhya Pradesh (Chattisgarh basin).

The Delhi Supergroup of Rajasthan differs from the Puranas of other parts of Peninsula in its more intense folding and in the amount of igneous activity. The Delhi Supergroup of rocks occupy a large extent of Rajasthan, from Delhi to Idar and full development being found in the main Rajasthan geosyncline of Ajmer, Merwar and Mewar area. The extent in space and time entitled the Delhi system of rocks to be considered as a major Supergroup.

Delhi Supergroup : The Delhi Supergroup of rocks buried more deeply along the main axis of folding of synclinorim. Shear zones and faults are common in Delhi Super group of rocks. It is also referred as Delhi fold belt. The Delhi Supergroup rocks occur in two belts- (i) the north Delhi fold belt in northeast of Rajasthan and developed in three sub-basins -- Alwar, Bayana and Khetri and (ii) the south Delhi fold belt along the Aravalli hill ranges in Central Rajasthan. The two belts are separated by migmatitic gneisses around Ajmer in the south and up to Khetri in the north. The Delhi Supergroup of rocks are considered to be middle to upper Proterozoic or Purana age. There is a profound unconformity between the Delhi and Aravalli Supergroups. The north Delhi fold belt rocks are divided into Alwar and Ajabgarh Groups and the south Delhi fold belt rocks are divided into Gogunda, Barotiya, Sendra, Rajagarh and Bhim Groups.

Tabel 20.2 The Succession of the Delhi Super group

		Group	Formation	Lithounit
		Siroli / Ras / Punagarh / Sendra granite, Newania Carbonatite, Kisangarh syenite		
D E L H I	S O U T H	Bhim	Dungarkhera Todgarh	Pelitic schist, Calc-gneiss and marble
		Rajgarh	--	Pelitic schist with quartzite
		Sendra	--	Meta-volcanics, impure marble, pelitic schist
	S O U T H	Barotiya	Barotiya Nanana Barr	Meta-volcanics, impure marble, pelitic schist Marble Mica-schist conglomerate
		Gongunda	Quartzite	--
		Ajithgarh, Dadikar, Bairat, Harsora, Saladipura, Udaipur and seoli granites		
	N O R T H	Ajabgarh	Arauli-Mandhan Bharkol Thana Gazi Kankwari Rajgarh	Quartz, staurolite schist, phyllite Quartzite with carbon phyllite Carbon phyllite and schist Schist and quartzite Conglomerate and quartzite
		Unconformity		
		Alwar	Weir-Sariska Kushalgarh Damdama Bayana Badalgarh Jogipura Telha / Sahaj-Govindapura Nithar / Serrate	Ferruginous quartzite Limestone and phyllite Conglomerate, quartzite Quartzite, Schist Feldspathic quartzite and shale Quartzite Meta-volcanics with quartzite schist Conglomerate, quartzite
		Railo (Delwara group)	Dogeta	Silicious dolomitic marble, phyllite
		Unconformity		
		Aravallis		

Kaladgi Group : The rocks of Kaladgi Group are named after the Kaladgi town in Bijapur district of Karnataka. The Kaladgi developed in an ovoid shaped Kaladgi basin covering an area of 8000 sq.km, and the west and the north of the basin is concealed by the Deccan Traps. Kaladgi Group consists of undeformed sediments, mostly unfossiliferous, deposited over the eroded edges of the Archean gneisses and schists and was designated by the name 'Purana' by **Holland** in 1907. The Kaladgi rocks are earlier classified into two groups -- the lower and the upper groups on the basis of unconformity. The lower Kaladgis comprises conglomerates, sandstones, quartzites, silicious limestones, clays and shales. The silicious limestone has lithological similarities with Vempalle limestone of Cuddpah Supergroup. The upper Kaladgis has a revised position in its stratigraphy, and given a Supergroup status. The lower group is named as Bagalkot Group while the upper sequence is designated as the Badami Group.

Pakhal Group : Rock of the Pakhal Group occur in the Proterozoic Pakhal basin, situated in the south-central part of the Peninsular shield, extending through the states of Andhra Pradesh, Madhya Pradesh and Maharashtra. Rocks of Pakhal bordering the Gondwanas in NW-SE direction along the Pranita-Godavari valley form into two belts -- the western and eastern belts. **King** (1881) carried out the pioneering geological work on the sediments of the Godavari valley and divided them into lower Pakhal series and an upper Sullavai series and correlated them with the Cuddapah and lower Vindhya respectively. Recently the sequence in this basin is broadly divided into the Pakhal Supergroup, Penganga Group and Sullavai Group. The Pakhal Supergroup is further divided into Mallampalli and Mulug Groups. The Pakhal Supergroup unconformably overlain the rocks of Penganga Group and Sullavai sandstone. The Albaka Sandstone bed is exposed in between Mulug and Penganga Groups. The Pakhal sediments mainly comprise conglomerates sandstones, limestones and ubiquitous occurrence of glauconite, overgrowths of feldspar indicating the sediments deposition under marine environment. The sedimentary structures like ripple marks, cross bedding indicate shallow water origin. The Pakhals was assigned middle Proterozoic age on the basis of Stromatolites.

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. Cuddpah rocks are first studied by

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2. Name the Unconformity which separate the Archeans and Cuddapahs

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20.2.4 Economic Importance of Cuddapahs

Copper : The Khetri Copper belt extends for about 80 km from Singhana (Jhunjunu district) to Raghunath garh (Sikar district) in Rajasthan. The copper ores occur in the form of chalcopyrite, pyrite, pyrrhotite, arsenopyrite and other sulphide minerals associated with slates, phyllites and basic rocks. Copper and lead deposits occur in quartzites and dolomites which were interbedded with shales around the granite dome in Agnigundala area of Guntur district in Andhra Pradesh.

Asbestos, Barytes and Steatite : Chrysotile asbestos is cross fibre variety and formed due to serpentinisation along the junction zones of trap sills and the host vemapalli dolomitic limestones. The Cuddapah traps are also responsible for the formation of Barytes and Steatite in the Vempalli limestones.

Barytes in sedimentary sequences at Mangampet in Cuddapah district is of volcanic sedimentary type and has reserve of 72 million tonnes. This is the world's largest single bedded-type deposit ever reported.

Building Stones : The Pulivendla and Nagari quartzites, conglomerates, slates in Andhra Pradesh and limestones, quartzites and conglomerates in Rajasthan are extensively used for building purpose. The Cumburn shales and slates in Andhra Pradesh yield rectangular blocks and slabs at various places and are hard durable building stones.

20.3 VINDHYANS

The Upper Vindhyan are mostly developed over the greater part of the Vindhyan exposures, while the lower Vindhyan are only developed in the Son valley. The Vindhyan rocks usually rest on the cuddapahs or older rocks with a very pronounced unconformity, and within the Vindhyan itself there are distinct unconformities.

The Vindhyan Super group comprise two distinct facies of deposits, one marine, calcareous and argillaceous characteristically developed in the lower part, and the other almost exclusively show a little structural disturbance in the Lower Vindhyan, and retain their original horizontal strata in the Upper Vindhyan. Ripple marks, mud cracks, current bedding in the Vindhyan sandstones point out the shallow agitated water of the coast, near the mouths of rivers.

20.3.1 Classification

The Vindhyan Super group is divided into four groups -- Semri, Kaimur, Rewa, Bhandar in the order of succession (Table 20.3). The lower division represented by Semri Group, is well exposed in the Son Valley, Dhar forest in Madhya Pradesh, Chittaurgarh-Mondasaur and Sapotrakarauli area in Rajasthan. The name Semri Group comes from Semri river in Bijawar area in Madhya Pradesh. The Group dominantly consists of limestone with subordinate amount of shale, sandstone, conglomerate and Porcellanoid beds. The Porcellinite formation contain volcanic products, which are contemporaneous with the Malani volcanics of the Western Rajasthan. The Fawn limestone and Kheinjua formation contains well preserved stromatolites. The Suket shales of Rohtas Formation exposed mainly in Rajasthan show disc-shaped remains of doubtful organic origin. The Semri Group is often intruded by dykes of dolerite and basalt in the Son valley.

The Upper Vindhyan are exposed in the great Vindhyan basin and consist of sandstone dominantly, and shales with minor amount of limestone. The Upper Vindhyan unconformably rest over the Semri Group and where the Lower Vindhyan are missing the

Upper Vindhyan rest over the Bundelkhand gneisses, Gwalior Group and Bijwar Group. The Rewa Group of rocks as separated from the underlying Kaimur Group by a diamendiferous conglomerate bed. The famous Panna diamond field is situated in Rewa rocks. The rocks of Bhandar Group well exposed in the central part of Vindhyan Basin.

20.3.2. Life in Vindhyans

In the Vindhyan Supergroup, a few obscure traces of animal and plant life are recorded. The only fossils that have been reported in Semri and Kaimur Groups are small carbonised horny discs, which belong to the genus of similar nature, named *Krishnania*, has been described by Sahni (1954). Stromatolites of algal origin have been reported in various Vindhyan formations. Coaly matter, spores, algal thallus, fungal spores etc. are described in them by many investigators. Recently jelly fish impression has been reported from Nimbahera limestone from Gayaripur area. The marked lithological similarity of the Upper Vindhyans with the purple sandstone of the salt range in Portwar Plateau may be in support of Cambrian age. Fossil records and radiometric data (1400 - 400 million years) indicate the age of Vindhyans as Middle to Upper Proterozoic.

20.3.3 Vindhyan Equivalents

The Vindhyans probably extended in the north under Indo-Gangetic alluvium to from the basement of the Himalayn fore deep. It is not established whether they have equivalents in some of the unfossiliferous rocks of the Sub-Himalayn region in Uttar Pradesh and Nepal, which are now found broken up and thrust southward over the Permo-Carboniferous and Tertiary rocks. Rocks resembling the Vindhyans occur as a scattered outcrops in Western Rajasthan. Typical Vindhyan equivalents are well exposed in the Cuddapah Basin, resting unconformably over Cuddapah Supergroup rocks known as Kurnool Group. The rocks in the Chattishgarh and Bastar basins are now correlated with the Kurnools, because of the lithological similarities.

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 Vindhyan succession consists of Groups

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4. Lower Vindhyans are well exposed in valley

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Table 20.3 Classification of the Vindhyan Supergroup

V I N D H Y A N S U P E R G R O U P	U P P E R	Group	Formation	Lithounit
		Bhandar	Upper Bhandar sandstone Sirbu Shale Lower Bhandar sandstone Bhandar limestone Ganurgarh shales	580 - 630
		Diamond bearing conglomerate		
		Rewa	Upper Rewa sandstone Jhiri shales Lower Rewa sandstone Panna shale	360 - 3000
		Diamond bearing conglomerate		
		Kaimur	Dhandraul sandstone Mangesar Formation Bijaigarh shale Gharghar sandstone Sushai breccia and shale Sasaram sandstone	8 - 400
		Unconformity		
	L O W E R	Semri	Rohtas Formation Kheinjuna sandstone and shale Fawn limestone Porcelanite & silicified shale Kajrahat limestone Basal sandstone & conglomerate	760 - 3055

Kurnool Group

The Kurnool Group mainly consists of quartzites, sandstones, shales and limestones, and unconformably overlies the Cuddapah Supergroup rocks in two sub basins-Kurnool and Palnad. The Kurnool sub-basin in Kunder valley exposed in the west-central part of the Cuddapah Basin while the Palnad sub-basin in Kunder valley exposed in the west-central part of the Cuddapah Basin. The limestones of Kurnool and Palnad sub-basins in Cuddapah Basin are the most important sources for cement industry. The lithostratigraphy of the Kurnool Group is given Table 20.4

Table 20.4 Classification of Kurnool Group

Formation	Lithology	Thickness (in m)
Nandyal Shale	Shale	50 - 100
Koilkuntla limestone	Limestone	15 - 50
Panium quartzite	Quartzite	10 - 35
Owk shale	Shale (ocherous)	10 - 15
Narji limestone	Limestone	100 - 200
Banganpalle quartzite	Conglomerate and quartzite	10 - 50
	Unconformity	
	Cuddapah Supergroup	

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. Name the basins, which are sources of cement industry

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Bhima Group : Rocks of Bhima Group are exposed on either side of Bhima river in the districts of Gulbarga and Bijapur of Karnataka. A small eastern part of the basin extends into Ranga Reddy district of Andhra Pradesh and occupying an area of 5200 sq.km. This is the smallest of all Proterozoic basins in India. The earlier classification by **Bruce Foote** divided the strata into lower and upper series. As per the revised classification, bulk of the Shahabad formation and the Katamdevarhalli formation of the earlier classification have been grouped under Shahabad formation resting over the Rabanpalli formation. Archean gneissic complex forms the base of the Bhima Group and the northern part of the basin is concealed by Deccan Trap flows and inter trappean beds. Recently specks of gold was found in basal conglomerate and sandstone of Rabanpalli Formation. This indicate the possibility of placer gold in coarse grained sandy rocks of the group. The features such as lithology, horizontal deposition and unmetamorphosed nature of the Bhima Group made them as equivalent of the Kurnool Group.

Table 20.5 Classification of the Bhima Group

Formation	Lithology
Shahabad Formation	Grey micritic impure limestone
	Dark blue grey massive limestone
	Variegated silicious and cherty limestone
	Blue grey blacky micritic limestone
	Flaggy impure (cherty argillaceous) limestone
Unconformity (Gradational contact)	
Rabanpalli Formation	Ekjmai purple shale member
	Kasthurpalli Glauconite member
	Kendrapalli quartz - arenate member
	Adki hill conglomerate member
Unconformity	
Archean gneisses	

20.3.4 Economic Importance of Vindhya

Vindhya are potentially a source for diamonds, pyrite, clays, ochres, cement grade limestone, and building stones. The upper Vindhya are remarkable for their diamond bearing horizons of strata lying between the Kaimur and Rewa groups. They are also found in Banganpalli formations of the Kurnool. The original source of the diamonds is related to the kimberlite pipes found at Majhgawan near Panna in Madhya Pradesh, Wajrakarur in Anantapur in Andhra Pradesh. Pyrite and Coal are reported from the Bijargarh shales near Amjhor in Uttar Pradesh. Limestones of the Vindhya are most important sources of raw material for the lime and cement industries in Bihar, Uttar Pradesh and Madhya Pradesh. In Andhra Pradesh bulk of the limestone resources are associated with the Cuddapah, Kurnool, Pakhal, Sullavai and Bhima Group of rocks. Vindhyan limestone of different colours was used in the inlaid decorations of buildings in Agra. The Bhandar sandstone are extensively used as building stones in northern India. The Owk shales in Kurnool district yield good fireclays and yellow ochres. Some Vindhyan sandstones yield good glassy sands on disintegration by weathering.

20.4 SUMMARY

The purana basins like Cuddapah, Delhi, Pranhita, Godavari (Pakhals), Vindhya, Chattishgarh, Baster, Bhima and Kaladgi are formed in Middle Proterozoic on the Cratonic parts of the Indian Shield. The profound unconformity in between Cuddapah Supergroup of rocks and Archean rocks, was designated by Holland as the Great Ep-Archean Unconformity. The Cuddapah Supergroup rocks first described and classified by W.King (1872) and later classified by Geological Survey of India into Papaghni, Chitravati, Nallamalai Groups and Srisailem quartzite. Folds and faults are remarkable in the Cuddapah basin. The rocks of Nallamalai sub-basin are highly deformed when compared to other sub-basins. Two periods of igneous activity have been recorded in the type locality. The Major Cuddapah equivalents are Delhi Super Group, Kaladgis and Pakhals. The Economic importance of Cuddapah basin is the occurrence of copper, asbestos, barytes and steatite, which are outlined in general. Vindhyan Supergroup is mainly consists of two facies of deposits (i) marine calcareous and argillaceous and (ii) fluvial or estuarine arenaceous deposits. The traces of animal and plant life in the form of Stromatolites of algal origin are reported to occur in Vindhyan rocks. The Vindhyan Supergroup is classified into lower and upper divisions, the lower division is referred to as Semri Group and Upper division as Kaimur, Rewa and Bhandar Groups. The Vindhya mainly consists of sandstones, limestones, shales and conglomerates. The Vindhyan equivalents in the Cuddapah Basin are known as Kurnool Group of rocks, and the rocks in Chattishgarh and Bastar basins are correlated with the Kurnool. The Economic importance of Vindhya shows that these formations are source for diamonds.

20.5 CHECK YOUR PROGRESS-MODEL ANSWERS

1. W.King (1872)
2. Ep-Archean Unconformity
3. Semri, Kaimur, Rewa and Bhandar Groups
4. Son valley
5. Kurnool and Palnad Sub-basins

BRAOU

BLOCK - VI INDIAN GEOLOGY - II

BRAOU

UNIT-21 THE GONDWANA GROUP

Contents

- 21.0 Objectives
- 21.1 Introduction
- 21.2 Distribution of Gondwanas
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- 21.5 Climate and Sedimentation
- 21.6 Economic Importance
- 21.7 Summary
- 21.8 Check Your Progress-Model Answers
- 21.9 Model Examination Questions

21.0 OBJECTIVES

After studying this unit you should be able to

- * explain the Gondwana Supergroup of rocks
- * describe the coal bearing horizons
- * define the igneous activity, climate and sedimentation
- * describe flora and fauna of Gondwanas

21.1 INTRODUCTION

After the formation of Puranas (Cuddpahs, Vindhya, Bhimas, Pakhal etc.) in southern part of Peninsular India, there was a long period of gap in sedimentation. It is evident from the absence of Ordovician, Silurian and Devonian sediments. During this period the Peninsular India, formed a part of a Super Continent called the "Gondwana Land". This continental mass, which included South America, Africa, India, Australia and Antarctica was covered by extensive ice sheet. In the Carboniferous period the climate warmed up, melting the ice sheet and forming the fluvio-glacial deposits, in the form of tillite or boulder bed (Talchir boulder bed). This bed forms the base of huge thickness of sedimentary strata comprising conglomerate, sandstone, shale and coal bearing strata which were deposited in narrow, linear, gradually sinking graben like troughs from upper Carboniferous to the end of Jurassic. These sediments were first studied by **Medlicott** (1872) and named them as Gondwana succession, now which is designated as the Gondwana Supergroup.

21.2 DISTRIBUTION OF GONDWANAS

Rocks belonging to the Gondwana Supergroup are well developed in the triangular area bounded by Damodar-Narmada-Sone valleys in the north, Godavari valley along NW-SE and the northern part of the east coast peninsular India (Figure 21.1). In this triangular area, the major basins present are NW-SE trending Sone-Mahanadi and Pranhita-Godavari basin, the E-W oriented Koel-Damodar and Satpura basins and N-S oriented Rajmahal basin. The Lower Gondwana rocks occur extensively in all the basins whereas the Upper Gondwana rocks are developed and preserved only in parts of Narmada, Mahanadi and Godavari basins. The Basal strata of the Upper Gondwana occur in all the major basins, whereas the upper strata have a restricted distribution. The Gondwanas encompass parts of Bihar, West Bengal, Madhya Pradesh, Maharashtra, Orissa, Andhra Pradesh and Tamilnadu. Apart from these the Gondwana rocks are found in foot Hills of Himalaya, Assam, Kashmir, Saurashtra and Kutch.

The Mahadeva Group consists of red and buff coloured sandstones with some red clays near the base and also on top. Fishes, Amphibians and Reptiles are found in the clay beds.

The Rajmahal Group consists of 450-650 m of basaltic lava flows with intercalated carbonaceous shales and clays. The inter-trappean sediments contain plant remains, fossil wood and flora. *Ptilophyllum acutifolium* have gained importance.

The Jabalpur Group is divided into lower Jabalpur and upper Umia formations. They consist of white and light coloured clays and massive soft sandstones. *Ptilophyllum acutifolium*, *Otozamites* sp. *Williamsonia indica* are important fossils found in Jabalpur Group.

The Upper Gondwanas of Godavari district in Andhra Pradesh are familiar and rest unconformably upon the Chintalapudi (Kamthi) sandstones. The Chintalapudi sandstone lie directly over the Archean gneisses and high grade metamorphic rocks of the Eastern Ghats Mobile Belt. Gollapalli sandstones, Raghavapuram shales and Tirupati sandstones overlying the Chintalapudi sandstone contain *Ptilophyllum acutifolium* and *Talniopterisensis*, assigning them to Upper Gondwanas.

These form the main coastal, Upper Gondwana sequence of the Godavari basin. Recently this succession was revised on the basis of lithology and fossil assemblage into the lower Raghavapuram Formation and the upper Tirupati Formation. These are overlaid by Rajahmundry sandstone of Tertiary age. The well known ball clays of Dwaraka-Tirumala are hosted by the Raghavapuram Formation. The coastal Gondwana of Krishna basin comprises the Budavada sandstones, Vemavaram shales, Pavalur sandstones, in the Guntur (Chebrolu area) and Prakasam (Uppuguduru area) districts. They are referred to as the Upper Gondwanas and correlated with the Godavari basin. Satyavedu and Sriperumbudur Formations of Upper Gondwanas in Chittoor district are considered homotaxial with Vemavaram (Krishna basin) and Raghavapuram (Godavari basin) formations.

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. The name Gondwana was introduced by

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2. Lower Gondwanas are characterised by the flora and Upper Gondwanas are characterised by the flora.

.....

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21.4 STRUCTURE AND IGNEOUS ACTIVITY IN GONDWANAS

Structure

The Gondwana rocks are confined to the tectonic trough with faulted boundaries as grabens of halfgraben structures arranged along linear zones. The faults run E-W and the strata dip generally towards the more faulted southern boundary in the Koel-Damodar and Satpura basins. In Pranhita Godavari and Sone-Mahanadi basins the trend of the faults is NW-SE and N-S in Rajmahal basin. Most of Gondwana basins in the Peninsula are free from folding and where present they are confined to the more pronounced faulted margins of the troughs. In the Himalayas the Gondwanas were highly affected by the Tertiary mountain building movements and coal seams subjected to crushing and devolatilisation.

Igneous Activity

Igneous activity is observed in some parts of Gondwana basins in the form volcanic flows, sills and dykes and mainly comprising mica-peridotite, lamprophyres and basalts. Basaltic flows, dolerite sills and dykes occur in Rajmahal hills, Garo hills of Assam, some parts of Damodar basin and in Satpura and Chattishgarh regions of Madhya Pradesh. Mica-peridotites and lamprophyres are confined to eastern part of Damodar basin and Darjeeling areas. The igneous activity is absent in Mahanadi basin, South Chattishgarh regions, Wardha-Godavari basin and coastal regions. Among these dykes, some are affected by subsequent faulting indicating that they are prior to faulting and some are passed through the fault zones indicating that, they are later to the faulting. The sills and dykes are related to Deccan volcanism.

21.5 CLIMATE AND SEDIMENTATION

The Gondwana period was initiated by the glacial climate during which a vast continental ice sheet covered a large part of the Gondwana land. Glaciers appear to have flowed out from Rajasthan and Madhya Pradesh as well as the Eastern Ghat areas. The most prominent centre of glaciation was the southeastern flank of present Godavari valley from where ice moved in north and northwesterly directions.

The climate gradually warmed during the period when fluvio-glacial sediments and varved clays were deposited. This is evidenced from the presence of the Talchir boulder bed of tillite at the base of the Gondwana sequence. In Damodar period the climate was definitely warmer and more humid and permitted the growth of luxuriant vegetation. An enormous amount of vegetation was carried by streams into the swamps and lake basins to form the coal beds. The nature of the flora as well as the presence of undecomposed feldspars in the sediments indicate that the climate was cold temperate. The upper part of Damodar period has experienced a somewhat drier climate as evidenced by the presence of reddish ferruginous sandstones. The presence of Labrinthodonts in the Panchet formation indicates a period of gradual drying up of the sedimentary basins. The Mahadeva Group consists of ferruginous sandstones of Triassic age and definitely sediments of an arid climate. During the Rajmahal time the climate has changed to humid temperature conditions and permitted the growth of vegetation. The Earth crust seems to have experienced tension in Gondwana land and resulted in the out pouring of lavas and volcanic material during the Rajmahal times. Recently, Casshyap (1977) divided the Gondwana strata into three distinct assemblages -- glacial at the base (Permo-Carboniferous) overlain by prolonged sequence of continental fluvial deposits (Permian to Jurassic) and perialic to marine deposits of Lower Cretaceous age. Gondwana rocks are predominately sandstones with bands of conglomerate and intercalated shales, and the frequent presence of current bedding indicates to a fluvial (fresh water) origin.

22.3 INTRUSIVES IN THE DECCAN TRAPS

Sills and dykes of dolerite are numerous in the traps but they are not evenly distributed. In Saurashtra they show a more or less radial disposition around Amrali and Jardan and also around the plutonic mass of Girnar. Dykes are very common in eastern Saurashtra in Gujarat, in the Narmada valley, in the Satpura region of Madhya Pradesh and also in Western Andhra Pradesh.

22.4 PETROLOGY, PETROGRAPHY AND CHEMICAL COMPOSITION

Petrologically the Deccan traps show general similarity from one area to another and uniform in composition and correspond to dolerite or basalt with an average specific gravity of 2.9. In Western India including Mumbai, Kathiawar and Kutch, the traps are associated with acid, intermediate and ultrabasic rock types derived through differentiation of the original magma.

Besides the usual dolerite and basalt, lamprophyre, limburgite, olivine gabbro, porphyritic basalt, porphyry andesite, monzonite, nepheline syenite, rhyolite, obsidian and pitchstone are recorded.

The bulk of the trap is composed of labradorite and clinopyroxene. Ophitic texture is common. The rocks often show phenocrysts of feldspar in doleritic types and interstitial glassy matter in the basaltic types. The common pyroxene in the lower and middle traps is augite to subcalcic augite with occasional pigeonite and is associated with olivine and ore minerals. Secondary minerals such as zeolites, calcite and chalcedony are often developed in the traps, either as fillings in the amygdoloidal cavities or as products of alteration.

The plateau basalts of the fissure eruption type when compared with the normal core basalts of the central eruption type show a higher iron and titanium content. The most of the flows in Deccan Plateau are middle stage basalts and are characteristically tholeiitic and represent the original magma of the province. Last stage basalts are restricted to only a few areas in western Maharashtra.

Chemically, majority of the basalts are high-alumina basalts and with relatively high Fe and Ti. The trace elements Cr, Ni, Co, Sc, Y, Sr, Pb, and Ba, seem to have behaved in a much more systematic and orderly manner when compared to the major elements.

The geochemical studies of the Deccan traps have led to the recognition of distinct and different magma types. It is believed that the origin of all magmas is from a common parentage by the partial fusion of the upper mantle. Primary mantle material is presumed to be of the composition of garnet peridotite with varying amounts of garnet or omphacite on partial melting, yield tholeiite and alkalibasalt types. The alkali basalt type would be generated at a greater depth than the tholeiitic type. Differentiation of either type of magma may take place during and/or after emplacement due to oxidation and reduction, gas fluxing, crystal settling and contamination.

22.5 THE BAGH BEDS

The Bagh beds occur below the traps near Bagh town, situated in the western part of Narmada valley, about 145 km west of Indore in Madhya Pradesh. The Bagh beds are also exposed in isolated outcrops around Kewadi-Chapdi, Arithi-Sipanpalia, Jangthi-Jampani and Mangeli-Wani villages in Dhule districts of Maharashtra. Bagh beds comprise marine sediments like conglomerate, sandstone and shale of Cretaceous age (Table 22.2). They contain several species of Anthozoa, Poryozoa, Echinodermata, Brachiopoda, Gastropoda, Lamelli-
branches and Fishes indicate mainly Turonian in age (Upper Cretaceous).

Tabel 22.2 The Succession of Bagh beds

Deccan Traps		
Unconformity		
Bagh Beds	Upper	Coralline Limestone Deola marl Nodular argillaceous limestone
	Lower	Nimar sandstone
Unconformity		
Metamorphics		

22.6 THE LAMETA BEDS

The Lameta beds are found below the traps near Lameta ghat on the Narmada river, a few kilometers south west of Jabalpur, Sagar, Bhopal, Indore, Jhanbua and Gwalior districts of Madhya Pradesh, along the western border of Andhra Pradesh, north border of Karnataka and western part of the Narmada valley in Gujarat. The Lameta sequence in the type locality, Lameta Ghat is as follows (Table 22.3).

Tabel 22.3 Lameta sequence at Lameta Ghat

Deccan Trap	
Unconformity	
Lameta Beds	
Upper sand	5-6 m
Upper limestone	3 m
Mottled nodular limestone	10-15 m
Lower limestone	1-4 m
Green sand	2-15 m

The Lameta beds containing fossils of Mollusca (Physa, Paludina and Corbicula), Fishes (Lepidosteus, indicus, Titanosaurus and Jabaluria tentris) indicate Upper Cretaceous age.

22.7 INFRA-TRAPPEAN BEDS

Infra-trappeans occur in isolated outcrops and exposed in hill slopes at Nagpur, Bandara, Chandrapur and Amaravati districts of Maharashtra, Chindwara district of Madhya Pradesh, Ranga Reddy, Adilabad, Nizamabad, East and West Godavari districts of Andhra Pradesh. Infra-trappean beds comprising sandstone, conglomerate, limestone and marl occur in between the basement granite gneiss and the traps. At Duddukuru near Rajahmundry, on either side of Godavari river, Infra-trappean sandstone and limestone overlie the Upper Gondwanas, its marine fossils such as Turritella, Cardita baumonti, Rostellaria, Ostrea etc indicate Upper Cretaceous age.

22.8 INTER-TRAPPEAN BEDS

Between successive eruptions of lava, there is considerable intervals of time which allowed fluvial and lacustrine deposits to form thin bands in the depressions which are known as Inter-trappeans. From the animal and plant remains in the sedimentary rocks, the age of associated traps are inferred. They comprise cherty limestones, shale and in some places conglomerates and sands in the order flows at the bottom and the younger flows at the top. They are exposed in Godavari district in Andhra Pradesh, Nagpur, Amaravathi and Chandrapur districts in Maharashtra and Chindwara and Jabalpur in Madhya Pradesh. The Inter-trappean beds near Mumbai containing fresh water frogs (*Oxyglossus*), tortoise (*Hydrapsis*) and arthropods (*Cylindrica*) indicate early Eocene age. Two Inter-trappean beds are noticed in Deccan traps on either side of Godavari river near Rajahmundry. they extend over 50km from Pangidi in west Godavari district to Kateru in the east Godavari district. The foraminifera assemblage, algal remains and charophyta indicate Lower Tertiary age (Early Eocene).

22.9 AGE OF THE DECCAN TRAPS

The age of the Deccan Traps is controversial. They are either assigned to Upper Cretaceous or Lower Tertiary based on different lines of field evidence.

1. The Bagh beds, Lameta beds and Infra-trappean beds are older to the Deccan traps as they underlie the trap rocks.
2. The Bagh beds contain several species of Anthozoa, Poryozoa, Echinodermata, Brachiopoda and Fishes indicate the Turonian (Upper Cretaceous) age.
3. The Lameta beds containing Mollusca, Fishes and Dinosaurs indicate Upper Cretaceous age.
4. The Infra-trappean beds containing main fossils such as *Turritella*, *Cardita baumonti*, *Ostrea* etc. indicate Upper Cretaceous age.
5. The Inter-trappean beds near Mumbai containing fresh water Frog, Tortoise and Arthropods indicate early Eocene age.
6. The Inter-trappean beds at Kateru near Rajahmundry have Foraminifera, Algal remains and Charophyta giving Lower Tertiary (Early Eocene) age to them.
7. Earlier Radiometric investigations gave age of 60-65 million years for Mumbai flows corresponding to Upper Cretaceous-Eocene boundary ages.
8. Recent Radiometric dating (K-Ar method and $^{40}\text{Ar}/^{39}\text{Ar}$ isotope method) of Deccan basalts has yielded the ages between 65-68 million years. The traps age at 65 million years placing them at the Cretaceous-Tertiary (K-T) boundary that make it globally significant.

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 beds are generally underlying the Deccan Traps

3. The age of Deccan Traps is
-
-

22.10 ECONOMIC IMPORTANCE

The Deccan traps are used as building stones, road metal and for cement concrete. Quartz, amethyst, agate and varieties of chalcedony which occur as geodes in basalts are used as gem stones. The traps are often capped by ferruginous and aluminous laterite, rich enough in alumina to give high grade bauxite. The black soil or regur formed from the Deccan Traps is suitable for rising cotton. The basalt is also used in manufacture of rock-wool.

22.11 SUMMARY

The Deccan traps have a very wide geographical distribution and are mainly fissure eruptions. The Traps are classified into three sub-groups--Kalsubai, Lonavala and Wai which consists of twelve formations. Sill and dykes of dolerites are very common in Deccan traps. Lamprophyres, nepheline syenite, rhyolite are also found in Deccan traps. Petrologically Deccan Traps show general similarity from one area to another in having ophitic texture and the mineral assemblage--labradorite, clinopyroxene and pigeonite.

The Deccan basalts are of tholeiitic and alkali basalt types and majority of the basalts are high alumina rich basalts showing Fe and Ti enrichment. The Bagh beds, Lameta beds, infra-trappeans and inter-trappean beds are the important stratigraphic horizons. The age of Deccan traps is of either Upper Cretaceous or of Lower Tertiary based on the field and radiometric evidence. Recent radiometric dating (K-Ar method and $^{40}\text{Ar}/^{39}\text{Ar}$ isotopic method) of Deccan traps has yielded the ages between 65 and 68 million years. The traps at 65 million years corresponding to K-T boundary. The traps have altered into high grade bauxite and black cotton soil.

22.12 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Kalsubai, Lonavala and Wai
2. Bagh beds, Lameta beds and infra-trappeans.
3. Upper Cretaceous to Lower Eocene.

22.13 MODEL EXAMINATION QUESTIONS

- I Answer the following questions in about 30 lines each**
1. Give an account of the Deccan traps
 2. Discuss about the age of Deccan traps
- II Answer the following questions in about 10 line each**
1. Bagh beds
 2. Lametas
 3. Inter-trappeans
 4. Infra-trappeans
 5. Classification of Deccan traps

* * *

UNIT - 23 THE YOUNGER FORMATIONS

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- 23.0 Objectives
 - 23.1 Introduction
 - 23.2 Distribution of Younger Formations
 - 23.3 Himalayan Palaeogene Succession
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 - 23.5 Tertiary Succession of Assam-Arkan basin
 - 23.6 Tertiary Rocks in Peninsular Region
 - 23.6.1 Tertiaries of Saurashtra
 - 23.6.2 Quilon-Warakalli Formation
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 - 23.6.4 Cuddalore Sandstone Formation
 - 23.7 Economic importance of Tertiaries
 - 23.8 The Karewas
 - 23.9 Summary
 - 23.10 Check Your Progress-Model Answers
 - 23.11 Model Examination Questions
-

23.0 OBJECTIVES

After studying this unit you should be able to

- * explain the Cenozoic era-Tertiary and Quaternary periods.
 - * describe the Siwalik Group.
 - * explain the Economic importance of Tertiary
 - * describe the Karewa Formations
-

23.1 INTRODUCTION

The Cenozoic era followed the Mesozoic era is the recent phase of the earth's history. The Era is generally divided into Tertiary and Quaternary periods. The tertiary system further divided into Palaeogene (Palaeocene, Eocene and Oligocene) and Neogene (Miocene and Pliocene). The Quaternary system comprises the Pleistocene and the Holocene (Recent) epochs. The rock formations in the Cenozoic era generally considered as "Younger Formations". The Cretaceous-Tertiary boundary is marked by the profuse basaltic Volcanism (Deccan Traps) and by the disappearance of great reptiles (Dinosaurs). During the Tertiary and Quaternary periods several changes in physiography, environment, fauna and flora occurred on a global scale. The Tethys ocean basin was the scene of an enormous accumulation of sediments. The mighty Himalayan range in the north was upheaved to its present position. The collision and coalescing of the India and Eurasian plates resulted in the triangular shape of the Indian peninsula. In the Himalayan belt, Tertiary rocks are characterized by an early marine facies and a later fluviatile facies.

The Quaternary system is important as the development of human species and their culture took place. The boundary between Tertiary (Neogene)-Quaternary is fixed at 1.6 million years. The characteristic feature of Pleistocene, the lower division of the Quaternary is the 198 glaciation and interglacial periods. In Kashmir, five periods of Glacial advances and four inter

glacial periods have been recognised and many mammalian fauna which were flourished, in the upper Tertiary period suddenly disappeared. The Kashmir and Narmada valley deposits recorded the first appearance of man by the second Inter-glacial period.

23.2 DISTRIBUTION OF YOUNGER FORMATIONS

The Tertiary Formations although covering large parts of the Extra-Peninsular region, are very poorly represented in the Peninsula. They are mainly found in the Baluchistan, Sind, Kashmir, Himachal Pradesh and along the Himalayan foot hill, Shillong-Mikir plateau in Assam and the shelf basins of Kutch-Saurashtra and western Rajasthan. Small patches of Tertiary sediments occur in the coastal regions of Kerala, Tamil Nadu, Andhra Pradesh and Orissa. The Quaternary deposits are well developed along the coast of Peninsular India, especially near the mouths of large rivers.

In Himalayan belt, the Tertiary rocks are exposed in two parallel belts, a northern belt of the Palaeogene rocks and a southern belt of Neogene rocks. The two belts are separated by the main boundary thrust.

23.3 HIMALAYAN PALAEOGENE SUCCESSION

The Palaeogene rocks of the Lesser Himalayas of Himachal Pradesh are referred to as Sirmur Group. They are exposed in a NW-SE trending belt bounded in the north by the Krol thrust and in the south by the main Boundary Fault. The succession comprising Subathu, Dagshai and Kasauli formations rest unconformably over the Simal Group of Late Precambrian age (Table 23.1). The Subathu formations have yielded definite marine fossils whereas, the overlying Dagshai and Kasauli formations contain an admixture of estuarine and fresh water sediments. The rock formation of the northwestern Himalaya that was correlated with the Dagshai and Kasauli formations has been grouped into the Daharmshala and Murree Groups.

Table 23.1 Classification of the Sirmur Group

Formation	Member / Lithology	Thickness (in m)
Kasauli (Upper Oligocene to Lower Miocene)	Massive Sandstone, subordinate shale	1250
Dagshai (Late Eocene to Oligocene)	Pabo : alternation of sandstone and clay Chimnum : red and purple clay stone with subordinate siltstone	1200 700
Subathu (Early to Middle Eocene)	B: red, green and indigo blue colour mudstone, shale, quartz, arenite A: green shale, foraminiferal limestone and oyster marls, quartz arenite, carbonaceous shale, calcareous sandstone	12-90 160
Unconformity		
Simlov Group		

23.4 HIMALAYAN NEOGENE SUCCESSION

The Neogene rocks of the Himalaya are developed in a long narrow depression in front of the rising mountains. This depression is a repository of thick sequence of molassic sediments of the Siwalik. The succession was named after the Siwalik hills near Haridwar in Uttar Pradesh. The rocks of this group is best exposed in the Tawi Valley of Jammu and Harthalyanagar area in Himachal Pradesh. The Siwalik sediments occur as an independent structural belt to overlie the Murree in Jammu sector of the Kashmir Himalaya and the Kasauli Group in the Himachal Himalaya.

The Siwalik Group is divisible into three sub-groups—lower, middle and upper (Table 23.2). The Siwalik Group consists essentially of sandstone, grits, conglomerates, claystone having the characters of fluvial deposits of torrential streams and floods in shallow fresh water basins. The lower part of Siwaliks contain fine to medium grained relatively matured sediments indicating a low relief for the Province. Graywackes indicating marine influence have also been reported from the lower part of the succession. The Siwalik deposits give evidence of warm humid climate throughout the greater part of the sedimentation. The upper Siwaliks again show the return of wet conditions. Towards the end of Tertiary times another uplift took place and the climate became distinctly colder, which caused maximum extinction of Siwalik fauna. The Siwalik formations have yielded a rich assemblage of Vertebrate fauna, Mollusca, Ostracodes, Charophytes, Spores, Pollens and plant remains.

Fauna of Siwaliks :

The fauna of Siwaliks is represented by Amphikyon, Dinotherium, Trilophodon, Diceratherium, Teleoceras, Balachitherium, Sivapithecus, Brahmapithecus, Surgivapithecus, Triphodon, Stegolophodon. The elephants are represented by Stegodon pentalophodon. A true one-toed horse, Eous sivalensis and the pigs and hippopotamus are also found.

Table 23.2 Classification of Siwalik Group

Sub-Group	Formation	Lithology	Thickness
Older Alluvium			
Gradational (Unconformity)			
Upper (Upper Pliocene to Lower Pliocene)	Boulder conglomerate	Coarse boulder conglomerate clays, sands grits	2300m
	Pinjor Tatrot	Conglomerates, sandstones, clays Sandstones, clays, conglomerates	
Unconformity			
Middle (Upper Miocene to Lower Pliocene)	Dhokpathan	Sandstones, shales, clays, pebbly at the top	1400 to 2000 m
	Nagri	Massive sandstone, shales, red clays	
Unconformity			
Lower (Middle Miocene)	Chinji	Nodular shale, clays, sandstones	1600m
	Kamlial	Dark hard sandstones, red and purple shales	
Unconformity			
Kasauli / Upper Murrees			

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. The boundary between Tertiary and Quaternary is fixed at million years.

2. The Paleogene rocks of the Lesser Himalaya of Himachal Pradesh are referred as

23.5 TERTIARY SUCCESSION OF ASSAM - ARKAN BASIN

The excellent development of Tertiary rocks is found in eastern and southeastern Assam and Arakan mountain belt and is given in Table 23.3. The thickness of individual stratigraphic units varies in different areas of the region. The formations with greater thickness are generally observed in Arakan basin.

Table 23.3 Tertiary Succession of Assam-Arkan basin

Age	Group	Formation	Lithology
Recent to Pliestocene	Sands, silts, clays and boulder beds of the alluvium		
Unconformity			
Plio-Pleistocene	Dihing	Dupitila (Upper Dhekiajuli)	Mottled sandstones and clays Soft sands and clays
Unconformity			
Mio-Pliocene	Dupitila (Lower)	Lower Dupitila sandstones, conglomerates and Namsang beds with variegated sandstones and clays	
Unconformity			
Miocene	Tipam (1200 to 3000m)	Girujan clays	Mottled clays and sandstones Massive sandstones with some clay bands and shales
		Tipam sandstones	Upper: sandstones with shales Middle : Primary Shales with sandstones
	Surma (4000 m)	Bhuban	Lower: sandstone with some shale, conglomerate
Unconformity			
Oligocene	Barail	Sandstone and shales	
Unconformity			
Upper Eocene	Renjis Jenams Laisangs	Primarily massive sandstone Shales with some sandstones, carbonaceous matter Bedded hard sandstones with shales	
Unconformity			
Palaeocene	Kopils/disangs		

23.6 TERTIARY ROCKS IN PENINSULA

23.6.1 Tertiaries of Saurashtra

The Tertiary formations of Gujarat are mainly developed in the Kutch and the Cambay basins. They are mainly marine and fluvio-marine deposits. The classification of Tertiaries in Saurashtra region is given in Table 23.4

Table 23.4 Tertiaries of Saurashtra

Geological Age	Formation	Member / Lithology
Upper Miocene to Pliocene	Dwaraka Formation	Laminated soft silt, limestone, laterites
	Piram beds	Conglomeate, Rich mammalian fossil Bones, sandstones, clays
Un conformity		
Lower Miocene	Gaj Formation	Kuda sandstone member
		Bhumbli conglomerate member
Unconformity		
		Ratanaput clay member
Unconformity		
Lower Eocene	Laterite rocks	
Upper Cretaceous	Deccan Trap Formation	

23.6.2 Quilon - Warakalli Formation

King (1882) divided the Tertiary rocks in the Quilon-Warakalli area in Kerala into Quilon and Warakalli beds. Later Paulose and Narayana swami have suggested classification as Quilon and Warakalli Formation. The Quilon Formation consists of fossiliferous limestones, sands and clays. The Quilon Formation is unconformably overlain by the rocks of the Warakalli Formation which occur as patches along the coast (Table 23.5).

Table 23.5 Tertiaries of Quilon and Warakalli

Formation	Lithology	Thickness in mm
Recent to sub recent	Soil and alluvium	
	Beach sand deposits	
	Lime shel deposits	
	Laterites	
Unconformity		
Warakalli formation (Mio-Pliocene)	Current bedded variegated sandstone interbedded with plastic clays, Carbonaceous and alum clays with gravel and pebble beds lignite seams	80
Unconformity		
Quilon Formation (Middle Miocene)	Fossiliferous shell limestone, alternating with thick beds of sandy clays calcareous clays and sandstone	70
Unconformity		
Archean Crystalline rocks		

23.6.3 Rajahmundry formation

The once called Rajahmundry sandstone is known as Rajahmundry Formation it consists of sandstone, clay and lignite of Mio-Pliocene age. It covers an area of 1100sq.km in the east and the west Godavari districts. The total thickness of Rajahmundry formation is about 600m. The lignite of this formation has characteristics similar to that of Neyveli. The stratigraphic succession of Rajahmundry formation is given in Table 23.6

Table 23.6 Rajahmundry Formation Succession

Geological Age	Formation	Member / Lithology
Recent to Pleistocene	Quaternary	Sandy Clay
Unconformity		
Miocene	Rajahmundry Formation	Upper : Variegated with interbands of white clay, sandstone, carbonaceous clay and lignite Lower : Sandstone, sand, clay / clayey sand
Unconformity		
Maastrichtian	Deccan Trap	Basaltic Flows

23.6.4 Cuddalore Sandstone formation

The Tertiary rock formation occur in South Arcot, Thanjavur and Ramanathpuram districts of Tamil nadu, and they are termed as Cuddalore Sandstone of Mio-Pliocene. The formation essentially consists of coarse to fine grained brown sandstones, associated with ferruginous and pebbly sandstones, clays and thin beds of limestone. In the Neyveli area, lignite occurring in Tertiary rocks, is economically significant. Near Tiruvakkarai (Villupuram district) petrified tree trunks are embedded in coarse, unsorted and pebbly sandstones of Mio-Pliocene age. The Karaikal beds (Eocene age) occur along the Pondicherry coast.

23.7 ECONOMIC IMPORTANCE OF TERTIARIES

The Lower Tertiary rocks known as Paleogene rocks of India constitute the chief source of Lignite and Oil and Natural gas. The Tertiary coal lignite occur in Kutch-Saurashtra areas in Gujarat, Neyveli in Tamil Nadu, Makum, Mikir hills and Dilli-Jaipur area in Assam, Maharastra, Jammu & Kashmir, Kerala and Meghalaya.

The Oil and Natural gas mainly occur in the Tertiary rocks of Cambay basin (mainly Middle Eocene), Bombay high along the west coast of Maharastra (Miocene limestone) and Nahorkatiya (Eocene), Digboi (Oligocene), the Brahmaputra Valley in Assam. The maximum concentration of Oil in Assam is confined to the contact between Barail and Surma formations. Strips of Tertiary rocks fringe the eastern coast and parts of western coast of India. The more promising of these seem to be Kaveri, Godavari, Krishna and Mahanandi deltas.

23.8 THE KAREWAS

The term 'Karewa' means terraces in the language of Kashmir. The formation consists of lacustrine and fluvial sediments intercalated with glacial sediments and have spread over

many parts of Kashmir. Lithologically the Karewas consists of blue, grey and buff coloured silts, sand, partly compacted conglomerates and varved clays of Plio-Pleistocene age. The Karewas have a maximum thickness of sediments of about 2000 meters. The succession of Karewas is given in Table 23.7.

Table 23.7 The Succession of Karewas

Member	Lithology
Upper	Erratics, sands, clays and varved clays containing remains of molluscs and some plants Second Glacial Sands, gravel, buff and blue clays and varved clays with leaf impressions of mainly subtropical plants and also shells first glacial
Unconformity	
Lower	Conglomerates and carbonaceous shales with lignite (Elephas, Rhinoceras etc.) Pre-glacial beds (Birds, fish, plants etc.)

The Indo-Gangetic Aluvium : The great alluvial track of the Ganges, Brahmaputra and the Indus are of the three main physiographic division separating the Peninsular region. The Pleistocene and Recent deposits covering the Indo-Gangetic basin are up to 1000 m thick. They are composed of gravels, sands and clays with remains of animals and plants. The Indo-Gangetic depression is believed to have been formed in the later stages of Himalayan orogeny when the Indian shield under thrust the Asian continent.

Laterites : It is most wide spread Pleistocene formation of the Peninsular India formed due to sub-aerial alteration. Laterite is a porous, pitted, clay-like rock with red, yellow, brown, grey and mottled colours. Laterite is often pisolitic, the pisolitic having a concentric structure and being cemented together by ferruginous or aluminous material. Laterite may be derived from a variety of rocks--basalts, gneissic rocks and sedimentary rocks including shale and impure limestones. The laterites are of high level and low level types. The high level laterites are found as capping hills and low level laterites are of secondary origin, derived from the high level laterite and recemented after deposition in the valleys or plains.

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 Neyveli lignite occurring in Tertiary rocks of

.....

.....

4. The Plio-Pleistocene formation of Kashmir

.....

.....

23.9 SUMMARY

The Cenozoic Era is divided into Tertiary and Quaternary periods. The Tertiary system further divided into Palaeogene (Paleocene, Eocene and Oligocene) and Neogene (Miocene and Pliocene) formations. The Quaternary system comprises the Pleistocene and Holocene (Recent) epochs. The boundary between Tertiary and Quaternary is fixed at 1.6 million years. The formations in Cenozoic era generally considered as Younger formations. During the Tertiary and Quaternary, several changes in physiography, environment, fauna and flora occurred on global scale. The Tertiary rocks are well preserved in Himalayan mountain belt, Assam and as patches in coastal regions of Peninsula. The Tertiary Palaeogene sediments of the Himalaya of Himachal Pradesh are referred to as Sirmur Group and the Neogene sediments as Siwalik Group. The Mammalian remains are the most important fossils in Siwalik strata. The age of Siwalik Group is considered to extend from Middle Miocene to Lower Pleistocene.

The Tertiary rocks occur as Patches in Coastal regions of Peninsula--Quilon-Warakalli Formations of Kerala, Rajahmundry formation of Andhra Pradesh, Cuddalore formations of Tamil Nadu and Karaikal beds of Pondicherry. Glacial or cold climate, development of human species, human culture are the distinguishing criteria indicating the beginning of Pleistocene. In Kashmir, five periods of glacial advances and four inter-glacial periods are recognised. Economically the Lower Tertiary rocks of India constitute the chief source of Lignite, Oil and Natural gas. The Quaternary formations are main sources of placer deposits. The Karewa formation occur in many parts of Kashmir and consists of blue-grey and buff coloured sand, conglomerate and moraines of Plio-Pleistocene age. The Indo-Gangetic alluvium has formed during the later stages of Himalayan Orogeny. Laterite is formed due to sub-aerial alteration during the Pleistocene period.

23.10 CHECK YOUR PROGRESS-MODEL ANSWERS

1. 1.6 million years
2. Sirmur Group
3. Cuddalore Sandstone
4. Karewas

23.11 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each

1. Give an account of Palaeogene Sediments of Himachal Pradesh.
2. Write an essay on Siwalik Group
3. Give the stratigraphic sequence of the Tertiaries of Assam.

II. Answer the following questions in about 10 lines of Assam.

1. The Karewas.
2. Quilon-Warakalli formation.
3. Rajahmundry formation.
4. Cuddalore Sandstone.
5. Economic importance of Tertiaries.

* * *

24.4 GEOLOGY

Andhra Pradesh forms an important segment of the Peninsular Shield of Indian Sub-continent. Geological formations from Archeans to Recent are present in the state and generalised Geological Succession for the state is given in Table 24.1.

24.4.1 Archeans

In Andhra Pradesh Archean rocks covered more than 65 per cent of the area. Archeans occur as linear schist belts of various sizes in gneissic terrain. The Archean rocks are Volcano-Sedimentary assemblages usually represented by high grade schists comprising garnet, staurolite, kyanite, sillimanite (rarely cordierite, sapphirine granulite enclaves in Karimnagar), mica schists, calc-silicate rocks, crystalline limestone, fuchsite-quartzite, banded hematite quartzites, metabasalts, amphibolites, mica-chlorite schists etc. The main schist belts in Andhra Pradesh are Karimnagar belt (in parts of Karimnagar, Adilabad, Warangal and Khammam districts), Veligallu Schist Belt (in parts of Anantapur, Chittoor and Cuddapah districts), Gadwal Schist Belt (in parts of Mahabubnagar and Kurnool districts), Kadiri Schist Belt (in parts of Anantapur and Chittoor district), Ramgiri-Penakacherla Schist Belt (mainly in Anantapur district), Jonnagiri Schist Belt (in parts of Anantapur and Kurnool districts), Peddavuru Schist Belt (in parts of Nalgonda and Guntur districts), Nellore-Khammam Schist Belt (in parts of Nellore and Khammam districts), Nellore Schist Belt (in parts of Nellore and Prakasam districts).

Table 24.1 Generalised Geological Succession : Andhra Pradesh

Geological Time	Group / Formation	
Recent to Mio-Pliocene	Soil, Beach Sands, Alluvium Cave deposits, Laterites, River terraces, Older Alluvium, Placers, Ash beds	
Mi-Pliocene	Rajahmundry formation	
Lower Eocene to Upper Cretaceous	Deccan Traps and Infra & Inter-trappeans	
Lower Cretaceous to Upper Carboniferous	<u>Gondwana Fluvialite</u> Upper Chikiala Formation Gangapur Formation Lower Kota Formation Maleri Formation	<u>Coastal Fluvio-Marine</u> Tirupati Formation Raghavapuram Formation Satyavedu Formation Kamthi Formation Baraker Formation
Upper Proterozoic to Middle Proterozoic	Kurnool Group Cuddapah Supergroup	Bhima Group Phakhals
Eparchaean Unconformity		
Middle Proterozoic to late Archean	Eastern Ghats	Charnockites Khondalites
Late Archean	Dharwar Supergroup	Pyroclastic rocks, Metabasalts, amphibolites, intrusive granites (Ramagiri, Kadiri, Gadwal, Nellore Schist Belts)
Middle Archean	Older supracrustals (Sargur Group ?)	High grade Schists, Migmatites, Kyanite, Silimanite, Cordierite, Mica Schists, Amphibolite, Anorthite-Ultramafic Complex Banded gneissic Complex

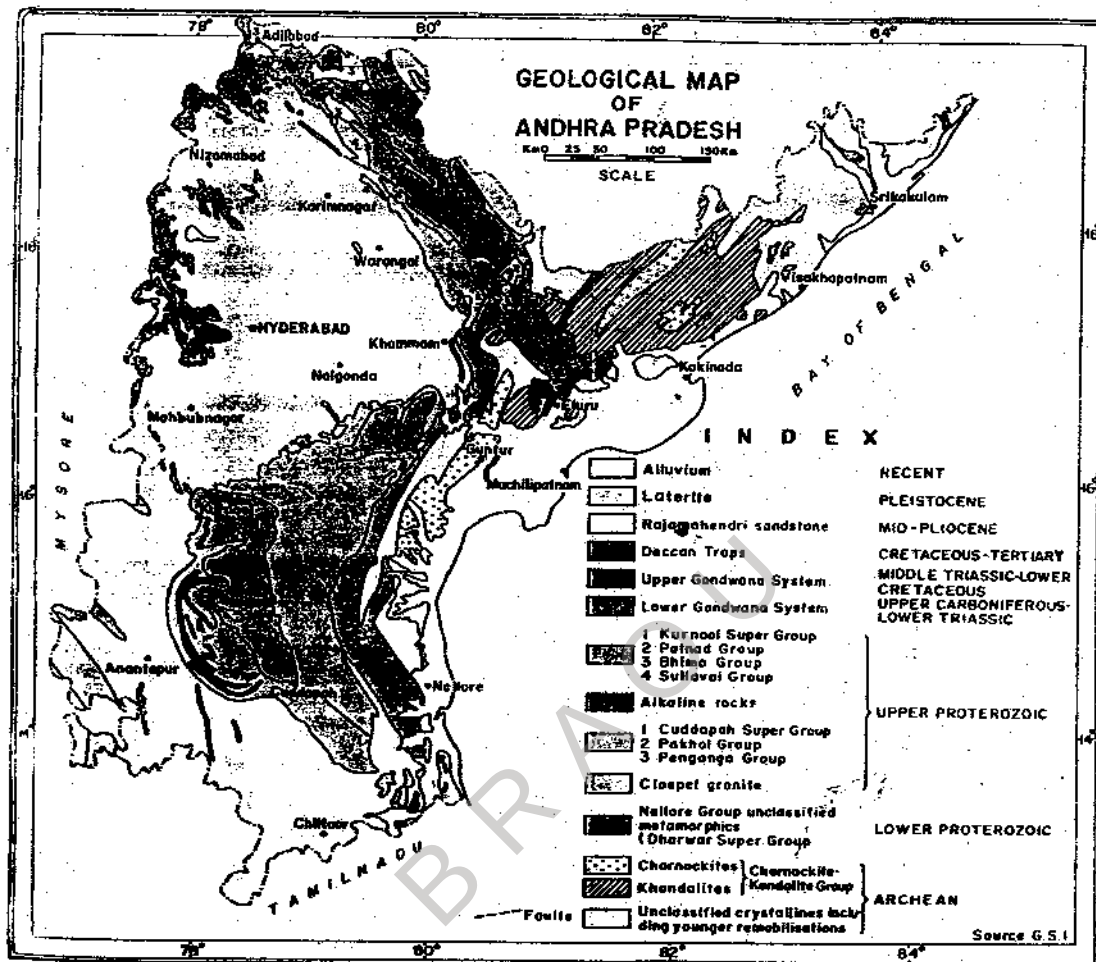


Fig. 24.1 Geological Map of Andhra Pradesh

The Eastern Ghats occur along the east coast of Andhra Pradesh and Orissa over a distance of 900 Kms. They are extending from south of Ongole to Brahmani river in Orissa. It is considered to be a classic example of a Precambrian Mobile Belt in the Peninsular Indian Shield. Recently it is also named as the Eastern Ghats Mobile Belt or Middle Proterozoic Mobile Belt. The Eastern Ghats encompass parts of Prakasam, Guntur, Krishna, East and West Godavari, Visakhapatnam, Vijayanagaram, Srikakulam and Khammam districts. The important rock types in Eastern Ghats are Khondalites, Charnockites, Calc-silicate rocks and Leptynites.

24.4.2 Cuddapah Supergroup

The Nallamalai, the Palkonda or Seshachalam hill ranges together with the plains in between are constituted mainly of Quartzites, Shales and Limestone belonging to Cuddapah Supergroup and Kurnool group of Middle Proterozoic age. They formed in the crescent shaped Cuddapah Basin in the south central part of the state, occupying an area of 44,500 sq.kms and are distributed in parts of Chittoor, Anantapur, Cuddapah, Kurnool, Mahabubnagar, Nalgonda, Guntur, Nellore, Prakasam, and Krishna districts. The Cuddapah formations are classified into four units—Papaghani, Chitravati, Nallamalai and Srisailem quartzites. Cuddapah Basin is a potential source for valuable non-metallic deposits like Asbestos, Barytes, Steatite and Limestone.

24.4.3 Kurnool Group

The Kurnool Group mainly consists of quartzites, sandstones, shales and limestones unconformably overlies the Cuddapah sediments in two sub-basins—Kurnool and Palnad. The Kurnool sub-basin in the Kundair valley encompasses parts of Kurnool, Cuddapah Basin covers the parts of Nalgonda, Krishna and Guntur districts. The Limestones of Kurnool and Palnad sub-basins in Cuddapah Basin are the most important sources for cement industry.

24.4.3 Pakhals

Rocks exposed in NW-SE direction along the Pranhita-Godavari Valley in Andhra Pradesh are referred as Pakhals. The Pakhals are unconformably overlain by the rocks of the Penganga Group and Sullavai Sandstone. They form a part of the western belt of the Pakhal with the impact of the Eastern Ghats orogeny. The Putnur limestone formation in Pakhal Basin exposed in Adilabad district is a good source for the cement grade limestone and manganese.

24.4.5 Bhima Group

The main Bhima Group is exposed in Gulbarga and Bijapur districts of Karnataka while only the small eastern part of the basin extends into Ranga Reddy district of Andhra Pradesh. The lower Rabanapalli formation of the Bhima Group consists of basal conglomerate followed by purple shale and sandstone unconformably on the Archean basement exposed over a small area in the state. The Rabanapalli formation is transitionally overlying by the Sahabad formation. It mainly consists of dark gray to bluish gray massive limestone, flaggy limestone and silicious cherty limestone. Some of the limestone is of cement grade while the rest is used for flooring purpose. The Bhima Group sediments are mostly horizontal beds, occasionally having gentle dips due to faults. The features such as lithology, horizontal deposition and unmetamorphosed nature of the Bhima Group are made to consider equivalent to the Kurnool Group.

24.4.6 Kimberlites, Alkaline Rocks and Carbonatites

The diamond bearing Kimberlite pipes occur in Wajrakarur area of Anantapur district, Jonnagiri in Kurnool district and Maddur in Mahabubnagar district.

Alkaline rocks, Anorthosites occur from Kanigiri to Elchuru in Prakasam district. Other minor occurrences are at Giddalurru, Idamakallu, Racherla in Prakasam district and Gundlapalle in Kurnool district.

Carbonatites are reported near Vinjamuru in Nellore district, Elchuru in Prakasam district, Nandipadu and Budamadugu in Khammam district.

24.4.7 Gondwanas

The Lower Gondwana constituting thick sequence of sandstones and shales associated with coal beds occur along the western margin of the Pranhita-Godavari basin. The basin extends into parts of Adilabad, Karimnagar, Warangal and West-Godavari districts.

The Upper Gondwana constituting thick sequence of sandstones and shales associated with coal beds occur along the western margin of the Pranhita-Godavari basin. The basin extends into parts of Adilabad, Karimnagar, Warangal and West-Godavari districts.

The Upper Gondwana marine and fluvio-marine facies rocks occur along the east coast of the state. the oldest fossil bird comparable to Archaeopteryx was reported from the Kota formation at Mukalpet.

24.4.8 Deccan Traps

The northern and northwestern part of the state covered by the Deccan Traps. They spread over 10,000 sq.km. in parts of Adilabad, Nizamabad, Medak, Mahabubnagar and Rangareddy districts. Infra and Inter-trappean beds are noticed in the East and West Godavari districts and also in Adilabad, Nizamabad and Rangareddy districts. Marine fossils such as Turitella, Cardita baumonti, Rostellaria etc are recovered from the infra-trappean of the state.

24.4.9 Rajahmundry Formation

The once-called Rajahmundry Sandstone is now known as Rajahmundry Formation. It consists of sandstones, clay and lignite of Mio-pliocene age and covers an area of 1100sq.km. in the East and West Godavari districts. The Rajahmundry Formation is divided into two members. The lower member consisting of sandstones, sand and clay/clayey sand rests on Deccan traps the upper most member consists of sandstones, white clay, carbonaceous clay and lignite. The Lignite of this formation has characteristics similar to that of Neyveli.

24.4.10 Quaternary Deposits

The quaternary deposits are well-developed along the east-coast of Andhra Pradesh especially near the mouth of rivers. The sediments are mainly black sands with ilmenite, magnetite, garnet, tourmaline, rutile, zircon and monazite as heavy mineral concentration along the beach and in river beds of Srikakulam, Vishakapatnam, Godavari and Krishna districts. Palaeochannels of Chitravathi and Pennar rivers in Cuddapah, Kurnool and Anantapur districts are found to be a source for alluvial diamond and gold. Recently the Geological Survey of India has brought to light the volcanic ash beds along river valleys in Srikakulam, Vishakapatnam, East Godavari, Kurnool and Nellore districts.

24.5 MINERAL RESOURCES

Andhra Pradesh is endowed with rich mineral deposits, important of which are asbestos, barytes, mica, copper, lead ores and magnese and less important ones are apatite, clays, coal, corundum, diamond, feldspar, ochres, quartz, steatite, bauxite, etc. These deposits can broadly classified into as Non-metallic, Metallic and Fuel deposits.

24.5.1 Non-Metallic Depoists

Asbestos

In Andhra Pradesh commercially valuable Crysoile variety of asbestos occur in Cuddapah district. It is noticed between Vempalle dolomitic limestone and sill. Asbestos mineralisation is generally confined to a serpentinsed zone noticed along the upper contact of a dolerite sill. It is a 20 km long belt between Brahmanapalli and Parnapalle through Ippatla, Cinnakudala Ramanutalapalle, Lingala, Velichinda. Andhra Pradesh has an in-situ reserve of 0.2 million tonnes. Crysoile asbestos recoverable reserve is nearly 0.1 million tonnes.

Barytes

Andhra Pradesh accounts for 96 per cent of Baryte deposits of the country while the smaller deposits are found in Rajasthan, Himachal Pradesh, Madhya Pradesh and Bihar. Barytes occur as veins in different lithologies, mainly in Cuddapah, Kurnool, Anantapur, Khammam, Mahabubnagar and Prakasam districts of the state. The in-situ reserve of Barytes, in A.P. is estimated at 78.8 million tonnes. Bulk of this reserve is present in the Mangampeta, Kodur Mandalam of Cuddapah district. It is the single largest depoist in the world with an estimated in-situ reserve of 74 million tonnes.

Mica

The Nellore Mica Belt is the most important mica producing area in Andhra Pradesh. The belt covering the Gudur, Bapur, Atmakur and Kavali area is about 90 kms long and 16 km wide. The country rocks in mica belt are garnetiferous mica schists, garnetiferous hornblende schists, chlorite schists of Dharwar Supergroup intruded by pegmatites and quartz veins. The mica occurs as books ranging in size from 15 to 90 cm across. The common Nellore mica is muscovite with occasionally presence of ruby-mica and phlogopite.

Steatite

Steatite is a massive rock of Talc. It is mined in Pendekal and Bethamcherla area of Kurnool district, Muchukota area of Anantapur district and Pulivendla area of Cuddapah district. The total reserve in Andhra Pradesh is about 2.1 million tones the main contribution being from Anantapur, Chittoor, Cuddapah, Kurnool, Nellore and Khammam districts.

Clays Deposits of clay are found in many localities of the Andhra Pradesh in formations of diverse geological ages. Clays are essentially of two types.. They are (i) Sedimentary and (ii) Residual deposits. The Sedimentary clay deposits associated with shales and sandstones of Gondwana Supergroup are present in Adilabad, Srikakulam, East and West Godavari districts. High grade China clay (Kaoline) occurs near Chintrala in Nalgonda district and Prabhagiriapatnam of Nellore district. The Residual type clay deposits occur in the altered Kurnool/Cuddapah formations. The Owk shale is altered to give rise to clays in Kurnool district and granites to clays in Mahabubnagar district. Clay also occurs in Deccan traps and is noticed in several localities of Rangareddy district.

Limestones

Andhra Pradesh has an estimated reserve of 18,580 million tonnes of limestone, of which 14,295 million tonnes is taken as a recoverable reserve. Bulk of the State's limestone resources are associated with the Cuddapah, Kurnool, Pakhal, Sullavai and Bhima group of rocks, and only minor occurrences are found in the Dharwars and Gondwanas. Massive of flaggy limestone mostly of cement grade belong to the Narji formation of Kurnool Group in Cuddapah, Kurnool, Guntur and Krishna districts.

Ochres

Ochres are naturally occurring mineral pigments of various colours like yellow, red, brown etc. In Andhra Pradesh red ochre occurs associated with ferruginous shales of Dharwar Supergroup in Anantapur district and in Vempalle and Pulivendla formations of Cuddapah Supergroup in Cuddapah district. Yellow ochre occurs in the East Godavari, Guntur, Kurnool, Rangareddy and Vishakapatnam districts.

24.5.2 Metallic Deposits

Bauxite

The Bauxite deposits occur as caps on Khondalites and Charnockite group of rocks of the Eastern Ghats in Andhra Pradesh. Bauxite is mainly confined to the East Godavari Visakhapatnam and Vizainagaram districts. The total reserve available in Andhra Pradesh is 657 million tonnes, and this accounts for 19.5 per cent of the country's bauxite reserves.

Copper

Copper and lead deposits occur at Angnigundala in Guntur district and at Mailaram in Khammam district of the state. Copper mineralisation in Mailaram area is associated with the quartz-chlorite schist of Archean age. In Angnigundala copper and lead deposits are associated with phyllites and shales of Nallimalai group of Cuddapah Supergroup. There are three deposits around Bandlamottu, Nallakonda and Dhukonda. The Copper deposits are confined to clacareous quartzites while the Lead deposits to dolomites. Other occurrences in the state are Gani-Kalva area of Kurnool district and Gariminipenta of Nellore district.

Gold

In Andhra Pradesh, the only working mine for gold is the Ramagiri Gold Field, located within the Penukonda-Pamidi schist belt in Anantapur district. The host rocks are massive amphibolites, Sericite-chlorite, phyllite quartz-sericite schist and ferruginous quartzites. In Chigargunta area of Chittoor district, which is a part of south Kolar schist belt, some economically significant deposits are found along a strike length of 3 km. The host rocks are metamorphosed basalt and acid tuffs. Recently the newly located schist belts for gold are Jonnagiri schist belt in Kurnool district, Gadwal schist belt in Mahabubnagar and Kurnool district, Avulathippanapalle area in Chittoor district and Veligallu schist belt in Anantapur, Chittoor and Cuddapah districts.

Manganese

In Andhra Pradesh the Manganese ore deposits are associated with Khondalite group in Vizaynagaram and Srikakulam districts. Kodur Devada, Garividi and Garbam areas are the chief producing centres. The important other occurrences are Penganga formation in Adilabad district and Cumbum shales in Prakasam district.

24.5.3 Fuel Deposits

Coal

In Andhra Pradesh, coal bearing Gondwana rocks occur in parts of the Adilabad, Karimnagar, Khammam, Warangal and West Godavari districts. The Coal measures from a part of the Pranhita-Godavari Gondwana belt. The coal mining is confined to Singareni, Kothagudem, Tanduru in Adilabad district (North Godavari area) and Karimnagar district (South Godavari area). In Andhra Pradesh the insitu estimated reserve of coal is 10,771 million tonnes and this accounts for 5.5% of the country's coal reserves.

Oil and Natural gas

Krishna-Godavari basin is a significant for oil and natural gas in Andhra Pradesh. The basin about 15000 sq.kms. of on-land and about 25000 sq.kms of adjoining off-shore. The West and Northwest side of the basin is covered by the Eastern Ghats and the east side by Bay of Bengal. The thickness of sediments varies from 3 km (in Krishna basin) to 7 km (in Godavari basin). Seismic survey followed by exploratory drilling carried-out by ONGC in both on shore and off shore areas in the basin has shown encouraging results for further follow-up. A number of hydrocarbons have been identified in the basin in the sediments of Eocene and Mio-pliocene age. On shore exploratory wells have been tested for oil and gas at Lingaboyinapalli, Cherla, Ravva and Yenuguvarilanka near Narasapuram, West Godavari district and Kunavarm, Bhimanapalli near Amalapuram and Razole in East Godavari district with encouraging results.

Uranium deposits

Uranium is used in the nuclear power generation as an atomic fuel. Uranium mineralisation has been reported from Vempalle dolomite and Pulivendal conglomerate/quartzite of Cuddapah basin. It is reported in Tummalapalle, Rachakuntapalle and Gadankipalle in Cuddapah district.

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. Enlist the different geological formations of Andhra Pradesh.

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4. What is the source rock for Diamonds?

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24.6 SUMMARY

Andhra Pradesh state is a part of the Peninsular India and physiographically divided into Coastal plains, Eastern Ghats, Interior Uplands and North-Western Plateau. The important hill ranges in the state are Eastern Ghats, Nallamala, Lankamalla and Palkonda or Seshachalam. The important rivers are Godavari, Krishna, Pennar and Thuganbadra covering most of the state. Geological formations from Archeans to Recent are present in the state. Archean rocks covering more than 65% of the state occur as linear schist belts consisting of volcano-sedimentary assemblages. the Eastern Ghats are confined to the East Coast of the state and mostly constituted by Khondalite and Charnockite group of rocks.

The crescent shaped cuddapah basin in the south-central part of the state, covers an area of 44,500 sq. kms. in parts of Chittoor, Anantapur, Cuddapah, Kurnool, Mahabubnagar, Nalgonda, Guntur, Prakasam, Nellore and Krishna districts. The Kurnool Group sediments unconformably overlie the cuddapah sediments in two sub-basins--Kurnool and Palnad. The Pakhals and Bhima group rocks are mainly exposed along NW-SE direction of Pranhita-Godavari valley and in Rangareddy districts respectively. The diamond-bearing kimberlites are found in the western part of the Cuddapah Basin at Wajrakarur in Anantapur district. Alkaline rocks and carbonatites mainly noticed in Prakasam district. The Lower Gondawana sediments with coal beds occur along the western margin of the Godavari basin while the upper Gondwana facies rocks occur along the east coast of the state. Deccan traps and inter and infra-trappeans are exposed in the northern and northwestern part of the state. The Quaternary deposits are well developed along the east coast especially near the mouth of rivers. Andhra Pradesh is endowed with a rich mineral deposits, important of which are asbestos, barytes, mica, copper, lead ores, bauxite, clays, petroleum etc.

24.7 CHECK YOUR PROGRESS-MODEL ANSWERS

1. Eastern Ghats, Nallamalai, Seshachalam, and Palkonda.
2. Godavari, Krishna, Pennar, Tungabhadra.
3. Archeans, Cuddapahs, Kurnools, Pakhals, Bhimas, Godawanas, Deccan traps and Quaternary.
4. Kimberlite.

24.8 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each

1. Describe the geological formations of Andhra Pradesh
2. Explain the mineral resources of Andhra Pradesh
3. Give an account of physiography of Andhra Pradesh

II Answer the following questions in about 10 lines each

1. Mention the important mountain ranges and rivers of the Andhra Pradesh
2. Describe the distribution of Archean rocks in Andhra Pradesh
3. Describe in detail the Baryte deposits of Andhra Pradesh.

* * *

SYLLABUS

BLOCK - I : STRUCTURAL GEOLOGY - FUNDAMENTALS

- Unit - 1 : Structural Geology - An Introduction
- Unit - 2 : Mechanical Principles
- Unit - 3 : Field Procedures
- Unit - 4 : Primary Structures

BLOCK - II : STRUCTURES

- Unit - 5 : Unconformities
- Unit - 6 : Joints
- Unit - 7 : Folds
- Unit - 8 : Faults

BLOCK - III : ECONOMIC GEOLOGY - ORE FORMATIONS

- Unit - 9 : Scope of Economic geology
- Unit - 10 : Igneous Processes
- Unit - 11 : Secondary Processes
- Unit - 12 : Organic and Metamorphic processes

BLOCK - IV : DESCRIPTION OF MINERAL DEPOSITS

- Unit - 13 : Ferrous and Ferroalloy minerals
- Unit - 14 : Non-Ferrous Minerals
- Unit - 15 : Non-Metallic minerals
- Unit - 16 : Fuels and Radio active minerals

BLOCK - V : INDIAN GEOLOGY - I

- Unit - 17 : Principles of Stratigraphy and Correlation
- Unit - 18 : Physical And Stratigraphic divisions of India
- Unit - 19 : Archean group
- Unit - 20 : Cuddapah and Vindhyan groups

BLOCK - VI : INDIAN GEOLOGY - II

- Unit - 21 : The Gondwana group
- Unit - 22 : The Deccan Traps
- Unit - 23 : The Younger Formations
- Unit - 24 : Geology of Andhra Pradesh

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FACULTY OF SCIENCE
THIRD YEAR (3 YEAR DEGREE COURSE) EXAMINATION

ASSIGNMENT - 1

GEOLOGY COURSE - III

Structural Geology, Economic Geology And Indian Geology

I. Answer the following questions in about 30 lines each

1. What is a Fault. Explain various types of faults.
2. What is unconformity. How do you recognise these in the field.
3. What are the three stages of deformation? Explain

II. Answer the following questions in about 10 lines each.

1. Explain the terms Strike and Dip
2. What are Joints?
3. What are anticline and syncline?

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2

BRAOU

FACULTY OF SCIENCE
THIRD YEAR (3 YEAR DEGREE COURSE) EXAMINATION

ASSIGNMENT - 2

GEOLOGY COURSE - III

Structural Geology, Economic Geology And Indian Geology

I. Answer the following questions in about 30 lines each.

1. What is economic Geology? How this knowledge is useful to the society?
2. Explain the processes of magmatic concentration.
3. Explain the ores used in the refractories and ceramics.

II. Answer the following questions in about 10 lines each.

1. What are ore minerals?
2. Explain Pegmatitic deposits.
3. What are the various types of coal?

BRAOU

BRAOU

FACULTY OF SCIENCE
THIRD YEAR (3 YEAR DEGREE COURSE) EXAMINATION
MODEL QUESTION PAPER
GEOLOGY
COURSE - III

Structural Geology, Economic Geology And Indian Geology

Time : 3 Hours

Max. Marks : 70

Section : A

Note : **A) Answer any three questions in about 30 lines each.**
 B) Each question carries 15 marks.

- 1) What is structural geology? Explain the scope and uses.
- 2) What is Fold? Explain various types.
- 3) Describe in detail about hydrothermal processes of ore formation.
- 4) Discuss about Iron Ores, Processes of formation and distribution in India.
- 5) Discuss about geological time scale.
- 6) Explain the gondwana system.

Section : B

Note : **A) Answer any five questions in about 10 lines each.**
 B) Each question carries 5 marks.

- 7) Describe the primary structures.
- 8) What is Unconformity?
- 9) Explain about Faults.
- 10) What is ore? Explain.
- 11) Explain the processes of sublimation.
- 12) Discuss about placer deposits.
- 13) Explain the distribution of chromite deposits in India.
- 14) Describe the Himalaya Mountains.
- 15) Explain the economic importance of Cuddapah system.
- 16) Describe the Archaean rocks of Andhra Pradesh.

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TABLE 21.1 CLASSIFICATION OF GONDWANAS

Geological Time		Group	Formation	East Coast Formations
Period	Division			
Cretaceous	Lower	Jabalpur	Umia	Tirupati-Pavalur-Satyavedu
Jurassic	Upper		Jabalpur	
Jurassic	Middle	Rajmahal	Kota	Raghavapuram - Vemavaram-
	Lower		Rajmahal	Sriperambadur
Triassic	Rahetic	Mahadeva	Maleri	Gollapalli - Budavada
	Keuper		Pachmarhi	
	Muschelkalk	Disconformity		Disconformity
	Bunter	Panchet	Panchet	Chintalapudi Sandstones
Permian	Upper	Damodar	Raniganj	
	Middle		Barren measures	
	Lower		Barakar, Karharbari	
Carboniferous	Upper	Talchir	Rikba	
			Talchir	
			Boulder bed	

The Talchir beds are found in most of the Lower Gondwana areas of the Peninsula in the faulted troughs or grabens. The Lower most member is a tillite or boulder bed, which succeeded by shales and sandstones. The boulder bed consists of an unsorted mixture of boulders, pebbles, rock fragments and clay, the boulders often showing facets and striae of glacial origin. *Glossopteris Indica*, *Gangamopteris* and *Noeggerathiopsis* are important fossils found in Talchir shales.

Marine Intercalations : Umria marine bed in Madhya Pradesh is characteristic of highly fossiliferous marine shelly limestone bed containing fossils of *Productus*, *Spiriferina*, *Reticularia* and others. It occurs in between Talchir and Barakar Formations. The marine bed within the lower Gondwana sediments indicates that the phase of the Tethys sea had transgressed over the Peninsula. The fossils are remnants of marine fauna, whose habitat was gradually becoming the fresh water by inundation from the rivers flowing into this arm of the sea from the surrounding land.

The Damuda Group comprises Karharbari, Barakar, Barren measures and Raniganj formations. Karharbari consists of pebbly grits and sandstones and has the fossils *Gangamopteris buriadica*, *Schizoneura octocaria*, *Glossopteris indica*, *Gangamopteris cyclopteroids*, *Noeggerathiopsis hislopi*.

Barakar are mostly white to fawn coloured sandstones and grits with occasional conglomerates and beds of shale associated with coal seams. The sandstones contain more or less decomposed feldspars. The flora include *Glossopteris*, *Vertebraria* and *Schizoneura*. Barren measures are entirely devoid of coal seams and consists mostly of sandstones characterised by clay, ironstone nodules having 35-40% iron. Raniganj formation consist of fine sandstones, shales and coal seams. The typical fossils are *Schizoneura*, *Gondwanensis*, *Phyllothea indica*, *Glossopteris india*, *Gangamopteris wittiana* and *Vertebraria indica*. Fossil wood (*Dadoxylon*) is found in the upper part of the formations.

The Panchet Group consists of Panchet Formation named after Panchet hill in the Raniganj Coal Field. The formation comprises a succession of coarse grained feldspathic sandstones, thin beds of green shales and variegated clay beds. The Panchet Formation comprises red bed facies of fluvioatile origin. The formation has yielded a rich assemblages of flora, vertebrates and fresh water invertebrates. The flora includes *Glossopteris pectopteris*, *Thinnfeldia*, *Cyclopteris*, *Pachyhacis* etc. The Panchet Formation is often overlain by the Mahadeva Group.

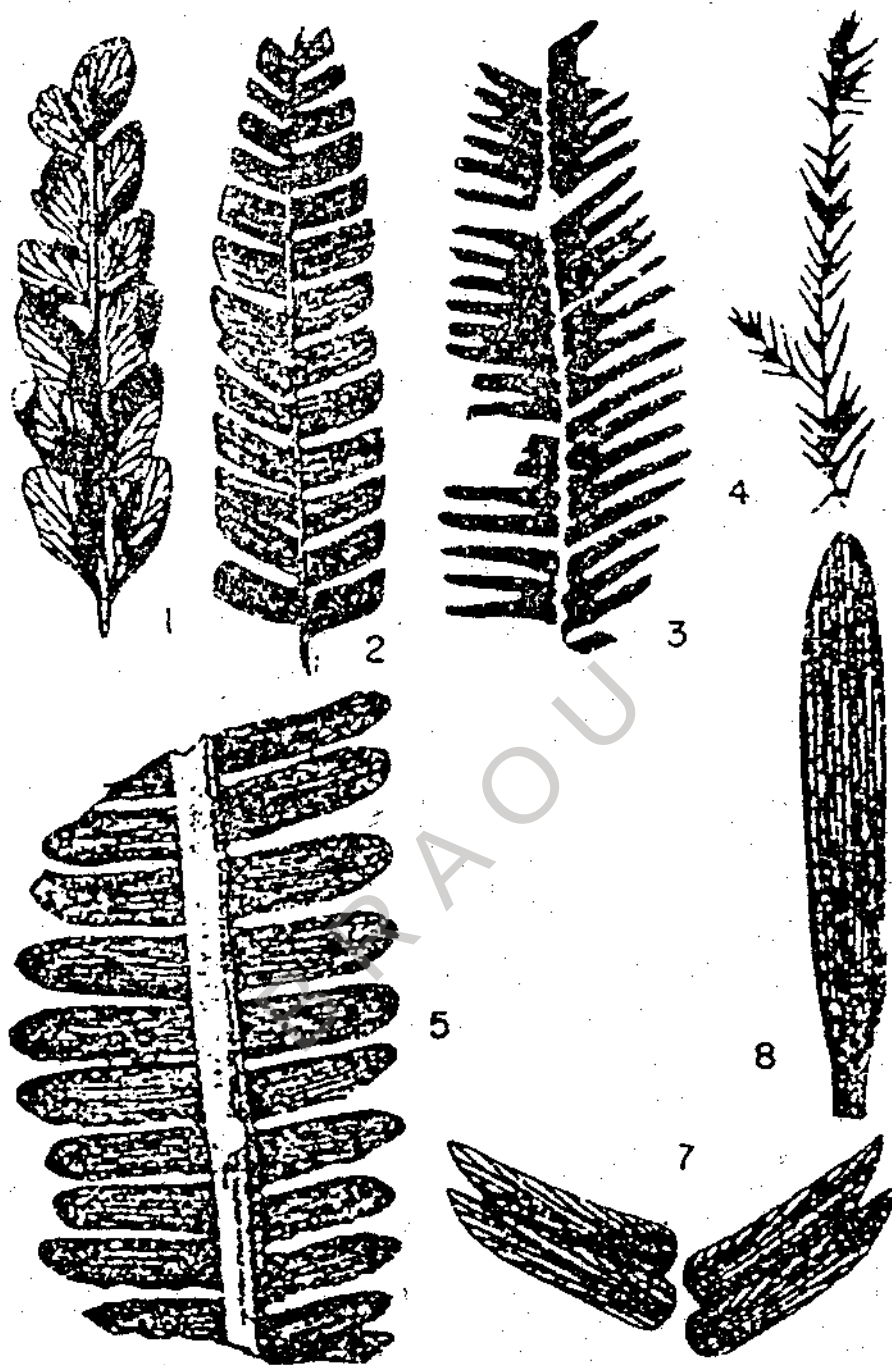


Fig. 21.2 Gondwana Flora

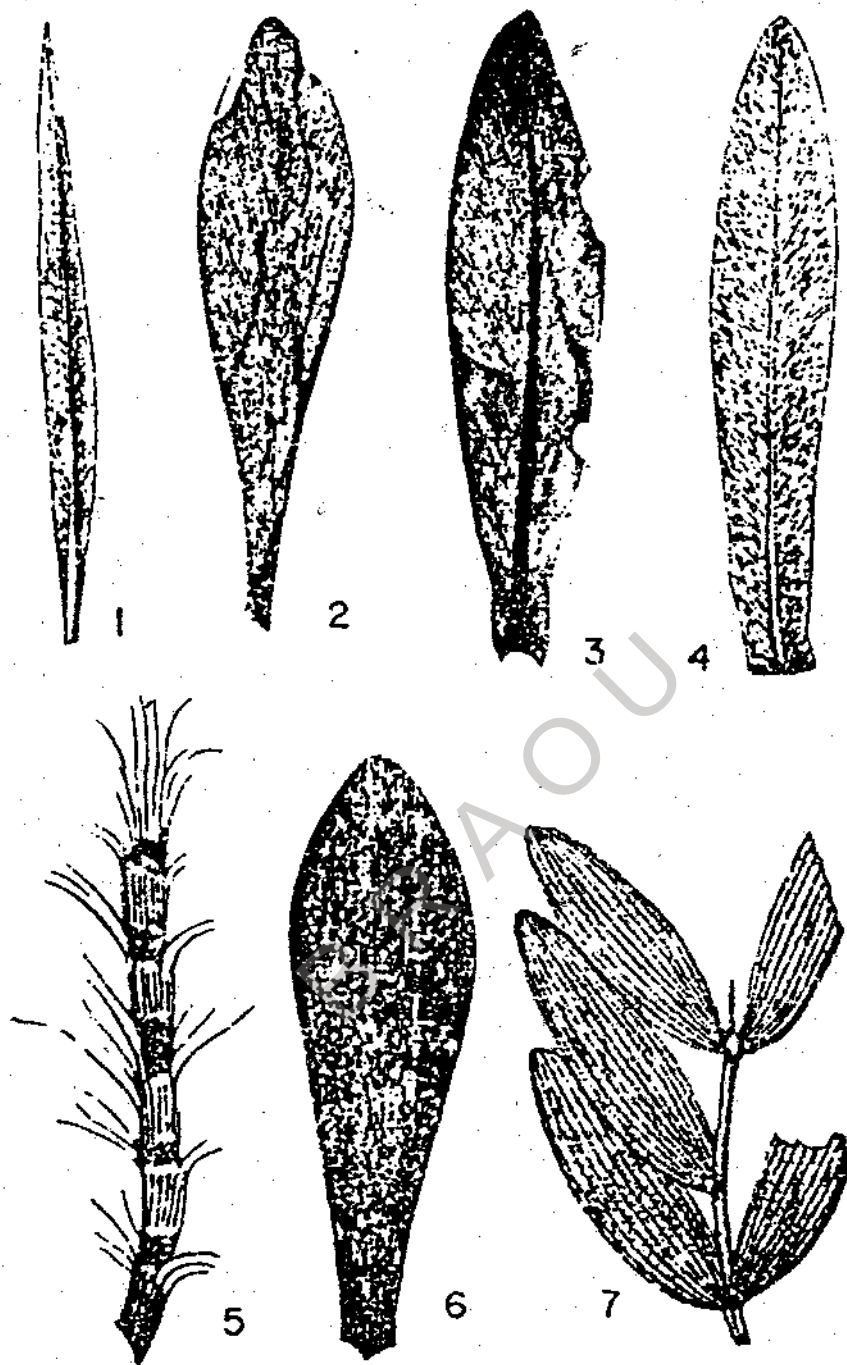


Fig. 21.3 Gondwana Flora

The Mahadeva Group consists of red and buff coloured sandstones with some red clays near the base and also on top. Fishes, Amphibians and Reptiles are found in the clay beds.

The Rajmahal Group consists of 450-650 m of basaltic lava flows with intercalated carbonaceous shales and clays. The inter-trappean sediments contain plant remains, fossil wood and flora. *Ptilophyllum acutifolium* have gained importance.

The Jabalpur Group is divided into lower Jabalpur and upper Umia formations. They consist of white and light coloured clays and massive soft sandstones. *Ptilophyllum acutifolium*, *Otozamites* sp. *Williamsonia indica* are important fossils found in Jabalpur Group.

The Upper Gondwanas of Godavari district in Andhra Pradesh are familiar and rest unconformably upon the Chintalapudi (Kamthi) sandstones. The Chintalapudi sandstone lie directly over the Archean gneisses and high grade metamorphic rocks of the Eastern Ghats Mobile Belt. Gollapalli sandstones, Raghavapuram shales and Tirupati sandstones overlying the Chintalapudi sandstone contain *Ptillophyllum acutifolium* and *Talniopterisensis*, assigning them to Upper Gondwanas.

These form the main coastal, Upper Gondwana sequence of the Godavari basin. Recently this succession was revised on the basis of lithology and fossil assemblage into the lower Raghavapuram Formation and the upper Tirupati Formation. These are overlaid by Rajahmundry sandstone of Tertiary age. The well known ball clays of Dwaraka-Tirumala are hosted by the Raghavapuram Formation. The coastal Gondwana of Krishna basin comprises the Budavada sandstones, Vemavaram shales, Pavalur sandstones, in the Guntur (Chebrolu area) and Prakasam (Uppuguduru area) districts. They are referred to as the Upper Gondwanas and correlated with the Godavari basin. Satyavedu and Sriperumbudur Formations of Upper Gondwanas in Chittoor district are considered homotaxial with Vemavaram (Krishna basin) and Raghavapuram (Godavari basin) formations.

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. The name Gondwana was introduced by

.....

.....

.....

.....

2. Lower Gondwanas are characterised by the flora and Upper Gondwanas are characterised by the flora

.....

.....

.....

.....

21.4 STRUCTURE AND IGNEOUS ACTIVITY IN GONDWANAS

Structure

The Gondwana rocks are confined to the tectonic trough with faulted boundaries as grabens of halfgraben structures arranged along linear zones. The faults run E-W and the strata dip generally towards the more faulted southern boundary in the Koel-Damodar and Satpura basins. In Pranhita Godavari and Sone-Mahanadi basins the trend of the faults is NW-SE and N-S in Rajmahal basin. Most of Gondwana basins in the Peninsula are free from folding and where present they are confined to the more pronounced faulted margins of the troughs. In the Himalayas the Gondwanas were highly affected by the Tertiary mountain building movements and coal seams subjected to crushing and devolatilisation.

Igneous Activity

Igneous activity is observed in some parts of Gondwana basins in the form volcanic flows, sills and dykes and mainly comprising mica-peridotite, lamprophyres and basalts. Basaltic flows, dolerite sills and dykes occur in Rajmahal hills, Garo hills of Assam, some parts of Damodar basin and in Satpura and Chattishgarh regions of Madhya Pradesh. Mica-peridotites and lamprophyres are confined to eastern part of Damodar basin and Darjeeling areas. The igneous activity is absent in Mahanadi basin, South Chattishgarh regions, Wardha-Godavari basin and coastal regions. Among these dykes, some are affected by subsequent faulting indicating that they are prior to faulting and some are passed through the fault zones indicating that, they are later to the faulting. The sills and dykes are related to Deccan volcanism.

21.5 CLIMATE AND SEDIMENTATION

The Gondwana period was initiated by the glacial climate during which a vast continental ice sheet covered a large part of the Gondwana land. Glaciers appear to have flowed out from Rajasthan and Madhya Pradesh as well as the Eastern Ghat areas. The most prominent centre of glaciation was the southeastern flank of present Godavari valley from where ice moved in north and northwesterly directions.

The climate gradually warmed during the period when fluvio-glacial sediments and varved clays were deposited. This is evidenced from the presence of the Talchir boulder bed of tillite at the base of the Gondwana sequence. In Damodar period the climate was definitely warmer and more humid and permitted the growth of luxuriant vegetation. An enormous amount of vegetation was carried by streams into the swamps and lake basins to form the coal beds. The nature of the flora as well as the presence of undecomposed feldspars in the sediments indicate that the climate was cold temperate. The upper part of Damodar period has experienced a somewhat drier climate as evidenced by the presence of reddish ferruginous sandstones. The presence of Labrinthodonts in the Panchet formation indicates a period of gradual drying up of the sedimentary basins. The Mahadeva Group consists of ferruginous sandstones of Triassic age and definitely sediments of an arid climate. During the Rajmahal time the climate has changed to humid temperature conditions and permitted the growth of vegetation. The Earth crust seems to have experienced tension in Gondwana land and resulted in the out pouring of lavas and volcanic material during the Rajmahal times. Recently, Casshyap (1977) divided the Gondwana strata into three distinct assemblages -- glacial at the base (Permo-Carboniferous) overlain by prolonged sequence of continental fluvial deposits (Permian to Jurassic) and perialic to marine deposits of Lower Cretaceous age. Gondwana rocks are predominately sandstones with bands of conglomerate and intercalated shales, and the frequent presence of current bedding indicates to a fluvial (fresh water) origin.

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 Gondwana Super group is classified into.....groups

.....

.....

.....

.....

21.6 ECONOMIC IMPORTANCE

The clay deposits associated with coal seams are worked for the manufacture of refractory bricks. The Barakar, Raniganj, Kamthi and Pachmari sandstones are used locally as building stones. The beds of sideritic iron are in ironstone shales of Raniganj are used to extract iron. Most of the coals in the Gondwanas are found in the Damodar Group except in Barren measures. The coal reserves in India are estimated to be about two lakh million tonnes.

21.7 SUMMARY

The Gondwanas were first studied and thus named by Madlicott (1872) which are later designated as the Gondwana Supergroup. The Gondwana sediments from huge thickness of sedimentary strata comprising conglomerates, sandstones, shales and coal bearing strata, and are deposited in narrow, linear, gradually sinking garben like troughs. The Gondwana Supergroup mainly confined to river basins -- Sone-Mahanadi, Pranrita-Godavari, Koel-Damodar, Satpura and Rajmahal. The Gondwana Supergroup is divided into two major divisions, Lower and Upper, based on the evidence of flora *Glossopteris* and *Ptilophyllum*. The Gondwana Supergroup divided into Talchir, Damodar, Panchet, Mahadeva, Rajamahar and Jabalpur Groups. The Damodar Group is important for the coal bearing horizons.

Igneous activity is observed in some parts of Gondwana basins represented by mica-periodotite, lamprophyres and basaltic flows. The Gondwana period was initiated by glacial climate, which is evidenced from the presence of Talchir boulder bed or tillite. During Damodar and Rajamahar times, the climate was warmer and more humid permitting the growth of luxuriant vegetation. The Upper Gondwanas of Godavari basin comprises Gollapalli sandstone, Raghavapuram shale and Tirupati sandstone. Its equivalents Budavada sandstones, Vemavaram shale and Pavaluru sandstones are developed in Krishna basin.

21.7 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Medlicott (1872)
 2. Glossopteris and Ptilophyllum
 3. Talchir, Damodar, Pnachet, Mahadeva, Rajamahar and Jabalpur
-

21.8 MODEL EXAMINATIONS QUESTIONS

I Answer the following questions in about 30 lines each

1. Describe the lithology, distribution and classification of Gondwana Supergroup.
2. Explain the significance of structures, climate and sedimentation in Gondwanas.
3. Give an account of Gondwana rocks of India.

II Answer the following questions in about 10 lines each

1. Igneous activity in Gondwana basins.
2. Gondwanas of Andhra Pradesh.
3. Gondwana Flora.

* * *

UNIT - 22 THE DECCAN TRAPS

Contents

- 22.0 Objectives
 - 22.1 The Deccan Volcanism
 - 22.2 Classification of Deccan traps
 - 22.3 Intrusive in the Deccan traps
 - 22.4 Petrology, Petrography and Chemical Composition
 - 22.5 Bagh Beds
 - 22.6 Lameta Beds
 - 22.7 Infra - trappean Beds
 - 22.8 Inter - trappean Beds
 - 22.9 Age of the Deccan Traps
 - 22.10 Economic Importance
 - 22.11 Summary
 - 22.12 Check Your Progress - Model Answers
 - 22.13 Model Examination Question
-

22.0 OBJECTIVES

After studying this unit you should be able to

- * describe the mode of formation.
 - * explain the classification of Deccan Traps.
 - * define the infra and intra trappeans.
 - * describe the age of Deccan traps.
-

22.1 THE DECCAN VOLCANISM

As a result of active compressive movements in the tethyan region during the Cretaceous, tension fractures were developed in the peninsular India resulting in the eruption of an enormous quantity of lava that flowed over hundreds of kilometers to form a large magma basin and are hence termed as fissure eruptions and are spread out far and wide as nearly horizontal sheets. The term Deccan Traps was first coined by W.H. Sykes in 1833 and derived the name from the vernacular "Dakhkan" meaning South and "Trap" from the Swedish word meaning stair to describe the step like, flat topped or terrace-like topography peculiar to the Deccan trap terrain. The flat topped plateau like features of basaltic composition have allowed them to be called as plateau basalts. The Deccan traps have very wide geographical distribution and occupy large tracts between Kutch in the northwest, Mumbai in the west, Belgaum in the south, Sarguja and Jhoshpur in the east and as far as Rajahmundry in the southeast, covering parts of the states of Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh and Karnataka.

22.2 THE CLASSIFICATION OF DECCAN TRAPS

The Deccan traps are classified earlier into three groups, upper, middle and lower based on the infra - and inter-trappean beds and ash beds. According to this classification the lower traps occupied Central India and Malwa and upper traps occurred at western margin in parts of Mumbai and Kathiawar. The above classification has been discarded as their positions are reversed, the older becoming younger and vice versa.

Recently a detailed classification is attempted in western Maharashtra where thick succession of lava flows are exposed. The Deccan Trap is divided into three sub-groups which consist of twelve formations based on petrological, mineralogical, geochemical and isotopic data. The three subgroups are the Kalsubai, the Lonavala and the Wai. The youngest is wai sub group exposed in the northwestern part of Andhra Pradesh.

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 are three sub-groups of Deccan traps?

.....

.....

.....

.....

Table 22.1 Stratigraphic Succession Of Deccan Basalt Group of the Western Ghats

Sub-Group	Formation	Member / Flow
Wai	Desur	
	Panhala	
Lonavala	Mahabaleswar	
	Ambenali	
Kalsubai	Poladpur	
	Bushe	
	Khandala	
	Bhimashankar	Monkey hill GPB Giravalli GPB
	Thakurvadi	Thakurvadi Chemical type Water pipe member Thakurvadi Chemical type High TiO ₂ , Thankurvadi basalt Thankurvadi chemical type Jammu Patti member
	Neral	Tuner Five Basalt Neral Chemical type Terambre Chemical type Ambivili picrite Basalt
	Igatpuri	Kashele GPB* Nilamati
	Jawhar	Thalghat GPB * Juni Jawhar Val River Golbhan phyric Devbandh Khardi phyric

22.3 INTRUSIVES IN THE DECCAN TRAPS

Sills and dykes of dolerite are numerous in the traps but they are not evenly distributed. In Saurashtra they show a more or less radial disposition around Amrali and Jarda and also around the plutonic mass of Girnar. Dykes are very common in eastern Saurashtra in Gujarat, in the Narmada valley, in the Satpura region of Madhya Pradesh and also in Western Andhra Pradesh.

22.4 PETROLOGY, PETROGRAPHY AND CHEMICAL COMPOSITION

Petrologically the Deccan traps show general similarity from one area to another and uniform in composition and correspond to dolerite or basalt with an average specific gravity of 2.9. In Western India including Mumbai, Kathiawar and Kutch, the traps are associated with acid, intermediate and ultrabasic rock types derived through differentiation of the original magma.

Besides the usual dolerite and basalt, lamprophyre, limburgite, olivine gabbro, porphyritic basalt, porphyry andesite, monzonite, nepheline syenite, rhyolite, obsidian and pitchstone are recorded.

The bulk of the trap is composed of labradorite and clinopyroxene. Ophitic texture is common. The rocks often show phenocrysts of feldspar in doleritic types and interstitial glassy matter in the basaltic types. The common pyroxene in the lower and middle traps is augite to subcalcic augite with occasional pigeonite and is associated with olivine and ore minerals. Secondary minerals such as zeolites, calcite and chalcedony are often developed in the traps, either as fillings in the amygdoloidal cavities or as products of alteration.

The plateau basalts of the fissure eruption type when compared with the normal core basalts of the central eruption type show a higher iron and titanium content. The most of the flows in Deccan Plateau are middle stage basalts and are characteristically tholeiitic and represent the original magma of the province. Last stage basalts are restricted to only a few areas in western Maharashtra.

Chemically, majority of the basalts are high-alumina basalts and with relatively high Fe and Ti. The trace elements Cr, Ni, Co, Sc, Y, Sr, Pb, and Ba, seem to have behaved in a much more systematic and orderly manner when compared to the major elements.

The geochemical studies of the Deccan traps have led to the recognition of distinct and different magma types. It is believed that the origin of all magmas is from a common parentage by the partial fusion of the upper mantle. Primary mantle material is presumed to be of the composition of garnet peridotite with varying amounts of garnet or omphacite on partial melting, yield tholeiitic and alkali basalt types. The alkali basalt type would be generated at a greater depth than the tholeiitic type. Differentiation of either type of magma may take place during and/or after emplacement due to oxidation and reduction, gas fluxing, crystal settling and contamination.

22.5 THE BAGH BEDS

The Bagh beds occur below the traps near Bagh town, situated in the western part of Narmada valley, about 145 km west of Indore in Madhya Pradesh. The Bagh beds are also exposed in isolated outcrops around Kewadi-Chapdi, Arithi-Sipanpalia, Jangthi-Jampani and Mangeli-Wani villages in Dhule districts of Maharashtra. Bagh beds comprise marine sediments like conglomerate, sandstone and shale of Cretaceous age (Table 22.2). They contain several species of Anthozoa, Poryozoa, Echinodermata, Brachiopoda, Gastropoda, Lamelli-branches and Fishes indicate mainly Turonian in age (Upper Cretaceous).

- * Coastal Plains comprising the Coastal Districts.
- * Eastern Ghats (hill ranges) running parallel to the coastal districts.
- * Interior uplands (Nallamalai, Lankamalai and Palakonda or Seshachalam hill ranges) and Plains mainly in the Rayalaseema region.
- * North-Western Plateau (Anantagiri Plateau) and Plains forming Telangana region.

The basin covered by the river Godavari occupies a large part of the northern half of the state. Penganga, Pranhita, Indravati and Manjira are its tributaries. The southern half of the state is occupied by the Krishna, Tungabhadra and Pennar river basins. The tributaries of Krishna are Tungabhadra, Dindi and Musi while the Chitravati, Papagni, Cheyyeru and Sagileru form the tributaries of the Pennar. There are also a number of small rivers such as Vamsadhara, Nagavali, Gundla Kamma, Manneru and Swarnamukhi. The Kolleru lake, large fresh-water lake occupies an area of over 250 sq.kms. between the Krishna and Godavari rivers. The lagoonal Pulicat lake, is in the southern most part of the state. There are numerous large and small artificial lakes, the prominent amongst are Pakhal lake, Osman Sagar, Himayat Sagar, Nizam Sagar, Lakhavaram lake and Nagarjuna Sagar.

24.3 CLIMATE

The Climate of the State is classified as Tropical Rainy in parts of the Telangana and the entire Coastal region, and as Hot Steppe in the entire Rayalaseema and parts of the Telangana region. In the region of Tropical Rainy climate the minimum daily temperature is above 18°C and the maximum is above 42°C . The average annual rainfall varies from 75 cm in the northern part and 50 cm to 90 cm in the southern part of the state.

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. The chief mountains of Andhra Pradesh are ...

2. The important rivers of Andhra Pradesh are ...

24.4 GEOLOGY

Andhra Pradesh forms an important segment of the Peninsular Shield of Indian Sub-continent. Geological formations from Archeans to Recent are present in the state and generalised Geological Succession for the state is given in Table 24.1.

24.4.1 Archeans

In Andhra Pradesh Archean rocks covered more than 65 per cent of the area. Archeans occur as linear schist belts of various sizes in gneissic terrain. The Archean rocks are Volcano-Sedimentary assemblages usually represented by high grade schists comprising garnet, staurolite, kyanite, sillimanite (rarely cordierite, sapphirine granulite enclaves in Karimnagar), mica schists, calc-silicate rocks, crystalline limestone, fuchsite-quartzite, banded hematite quartzites, metabasalts, amphibolites, mica-chlorite schists etc. The main schist belts in Andhra Pradesh are Karimnagar belt (in parts of Karimnagar, Adilabad, Warangal and Khammam districts), Veligallu Schist Belt (in parts of Anantapur, Chittoor and Cuddapah districts), Gadwal Schist Belt (in parts of Mahabubnagar and Kurnool districts), Kadiri Schist Belt (in parts of Anantapur and Chittoor district), Ramgiri-Penakacherla Schist Belt (mainly in Anantapur district), Jonnagiri Schist Belt (in parts of Anantapur and Kurnool districts), Peddavuru Schist Belt (in parts of Nalgonda and Guntur districts), Nellore-Khammam Schist Belt (in parts of Nellore and Khammam districts), Nellore Schist Belt (in parts of Nellore and Prakasam districts).

Table 24.1 Generalised Geological Succession : Andhra Pradesh

Geological Time	Group / Formation	
Recent to Mio-Pliocene	Soil, Beach Sands, Alluvium Cave deposits, Laterites, River terraces, Older Alluvium, Placers, Ash beds	
Mi-Pliocene	Rajahmundry formation	
Lower Eocene to Upper Cretaceous	Deccan Traps and Infra & Inter-trappeans	
Lower Cretaceous to Upper Carboniferous	<u>Gondwana Fluvatile</u> Upper Chikiala Formation Gangapur Formation Lower Kota Formation Maleri Formation	<u>Coastal Fluvio-Marine</u> Tirupati Formation Raghavapuram Formation Satyavedu Formation Kamthi Formation Baraker Formation
Upper Proterozoic to Middle Proterozoic	Kurnool Group Cuddaph Supergroup	Bhima Group Phakhals
Eparchaeon Unconformity		
Middle Proterozoic to late Archean Late Archean Middle Archean	Eastern Ghats Dharwar Supergroup Older supracrustals (Sargur Group (?))	Charnockites Khondalites Pyroclastic rocks, Metabasalts, amphibolites, intrusive granites (Ramagiri, Kadiri, Gadwal, Nellore Schist Belts) High grade Schists, Migmatites, Kyanite, Silimanite, Cordierite, Mica Schists, Amphibolite, Anorthite-Ultramafic Complex Banded gneissic Complex

FACULTY OF SCIENCE
THIRD YEAR (3 YEAR DEGREE COURSE) EXAMINATION

ASSIGNMENT - 2

GEOLOGY COURSE - III

Structural Geology, Economic Geology And Indian Geology

I. Answer the following questions in about 30 lines each

1. What is economic Geology? How this knowledge is useful to the society?
2. Explain the processes of magmatic concentration.
3. Explain the ores used in the refractories and ceramics.

II. Answer the following questions in about 10 lines each.

1. What are ore minerals?
2. Explain Pegmatitic deposits.
3. What are the various types of coal?

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FACULTY OF SCIENCE
THIRD YEAR (3 YEAR DEGREE COURSE) EXAMINATION
ASSIGNMENT - 1
GEOLOGY COURSE - III
Structural Geology, Economic Geology And Indian Geology

I. Answer the following questions in about 30 lines each

1. Explain the Dharwar rocks of Karnataka.
2. Describe in detail about Cuddapah system.
3. Write an essay about Andhra Pradesh stratigraphy.

II. Answer the following questions in about 10 lines each.

1. Write about Kurnools.
2. What are the fossils of Gondwana system?
3. Discuss about the age of Deccan traps.

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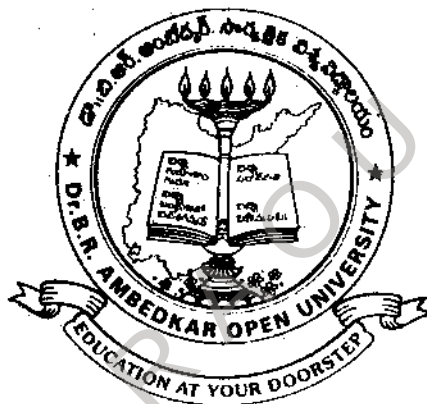
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GEOLOGY

Geology - IV

COURSE - IV

MINERAL EXPLORATION, MINERAL ECONOMICS AND ADVANCED ASPECTS



"We may forgo material benefits of civilization, but we cannot forgo our right and opportunity to reap the benefits of the highest education to the fullest extent..."

Dr. B.R. Ambedkar

**Dr. B.R. AMBEDKAR OPEN UNIVERSITY
HYDERABAD**

2003

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Dr. B.R. Ambedkar Open University, Hyderabad

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PREFACE

This book deals with the topics in Geology included in the syllabus for the Third Year of the B.Sc., course offered by the Dr. B.R. Ambedkar Open University. These topics generally cover the core area of the subject to be studied in the Third Year of the three-year Degree Course in Science (B.Sc.). The syllabus for the sake of convenience is divided into Blocks, each of which comprises of number of units. Each Block generally covers a specified area of the subject. The units are prepared by specialists in accordance with a format so designed as to enable the student to read and understand them without much difficulty. Each unit begins with a statement of its contents, objective followed by introduction and has at its end assignments intended to test the student's comprehension of its subject matter. Technical terms with which the student may not generally familiar are given at the end of each unit under the head 'Glossary'.

The objective of this book is to give exposure to the students about mineral exploration, mineral economics and advanced aspects of Geology. There are 24 units grouped under 6 blocks. The first and second blocks deal with Mineral Exploration. Third and fourth blocks deal with Mineral Economics. The fifth and sixth blocks are specially designed for the advanced aspects of Geology.

The advanced aspects from units 17 to 24 are explained in order to give the students the exposure and knowledge in these topics to help them to study post graduation courses in Earth Sciences.

The University hopes that this course material will help the students to get acquainted with the concepts and principles of mineral exploration, mineral economics and advanced aspects of Geology.

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BLOCK – I MINERAL EXPLORATION – I

BRAOU

UNIT : 1 EXPLORATION PRINCIPLES AND STRATEGIES

Contents

- 1.0 Objectives
- 1.1 Introduction
- 1.2 Basic Exploration Principles
- 1.3 Reconnaissance - Direct Field Evidence
- 1.4 Methods of Prospecting and Exploration
 - 1.4.1 Airborne Methods
 - 1.4.2 Ground Exploration Methods
 - 1.4.3 Three Dimensional Sampling
- 1.5 Exploration Strategies
 - 1.5.1 Field Guides
 - 1.5.2 Choice of Exploration Method
- 1.6 Summary
- 1.7 Check Your Progress - Model Answers
- 1.8 Model Examination Questions
- 1.9 Glossary

1.0 OBJECTIVES

In this unit, various mineral prospecting and exploration principles and exploration strategies are described.

After completion of this unit, you will be able to

- describe the basic principles of prospecting and exploration
- explain the methods of prospecting and exploration
- describe the exploration method depending upon the information obtained from preliminary studies of ore deposits.

1.1 INTRODUCTION

A systematic search for mineral deposits by geological, geophysical and geochemical investigations constitutes the subject matter for mineral exploration. Basic understanding of the geological principles is necessary for carrying out mineral exploration programme. But when we do not have direct field evidences of the ore bodies, we have to seek indirect evidences by way of pursuing geophysical, geochemical and geobotanical investigations. For locating target areas, the geologist may choose the easier and less costly ground methods like reconnaissance, tracking of boulders, outcrops etc. for evaluating direct field criteria leading to mineral discoveries. Airborne methods, ground methods and three dimensional methods are available for exploration. In formulating an exploration strategy some basic geologic knowledge and other data of each deposit are necessary. Various factors influence the choice of exploration methods and also the quantum of exploration in many cases.

1.2 BASIC EXPLORATION PRINCIPLES

Search for mineral deposits may be compared to the pastime of shooting at a target. But for

the geological marksman, his bull's eye (the ore body) is concealed and betrayed only by the rings (like an alteration halo) that surround it. A systematic search for such targets constitutes the subject matter for mineral exploration. But when we do not have direct field evidence by way of these targets, we have to seek indirect evidences by way of pursuing geochemical and geophysical investigations.

Mineral exploration consists of two activities. One is prospecting, which in essence is the choosing of suitable mineral targets for exploration. The other is exploration, which is proving of targets located during prospecting. The methods employed during either of the activities, cannot be rigidly isolated. However, certain types of activities are typical of both and can be broadly recognised. But prior to starting prospecting or exploration, it is necessary to choose the target areas, which can yield mineral deposits. The selection of target areas should be done by a process of sequential elimination of areas of poor potential. Such elimination is possible by reference to available literature in many cases. However, the whole process of target selection involves much more than a mere study of literature. Literature pertaining to prospecting areas, may be in the form of published geological reports with maps, unpublished geological reports, memoirs, records etc., available with the Geological Survey of India (GSI) or the Directorate of Mines and Geology in the State capitals and sometimes with private organisations.

For locating target areas, the geologist may choose the easier and less costly ground methods, when the areas are small or the more sophisticated and also expensive aerial methods, which are ideally suited for coverage of very large-areas. The ground methods include reconnaissance, tracking of boulders, outcrops etc. for evaluating direct field criteria leading to mineral discoveries.

1.3 RECONNAISSANCE - DIRECT FIELD EVIDENCE

The Geologist should undertake a rapid reconnaissance of the various target areas, as a first step, to see all the rock exposures. Natural or manmade cuttings generally expose rocks for easy examination. The beds of river course, nallas and streams are best available natural openings. If any source of float ore is found in such stream beds, efforts should be made to locate the original sources. The rail, road, canals, and well cuttings expose rocks and mineral deposits. The presence of mineralisation may be indicated by direct field evidence in several cases. Such features include 1) Float ore, 2) Topography, 3) Stratigraphy 4) Lithology, 5) Contact surfaces, 6) Structure, 7) Alteration haloes and 8) Old workings, tailing dumps and evidence of smelting activity of metallic ores etc. The presence of float ore on the escarpment side of Sandur Iron Ores, Karnataka; old workings and slag heaps at Agnigundala Copper-Lead Mines of Andhra Pradesh; scheelite in the tailing dumps of Kolar Gold Fields, Karnataka are some of the classical examples where these field evidences were fruitful. The other field evidence criteria constitute the so-called physiographic, mineralogical, stratigraphic, lithological and structural guides in mineral exploration, which are detailed in the following units.

1.4 METHODS OF PROSPECTING AND EXPLORATION

A variety of methods are available for exploration. Each has specific use, value and some inherent limitations. Choosing the techniques for specific field conditions calls for a broad knowledge of the methods and their limitations. These exploration methods are broadly divided into i) airborne methods, ii) Ground methods and iii) Three-dimensional.

1.4.1 Airborne Methods

Remote sensing, Photogeological and Aerial geophysical exploration studies constitute the airborne methods.

a) **Remote sensing:** The principles of remote sensing centres around the capacity of all objects to reflect electro-magnetic energy. Theoretically, all objects display a characteristic (spectrum of emitted, absorbed and reflected radiation. In practice, however, this spectral reflectance is influenced by the reflectivity characteristics of the object as well as atmospheric transmissivity. The former characteristic is made use of in most remote sensing operations. The spectrum contains many bands and wave lengths of which visible and infra-red spectra are used for conventional photographic reproduction in aerial and space photographs. This technique has certain advantages like comprehensive, instantaneous synoptic view of large areas; repetitive observations; uniform data with wide choice of scales, over others.

b) **Photogeological study:** Photogeology is an ideal tool for exploration, where geomorphologic features have an influence on mineral occurrence and concentration. It was used in locating several bauxite bearing laterite cappings in the East Coast. Maps made by photogeological methods are not complete without selective or detailed field checks. Aerial Photos are made by Cameras mounted on aeroplanes. The terrain is photographed in continuous and lateral overlaps, so that stereo-photo models of the area can be seen, when a set of overlapping photographs are placed under a stereoscope.

c) **Airborne geophysical methods:** The principle is same as for ground geophysical methods, which are described separately.

1.4.2 Ground Exploration Methods

Ground exploration methods are the most important in delineating the physical boundaries and chemical nature of the individual deposits and consist of two operations viz. Detailed ground definition of targets and three-dimensional sampling. These are listed below.

By aerial or other methods, target areas are selected for ground exploration. During ground exploration, the deposits are broadly delineated. Such delineation can be achieved by regional geological mapping, scout drilling followed by three dimensional sampling.

a) **Detailed ground definition or targets:** Regional geological mapping is carried out for delineating potential mineral bearing areas on 1: 250,000 to 1: 25,000 scale. These are usually available with Geological Survey of India. If it is a totally virgin area, the exploration agency has to prepare the geological map. The geological map constitutes the most important ingredient for exploration.

b) **Geochemical sampling and mapping:** The quantitative determination of the anomalous distribution of certain elements in the surface soil and subsurface overburden and comparison with a known background value give an idea of the rock and mineral deposits hidden below the ground. This is the essential principle of geochemical prospecting. The common practice followed in geochemical method is the collection of soil, stream-sediment, water, rock samples at regular intervals, the grid lines being transverse to the strike of the suspected zone of mineralisation. The metal content is determined by rapid geochemical analysis of samples. Geochemical methods are very effective in locating targets of base metal mineralisation.

Soil Sampling: Residual soils in temperate and tropical regions carry mineral particles of

parent rocks. Soil geochemical sampling aims recognising such values, anomalously high value concentrations indicating of soil capping target.

Stream sediment sampling: This is the most widely used technique in geochemical surveys. Fine stream sediments collected from active stream channels or flood plains carry mineral matter in fine form derived from their original source rock.

Water sampling: Water sampling is of relatively little value except in the case of uranium and in rare cases, Zinc and Copper. Water samples are collected from lakes, rivers from underground sources.

Rock sampling: Rock samples are collected from visible rock outcrops by cutting out chips of rocks from predetermined grid points.

Indicator and pathfinder elements: In a geochemical survey an element measured in order to detect an ore body is termed an indicator element. In a majority of cases, the indicator element is an economically valuable component of the ore being sought for example Cu for copper ores or U for uranium ores. However, if the valuable component is difficult to analyse, immobile or yields data, which are difficult to interpret, another element associated with the ore may be more useful. Such an element is called a pathfinder element. Before deciding to use a pathfinder element, the reason for its association with ore and the range of geochemical environments in which the association occurs should be examined.

Geochemical prospecting data can be more effectively interpreted by computer methods. The methodology in brief is based on the following concepts. Any area under investigation will have three types of geochemical values. One is the background value, which describes the average metal value of the area in the un-mineralised zone. The other is the threshold value which describes the zone separating the average values from the anomalous values. Lastly there are the anomalous values, which are above the threshold values, which zone constitutes the best target area for exploration.

c) Geobotanical sampling and mapping: The presence and variety of a particular plant species in the area of mineralisation have been recognised as a guide to locating ore, since many years, however, it is only in recent times that it has started becoming an organised science and a method of exploration.

The growth and distribution of a particular plant in a given area are known to be influenced by subsurface geology. Geobotanical survey involves a visual study of the nature and distribution of the vegetative cover, plant distribution, the presence of indicator plants, mutational or morphological changes in species introduced by mineral enrichment etc.

d) Geophysical methods: Geophysical prospecting is the search for hidden mineral deposits by measurement of certain physical properties of the earth surface. Properties like gravity, magnetism, seismicity, electrical conductivity and radioactivity of rocks are measured in the field and interpreted with available geological data. Five major methods are available 1) Gravity, 2) Magnetic, 3) Electrical, 4) Seismic and 5) Radiometric methods.

Gravity method: The principle here is to locate the anomalies of gravity from place to place in area of search. The heavy mass may be a massive sulphide ore, iron ore, bodies of chromite etc. all of which cause deflections indicating gravitational influence. Instruments used to measure these deflections are pendulum, torsion balance and gravimeter.

Magnetic method: Certain rocks have magnetic properties. They exert their magnetic influence above the normal magnetic field of the earth. Minerals like magnetite, pyrrhotite exert magnetic influence causing deflection on the magnetic needle. Sensitive instruments like magnetometers are used to detect these minerals.

Electrical methods: These methods are relevant in survey for metallic mineral deposits. Some make use of conductivity and self potential, while others make use of the inductive response properties of rocks. Some others are based on measurement of the resistivity of rocks.

Seismic method: In this method the capacity of rocks to transmit earthquake waves is studied. Artificial earthquakes are produced by explosion and sensitive seismographs measure the waves. Reflection and refraction of waves are studied in this method.

All these methods, except seismic, are capable of being executed by airborne instruments to cover large areas rapidly. Electrical methods offer the best scope for application in small areas.

Radiometric method: Radioactive minerals like uranium and thorium can be easily detected and estimated by the help of this method. Portable Geiger-Muller counters, radiation survey meters are used for this type of exploration. This is applicable only for radioactive mineral deposits.

e) **Scout drilling and rapid sampling:** Scout drilling is done exclusively for confirming the presences of deposits discovered on the basis of exploration conducted by geochemical, geobotanical and geophysical methods. Scout drilling can be done by coring or non-coring drills. The drilled samples are analysed by rapid methods.

1.4.4 Three Dimensional Sampling

Three dimensional sampling constitutes the final stage of exploration, which aims at establishing the dimensions and grade of the deposit in all its details. This operation involves detailed geological mapping, trenching and pitting, drilling and exploratory mining and sampling pertaining to each operation.

Of the several methods mentioned above, three-dimensional sampling (detailed ground exploration) is the most important in the final evaluation of a deposit. All other techniques are rarely used together and some of them like remote sensing are still in a developmental stage.

The major criterion for making a choice should be the discriminating capacity of the method considered. Some of them like geochemical sampling, geobotanical sampling, remote sensing, aerial photography etc. have a low discriminating capacity. These techniques do not lead to a direct discovery of mineral deposits but are tools required for rather general investigations. They are best utilised when combined with methods of high discriminating capacity.

Another criterion considered in choosing the technique is the status of the terrain. In virgin areas, one might have to choose large target areas and it is important, that the first stage of elimination be done rapidly. Here, choice may be made in favour of rapid techniques even if they have poor discriminating capacities. Expense and ready availability of equipment and

skills also may influence the choice of techniques.

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. Name the different methods of prospecting and exploration.

2. What is an indicator element?

1.5 EXPLORATION STRATEGIES

It has been mentioned, that no two deposits, even though of the same mineral or ore, generally bear absolute comparison with each other. Naturally, an exploration strategy, which has proved successful in one deposit, may not meet with the same success in another. In formulating an exploration strategy therefore, some basic geologic knowledge and other data of each deposit are necessary. In order to collect data systematically, the following check list of observations to be made and recorded is recommended.

Check List of Preliminary Observations

1. Status of the Area:
 - (a) Developed area with good communications or
 - (b) Undeveloped area
2. Topography of the terrain
 - (a) plain/wooded/barren
 - (b) hilly/wooded/barren
 - (c) mountainous/wooded/barren
3. Regional geology and structure of the terrain
 - (a) Igneous
 - (b) Sedimentary
 - (c) Metamorphic

- (d) Residual
- (e) Alluvial terrain
- (f) Structure and tectonics - simple or complicated.
- 4. Size of the ore body:
 - (a) Length
 - (b) Width and
 - (c) Depth.
- 5. Outline of the ore body:
 - (a) Simple
 - (b) Irregular or
 - (c) Complex.
- 6. Types of ore bodies:
 - (a) Capping
 - (b) Reef
 - (c) Veins (various types of veins)
 - (d) Disseminations
 - (e) Lenses and pockets and other irregular bodies or
 - (f) Stratified sedimentary beds.
- 7. Nature of the enclosing rock:
 - (a) Lithology
 - (b) Hard, medium, soft, friable etc.
- 8. Wallrock alternation:
 - (a) Pronounced
 - (b) Prominent
 - (c) Not prominent or
 - (d) Totally absent
- 9. Mineralogy:
 - (a) Monomineralic
 - (b) Poly mineralic and
 - (c) Nature of gangue minerals
- 10. Structure:
 - (a) Simple
 - (b) Fairly complex
 - (c) Complex or
 - (d) Very complex.
- 11. Disposition:
 - (a) Extent of ore burden:
 - I) no overburden
 - II) Partially covered by overburden or
 - III) Fully covered by overburden.
 - (b) Depth extension:
 - I) confined to the surface
 - II) Partially confined to the surface or
 - III) Fully extending underground
- 12. Ground/Surface Water:
 - (a) Present, but not likely to cause any trouble
 - (b) Present and likely to interfere with drilling, pitting, branching, aditing etc., or
 - (c) Not present at all
- 13. Field evidence about ore genesis;
 - (a) Clear or
 - (b) Not clear

14. Climate of the area with records of rainfall and temperature variations:
- (a) Desert
 - (b) Arid
 - (c) Semi-arid
 - (d) Humid etc.

1.5.1 Field Guides

Each mineral deposit will have typical characteristics of its own and even deposits of the same mineral occurring close together exhibit semi diverse characteristics. However, broad similarities of certain characteristics are also noticeable, which make it possible to draw general inferences. In the case of Indian mineral deposits also vast diversities between any two deposits of the same mineral in a particular type are noticeable. Based on these, it is necessary to recognise certain field guides, which help in the search for a given mineral deposit. Many of such guides may be required to recognise a particular mineral deposit.

1.5.2 Choice of Exploration Method

The various factors mentioned above influence the choice of exploration method and also the quantum of exploration in many cases. The latter is also dependent on the required degree of precision of the exploration data.

After a promising mineral deposit has been located, and its broad characteristics are studied, the next step is to choose a particular scheme for detailed exploration based on other guiding factors like cost, time etc.

There are many factors which go a long way in helping the exploration geologist in his choice of an exploration method. The factors mentioned below can be made use of either individually or in varying combinations.

Capacity of exploration method to give reliable type of samples in sufficient quantity: The primary objective of any exploration programme is to collect samples of desired quantum and type and to prove the quality and extent of the deposit. Hence, it is important to choose such a method, which yields such samples laterally and in depth. Samples should be available continuously at regular intervals. In the surfacial deposits (also shallow), pitting yields most reliable samples. But, as mineralisation extends down-wards, most of the observations have to come from diamond-core drilling, which later be substantiated by samples obtained from exploratory mining.

Efficiency of the Method in Operation: This aspect depends on a host of conditions like the organisation of the team, nature of the country rock, stratigraphic sequence, nature of mineralisation, structural features etc. Pitting in hard rocks like quartzite is time-consuming and costly and it can be resorted to only under compelling circumstances. In such cases, core drilling will yield equally reliable data.

Cost Bearability: The total cost of operations should not become unbearably high. The geologist should remember that the money sunk in exploration cannot be recovered in any form except in the sale value of the ore to be proved. The amount spent on this account should be easily absorbed by the sale price later.

Maintenance of required speed of operation: The exploration programmes are mostly time bound. Sometimes, either due to break down of machinery or any other reason, the

programme may get staled. Hence, the method chosen should be quite flexible with either spare machinery or manpower or by opting for substitution of the programme with another suitable method.

Conformity with shape, size and pattern of mineralisation: This factor almost totally controls any exploration operation. For deposits of large aerial extent and surfacial nature, pitting and trenching are adopted. Asbestos, bauxite, magnesite and diamond are explored by these methods. However, spacing of the pits or trenches is of vital consideration as it influences the total cost of operation. Care should, however, be exercised in exploring some minerals like mica either by pitting or by drilling. For deep-seated deposits such as chromite, copper, lead and zinc ores, drilling has to be undertaken. The structure and stratigraphic sequence often control drilling in such deposits.

Topography of the area: Some areas remain inaccessible due to their altitude, thick vegetation, poor ground condition like marshy terrain and lack of communication. Though man can reach these areas, it would be very difficult to take materials and machinery. This particular situation has been faced in the case of bauxite deposits. Even many iron ore deposits had been inaccessible in India until recently. The exploration geologist will have to choose such a method which entails easy transportation of men and material, availability of firm ground for setting up camps and drilling machines, availability of other facilities etc.

Marketability of ore at the exploratory Stage: In some exploration programmes, it may be necessary to sell the ore raised during the operation. In such cases the choice may be in favour of a method, which may yield large quantities of ore. This is generally the case in the exploration of copper ore, which is sent to smelters even far removed from the deposit. Similar is the situation with mica, asbestos etc.

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. Name the factors which help the exploration geologist in the choice of an exploration method.

1.6 SUMMARY

In this unit, various mineral prospecting and exploration principles and exploration strategies are described. The geological approach in search for mineral deposits have been deal in light of ground surveys and airborne inventories. The identification of direct field evidence may lead to locate a valuable occurrence. The airborne surveys are to be carried over a wide

terrain and information obtained has to be checked by ground surveys to hit the target of mineralisation. Ground exploration methods are important in delineating the physical boundaries and chemical nature of the individual deposits

The geochemical exploration techniques involve sampling of rocks, soils, and water and plant species, which may show presence of ore.

Geophysical prospecting helps in the search of hidden mineral deposits by measurement of certain physical properties of the earth surface. Properties like gravity, magnetism, seismicity, electrical conductivity and radioactivity of rocks are measured in the field and interpreted with available geological data.

Three-dimensional sampling constitutes the final stage of exploration, which aims at establishing the dimensions and grade of the deposit in all its details. This operation involves detailed geological mapping, trenching and pitting, drilling and exploratory mining and sampling pertaining to each operation.

The Exploration strategy will have to be laid out taking cognisance of geological, geomorphologic, and geographical conditions. The technique of exploration differs from deposit to deposit even in the same mineralised district.

1.7 CHECK YOUR PROGRESS - MODEL ANSWERS

1.
 - (i) Air borne methods
 - (ii) Ground Methods
 - (iii) Three dimensional sampling
2. In a geochemical survey an element measured in order to detect an ore body is termed an indicator element.
3.
 - (i) Capacity of exploration method to give reliable type of samples in sufficient quantity.
 - (ii) Efficiency of the method in operation.
 - (iii) Cost bearability.
 - (iv) Maintenance of required speed of operation.
 - (v) Conformity with shape, sizes and pattern of mineralization.
 - (vi) Topography of the area.
 - (viii) Marketability of ore at the exploratory stage.

1.8 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in 30 lines each.
 1. Give an account of role of remote sensing and photogeological methods in mineral exploration.
 2. Describe the role of indicator and pathfinder elements in geochemical prospecting.
 3. Describe how field guides could be useful in respect of the following mineral deposits:
(a) Chromite (b) diamond (c) copper
(d) Lead-zinc (e) gold (f) bauxite
 4. What are the various factors that influence the choice of an exploration method?

II. Answer the following questions in 10 lines each

1. Reconnaissance
2. Geobotanical guides
3. Geophysical anomaly
4. Field guides

1.9 GLOSSARY

Aditing	: An adit is a horizontal or near horizontal opening driven into the ore body from some surface so that a cross section of the ore body is available for study and sample collection. In large ore bodies, a number of adits may be required to study several cross- sections. In mining also adits find place for ventilations, transportation etc.
Geochemistry	: A branch of geological science, which comprises the study of the composition of the earth and the chemical processes responsible for its formation
Geophysical Anomaly	: A geophysical observation indicating departure or deviation from the usual pattern. E.g. Magnetic high.
Mineral prospecting	: Mineral prospecting is the preliminary stage in and exploration mineral search to identify suitable targets. Proving of such identified targets constitutes the mineral exploration.
Mutational effect	: Mutation is a sudden, heritable change. The change appears all of a sudden, and is passed from generation to generation.
Pitting	: Pitting is the process of digging openings to penetrate soil cover and other loose material to reach mineral ore bodies concealed underneath. Pitting can be done manually or with the help of machines. Pitting is a very widely used exploration method and many are very effective in proving deposits, which are widely exposed on the surface and are relatively thin. They are least effective when the outcrop is linear and narrow and the ore body is steeply dipping.
Reconnaissance	: A preliminary survey in mineral prospecting conducted to ascertain the feasibility of occurrence of a mineral deposit. Detailed investigation is not carried out in this.
Remote sensing	: It is an airborne exploration method, based on the reflective characteristics of objects for electro-magnetic energy, used to study surface features of the earth.
Seismograph	: An instrument used to detect and measure the intensity of

earthquake waves.

Trenching

A trench is a narrow linear excavation, which is generally done to expose concealed outcrops. Where the soil or other secondary cover is not too deep (say less than one metre). A trench may be very deep and very long in certain specific cases where the distribution, size and shape of the mineral concentration is to be studied. Normally, however, trenches are put to expose the outcrops preferably from the footwall contact to the hanging wall contact. The actual excavation may be done by manual methods or by excavating machines.

Trenches are most valuable when the outcrop is narrow and linear. Trenching has been adopted as a major exploration method in many iron ore and bauxite deposits. Trenches can give detailed information about the nature of the hanging wall and footwall rocks, the lithological and grade variation of the ore body, structural details of the ore body etc.

* * *

UNIT : 2 GEOPHYSICAL METHODS

Contents

- 2.0 Objectives
- 2.1 Introduction
- 2.2 Geophysical methods
 - 2.2.1 Gravity methods
 - 2.2.2 Magnetic methods
 - 2.2.3 Electrical methods
 - 2.2.4 Seismic methods
 - 2.2.5 Radioactive methods
- 2.3 Summary
- 2.4 Check Your Progress - Model Answers
- 2.5 Model Examination Questions
- 2.6 Glossary

2.0 OBJECTIVES

In this unit, the concepts of geophysical methods of mineral exploration like gravity methods, magnetic methods, electrical methods, seismic methods and radioactive methods are described.

After completion of this unit you will be able to

- describe the geophysical methods of mineral exploration
- explain the geological setting in order to identify the mineral resources
- explain the specific application and limitation.

2.1 INTRODUCTION

Geophysical prospecting involves specialised techniques and gives consistent results only in the hands of a scientist, who has a thorough understanding of the geophysical principles and the ability of interpreting the results. A geologist, if he has made a special study of geophysical prospecting, can carry out the surveys himself. Otherwise, it is better for him to know enough about their possibilities and limitations to exercise judgement as to the conditions under which they are applicable, to distinguish truly scientific methods, and correlate the geophysicist's results with geological conditions.

2.2 GEOPHYSICAL METHODS

Geophysical prospecting in the search for hidden mineral deposits by the measurement of certain physical properties of the earth's surface. This involves the field measurement of certain properties like gravity, magnetism, seismosity and electrical conductivity of rocks by sensitive instruments and the interpretation of such data. Knowledge of the potential of this method is essential for exploration geologists.

Five major geophysical methods are available: these are gravity, magnetic, electrical, seismic and radioactive methods, which are useful in the mineral exploration to locate, sub surface mineral deposits.

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 are the major geophysical methods? Name them.

2.2.1 Gravity Methods

Gravity methods are based on local variations in the direction and intensity of earth's gravitation field. The principle involved here is to locate the anomalies of gravity from place to place in an area search. If a plumb bob is suspended freely, it will point towards the centre of the earth. If a heavy mass is nearby, it will exert a gravitational pull on the plumb bob with the result that the bob will show a deflection. The heavy mass may be a body of massive sulphide ore, iron ore, bodies of chromite etc., all of which are known to cause such deflections. Instruments measure these deflections. Three such instruments are in common use. They are pendulum, torsion balance and gravimeter. Of these, gravimeter is the most useful.

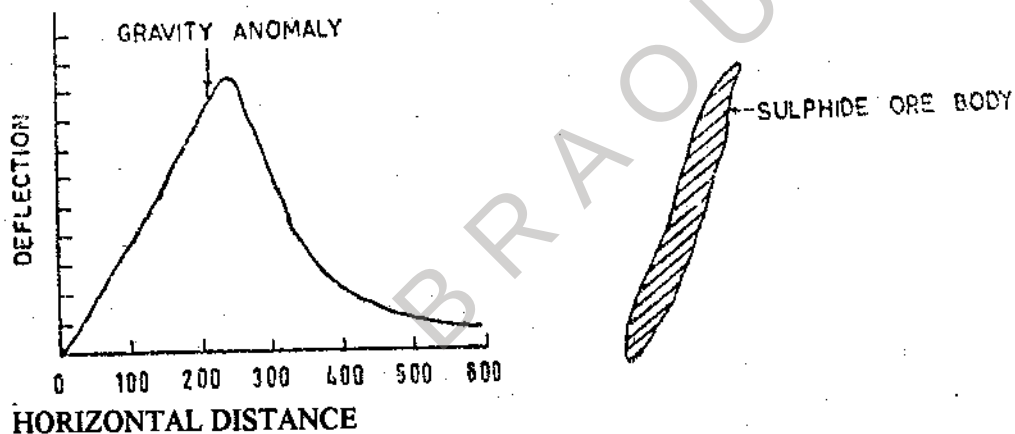


Fig. 2.1 Gravity Anomaly Graph
(Reproduced from Elements of Mineral Exploration by IBM)

In the field, traverses are laid at intervals, varying with the scale of operations, as in the case of geological traverses. Measurements of gravity are made at pre-determined points and the readings are replotted on a graph with distances on the X- axis and deflections on the Y- axis. The resulting graph will show an anomaly if the traverse is over a body, which exerts gravitational pull of its own. Fig 2.1 illustrates the concept and the peaked portion of the graph represents the anomaly. Anomalies can be interpreted by contouring also, where the peaked values will be better reflected in the areas of anomaly.

Gravity methods are used widely in petroleum exploration. Applicability of this method for ore search has been rather limited, because the topography characteristic of many mining areas complicates the interpretations. However, it has been quite successful in locating

mineral deposits like chromite. Strong contrast in the specific gravity between the prospecting mineral and its associated mineral or rock facilitates the application of gravity methods profoundly.

2.2.2 Magnetic Methods

Certain minerals and rocks have magnetic properties. They exert their magnetic influence above the normal magnetic field of the earth. Ores, which consist of magnetic minerals, exert a direct effect on suitable instruments. Iron ores in which the principal mineral is magnetite have been sought and found by the use of a magnetised needle since the 17th century; but even haematitic and limonitic ores usually contain enough magnetite to permit exploration by this method. Commercial ore minerals other than iron oxides are not directly detectable by ordinary magnetic means, but this fact does not necessarily exclude the use of magnetic methods in the search for them, because magnetic minerals occur as accessories in some ores of the non-ferrous metals. Minerals, which contain magnetite in subordinate form such as magnetite in asbestos, and pyrrhotite associated with base metals also, may exert magnetic influence. To cite an example, application of this method in the Sudbury Nickel deposits were quite successful, because pyrrhotite, which exerts a notable magnetic effect, accompanies the nickel and copper minerals in this area. The magnetic influence causes deflections of a needle, which are measured by sensitive instruments like magnetometer on traverses just as in the case of gravity measurements. The data can be interpreted in the same way as gravity data.

Apart from the direct effect of the ore minerals themselves, magnetic methods may afford structural information that leads to the discovery of ore. Magnetic methods have been used to advantage for tracing geological contacts under covered ground. They are usually applicable to basic igneous bodies, which contrast physically with sediments that adjoin them, and have proved particularly useful in the Precambrian shield, where contrasts in magnetic susceptibilities of lavas, sedimentary rocks, and intrusive rocks are frequently sufficient to trace contacts, reveal discontinuities, or provide 'markers' for outlining structure. In the Lake Superior copper region, magnetic methods have been very useful for tracing out the basaltic flows, a process which is made possible by the concentration of magnetic material in certain horizons in the flows.

2.2.3 Electrical Methods

Electrical methods depend for their success on the contrast in electrical properties between an ore body and the rocks that surround it. If they are used in deciphering structure, instead of an ore body itself, they depend on contrast in electrical properties between different rock formations. The principal electrical property involved is conductivity, which may express itself in determining the paths that the current follows in flowing through a rock mass (more accurately described as the field of flux) or in the drop of potential from point within the field. Some of the other properties that may be measured are electrostatic capacity, inductance, and magnetic permeability.

Massive sulphide bodies are highly conductive and the most spectacular successes have been achieved with ores of this sort. The conductivity of most rocks is much lower than that of massive sulphides, yet there is a wide variation as between one type of rock and another. Graphitic beds are strongly conductive, whereas massive quartz veins are highly resistant. Water, if it contains dissolved salts as most groundwater does, is a much better conductor than rock itself, hence the conductivity of rocks is determined largely by the water held in pores and fractures and, therefore, by the porosity and the texture of the rock. Faults and

shear zones, since they are likely to be water- courses, are usually zones of good conductivity.

The following electrical methods are generally recognised: resistivity, self-potential, induced polarisation and down the hole electrical methods.

Electrical methods are particularly relevant in surveys for metallic mineral deposits. Within these, there are various techniques. Some make use of conductivity and self-potential, while others make use of inductive responsive properties of rocks. In the self-potential method, the electrical energy in the rock is directly measured. In the resistivity methods, measurements are made to find out the different resistivities of rocks. In the inductive responsive method high frequency alternating current is introduced into the earth and the length and phase differences of the induced potential are measured on the surface. These phase and length differences are influenced by the electrical properties of rocks and are used in recognising specific formations.

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. List out the different electrical methods.

Choice of Methods: The large number of methods and combinations of methods offers a wide choice or means of surveying. No one method is 'best', the method selected should be the one best suited to the particular problem in hand. In general self-potential methods work best, where the rock conductivity is relatively high, whereas induction methods are advantageous in rocks of low conductivity, that are covered by thick overburden.

Of the methods of surveying, the self-potential measurements are well adapted to the detection of broad conductive ore bodies and to determining the strike of concealed formations, whose dip is steep.

Resistivity methods are widely used for structural studies of beds having greatly differing resistance, particularly for determining the depths of flat dipping formations.

Induced-polarisation (potential-drop) methods give sharp indications at the contacts of steep formation boundaries. They have been used extensively in locating quartz veins in the course of exploration for gold.

Electromagnetic methods have been successful in locating bodies of heavy sulphide, but can also be applied to disseminated sulphides. They are useful for determining the depth of beds or other sheet like bodies of gentle beds.

2.2.4 Seismic Methods

In seismic methods, the capacity of rocks to transmit earthquake waves is studied. In dense rocks, the waves travel very fast. Explosions produce artificial earthquakes and the waves are measured by sensitive seismographs. There are two types of measurements in this method. One measures the property of reflection and the other the property of refraction. In the reflection method the time taken by the various surfaces to reflect seismic waves is measured. In the refraction method, the principle used is that surface waves travel at a lower speed compared to the deeper waves.

In connection with mining, seismic methods are used to determine the depth of bedrock, preparatory to diamond drilling. In oil prospecting these methods are used very widely and successfully to determine the depth to key stratigraphic horizons, their use in problems relating to mining geology are comparatively limited, because of the complex structural conditions usually involved.

All the above geophysical methods, except the seismic, are capable of being executed by airborne instruments for covering large areas rapidly. Electrical methods offer the best scope for application in small areas. The exploration geologist's function is essentially to decide at what stage and in which terrain geophysical surveys are most useful and then to carry out the follow up action on the basis of geophysical findings.

2.2.5 Radioactive Methods

Ores of uranium and radium may be detected by measuring the effects of their radioactivity. Modern methods of greater sensitivity employ ionization chambers, or the Geiger -Muller counter, a device equipped with meters, ear-phone or count registers, which make it possible to see or hear the gamma rays. Portable radiation survey meters are also available now with Electronics Corporation of India Limited, to make rapid radiometric surveys in the field by detection of beta and gamma radiations. The tests can be applied either in the field, underwater or in drill holes, or on specimens of soil and rock in the laboratory.

Radioactivity can be detected in extremely minute amounts, but its use for detecting hidden ore is limited by the blanketing effect of rock cover, as even the most penetrating natural radiation is absorbed by a few yards of soil. Gamma rays are of penetrative type while beta rays are easily absorbed.

The location of ore at greater depths by radioactive instruments must therefore depend upon the migration of radioactive elements from the source, either by transport in solutions during or following ore deposition or by diffusion of radon, the only gaseous member of the radioactive series. Such processes may result in an aureole or in localisation of radioactivity along faults or fissures and thus provide somewhat greater depth penetration to radioactive methods.

Rocks are radioactive in measurable degree, the acid-rocks more so than the basic as a general rule, and there is sufficient variation between one formation and another to permit correlation of certain beds for example, formations in churn-drill holes. Furthermore, certain ground waters have an appreciable content of radon and of soluble radioactive materials, so those faults containing such water might be recognised and traced by measuring variations in radioactivity. However, this application is of limited use as yet, and should be considered only where relatively radioactive material is known to exist below. For instance, investigations for monazite and uranium potentialities have become quite easier today with

the help of portable radiation survey meters in the field.

2.3 SUMMARY

Geophysical methods like gravity, magnetic, electric, seismic and radioactive methods are useful in the mineral exploration programme to locate sub surface mineral deposits. Gravity methods are used widely in petroleum exploration and locating mineral deposits like chromite. Certain minerals and rocks have magnetic properties. They exert their magnetic influence above the normal magnetic field of the earth. Apart from the direct effect of the ore minerals, magnetic methods may afford structural information that leads to the discovery of ore.

Electrical methods are particularly relevant in surveys for metallic mineral deposits. Within these, some make use of conductivity and self-potential, while others make use of inductive responsive properties of rocks. Seismic methods are used to determine the depth of bedrock in mining. In oil prospecting these methods are used very widely and successfully to determine the depth to key stratigraphic horizons, their use in problems relating to mining geology are comparatively limited, because of the complex structural conditions usually involved. Ores of uranium and radium may be detected by measuring the effects of their radioactivity. Radioactivity can be detected in extremely minute amounts, but its use for detecting hidden ore is limited by the blanketing effect of rock cover.

The geophysical methods, except seismic and radioactive methods, are capable of being executed by airborne instruments for covering large areas rapidly. Electrical methods offer the best scope for application in small areas. The exploration geologist's function is essentially to decide at what stage and in which terrain geophysical surveys are most useful and then to carry out the follow up action on the basis of geophysical findings.

2.4 CHECK YOUR PROGRESS - MODEL ANSWERS

- 1) The five major geophysical methods are
a) Gravity, b) Magnetic, c) Electrical, d) Seismic and e) Radioactive methods.
- 2) The different electrical methods are
a) Resistivity, b) Self-potential c) Induced polarisation and d) Down the hole.

2.5 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in 30 lines each.

1. Describe the basis for geophysical prospecting and outline the scope of methods briefly.
2. Describe the role of electrical methods in mineral prospecting.
3. Outline the importance of radioactive methods in mineral exploration.

II. Answer the following questions in 10 lines each.

1. Geophysical study for knowing structure

2. Geophysical methods employed for location of Sulphide deposits
3. Geophysical methods employed for location of petroleum deposits
4. Which Geophysical method is useful for location of chromite deposits?

2.6 GLOSSARY

- Geophysics : Geophysics is a branch of earth science, where the physical principles are applied to understand the physics of the earth.
- Radioactivity : Radioactivity is the property of certain atomic nuclei (radioactive nuclei) which emit spontaneously particles (Alphas, Gammas etc.) or X-rays accompanied by the capture of an orbital electron by the nucleus, or to divide into two lighter nuclei.
- Radioactivity Measurements : The interaction between radiation and matter is accompanied by effect such as formation of ions and liberation of heat. These effects can be used to detect radiations. The operation of many measuring devices namely detectors is based on the ability of radiations to ionise molecules. The detectors commonly used are ionisation chambers and Geiger-Muller counters, whose operation and design are similar. They essentially consist of a container with two electrodes to which an electric voltage is applied. The space between the electrodes is filled with a dry gas, which is a good insulator.

UNIT : 3 GEOCHEMICAL AND GEOBOTANICAL METHODS

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- 3.1 Introduction
- 3.2 Scales in Geochemical Exploration
 - 3.2.1 Reconnaissance surveys
 - 3.2.2 Detailed surveys
- 3.3 Geochemical environment
 - 3.3.1 Deep-seated environment
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- 3.5 Association of elements – Indicator and Pathfinder elements
- 3.6 Patterns of Geochemical distribution
 - 3.6.1 Normal Background values
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- 3.7 Sampling media in geochemical exploration
- 3.8 Biogeochemical and Geobotanical Exploration
 - 3.8.1 Biogeochemical anomalies
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- 3.9 Summary
- 3.10 Check Your Progress – Model Answers
- 3.11 Model Examination Questions

3.0 OBJECTIVES

In this unit, geochemical surveys, biogeochemical and geobotanical exploration methods are described,

After completing this unit, you will be able to:

- explain the geochemical environment
- explain the association of elements and pattern of geochemical distribution
- describe sampling media in geochemical exploration
- describe the biogeochemical and geobotanical exploration

3.1 INTRODUCTION

Geochemical prospecting for minerals includes any method of mineral exploration based on systematic measurement of one or more chemical properties of a naturally occurring material. The chemical property measured is most commonly the trace content of some element or group of elements. The naturally occurring material may be rock, soil, gossan, glacial debris, vegetation, stream or lake sediment, water, or vapour. The purpose of the measurements is the discovery of abnormal chemical patterns, or geochemical anomalies, related to mineralisation. Geochemical methods of exploration should be viewed as integral component of any mineral exploration programme. The goal of every exploration method is to find clues that will help in locating hidden ore deposits. The presence of a particular plant species in the area of mineralisation has been recognised as a guide to locating ore, since many years. However, in recent times, it has developed as an organised science and as a method of

exploration. The growth and distribution of a particular plant in a given area is known to be influenced by the subsurface geology.

Geobotanical survey involves a visual study of the nature and distribution of the vegetative cover, plant distribution, the presence of indicator plants, mutational or morphological changes in species introduced by mineral enrichment etc. Tracking of indicator plants is more useful in this exploration. Visual observation of plants, when used as a guide to buried ore is known as geobotanical prospecting. Whereas biogeochemical methods require chemical analysis of plant organs, the geobotanical methods depend on direct observations of plant morphology and the distribution of plant species.

3.2 SCALES IN GEOCHEMICAL EXPLORATION

Geochemical surveys are usually classified as reconnaissance surveys or detailed surveys, according to their purpose and scale. They can also be classified according to the material sampled in the survey viz., soil, vegetation, sediment, water, rock, or vapour. Some of these sampling media are more effective in reconnaissance surveys; others are suitable in detailed surveys.

3.2.1 Reconnaissance surveys

In a reconnaissance survey, the purpose is to search a relatively large area for indications of ore. The spacing and type of samples are chosen to detect the favourable provinces or ore bodies with few samples or at as low a cost as possible. The aim in a reconnaissance survey is to determine the mineral possibilities of a relatively large area, eliminate the barren area, and draw attention to local areas of interest. Areas of tens of thousands of square kilometers are evaluated during reconnaissance surveys, often with no more than one sample per 1 sq km to 100 sq km.

In more detailed reconnaissance surveys, samples of sediment from streams and lakes, and water from streams, lakes, springs, seepages, and wells are the most effective and widely used media.

3.2.2 Detailed surveys

The purpose of detailed surveys is to outline mineralised area and to pinpoint the mineralised source with the greatest possible precision, preparatory to physical exploration by trenching, drilling, or underground work. In order to localise the bedrock source, relatively close sample spacing, normally between 1 m and 100 m, is required. The application of detailed surveys is mostly restricted to limited areas of particular interest, selected on the basis of other geochemical, geological, or geophysical information. The anomalies should be well defined and should occur in close proximity to the ore.

3.3 GEOCHEMICAL ENVIRONMENT

The earth is a dynamic system in which materials are moved from place to place and changed in form and composition by a variety of processes. The geochemical environment is defined by pressure, temperature, and availability of the most abundant chemical components. On the basis of differences in pressure, temperature, and chemistry, the geochemical environment of the earth is classified into two major groups. deep-seated environment and surficial environment.

3.3.1 Deep-seated environment

The deep-seated environment extends downward from the lowest levels reached by circulating surface water to the deepest level at which normal rocks can be formed. It is an environment of high temperature and pressure, restricted circulation of fluids, and relatively low free-oxygen content. Magmatic and metamorphic processes predominate in this zone. The terms hypogene, primary, and endogenic are used to refer to phenomena in this environment.

3.4.2 Surficial environment

The surficial environment is the environment of weathering, erosion, and sedimentation at the surface of the earth. It is characterised by low temperatures, low pressure, free movement of solutions, and abundant free oxygen, water, and carbon-di-oxide. The terms supergene, secondary, and exogenic are used to refer to processes in this environment.

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 the purpose of a reconnaissance survey?

2. What is the geochemical environment?

3.4 GEOCHEMICAL DISPERSION

In geochemical prospecting, the primary object is to detect the differences in the distribution of the elements. The material in the earth tends to be redistributed, fractionated, and mixed with other material. The process, in which atoms and particles move to new locations and geochemical environments, is called geochemical dispersion. The dispersion occurs in dynamic systems in which earth materials are undergoing changes in chemical environment, temperature, pressure, mechanical strain, or other physical conditions. The response of an element to dispersion processes is governed by its mobility, that is, the ease with which an element may be dispersed relative to the matrix of other materials surrounding it. In some

environments, mobility depends on the mechanical properties of the mobile phase. The relationship between mobility and chemical differentiation is more involved.

In searching for traces of material that have been dispersed away from the ore body, lower sample density is required for discovery since these dispersion patterns may form a considerably larger target area than the ore body.

3.5 ASSOCIATION OF ELEMENTS – INDICATOR AND PATHFINDER ELEMENTS

In geochemical survey an element measured in order to detect an ore body is known as indicator element or pathfinder element. In majority of situations, the **indicator element** is an economically valuable component of the ore being sought, for example, Cu for Cu ores or U for U ores.

However, if the valuable component is difficult to analyse, immobile, or yields data, which are difficult to interpret, another element associated with the ore may be more useful. Such an element is called a **pathfinder element**. Before deciding to use a pathfinder element, the reason for association of the pathfinder element with ore and the range of geochemical environments in which the association occurs should be examined.

Elements tend to be associated because of similar relative mobility in a group of geological processes. For instance, an element with high mobility in the surficial environment may allow more efficient detection of an ore composed of immobile elements if it is consistently associated with such ores. Molybdenum (Mo) is more mobile than Copper (Cu) in most surficial environments and can be used as a pathfinder for porphyry-copper deposits which typically contain some Mo. In other cases, the pathfinder may produce clearer and less ambiguous patterns of high values than more abundant elements of the ore, as in the case of Cu as pathfinder for Ni-Cu ores, which typically occur in nickel rich rocks that furnish high Ni values, whether mineralised or not. The pathfinder element may be more easily detected than the element being sought, as in the case of As a pathfinder for Gold (Au) deposits. The essential characteristic is that the pathfinder element should have a consistent relationship to mineralisation. The pathfinders are normally usable only for certain types of ore or geochemical environments, for instance Mo is not a pathfinder for all Cu deposits, only for porphyry-copper deposits, the most widely used pathfinders are given below.

Table 1: PATHFINDERS

Pathfinder Element	Material sampled	Ore type
As	Wallrock, residual soil, stream sediment	Veni-type Au ore
Hg	Wallrock and soil complex	Pb-Zn-Ag ores
Se	Gossan, residual soil	Epigenetic sulphides
Ag	Residual soil	Ag bearing Au ore
Mo	Water, steam sediment, soil	Porphyry-copper deposits
SO ₄	Water	Sulphide deposits

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. Explain the geochemical dispersion.

4. What is a pathfinder element?

3.6. PATTERNS OF GEOCHEMICAL DISTRIBUTION

In any given area, the geographic distribution of a given element in rocks, soils, and other materials is a response to the sum total of all the processes concerned in the movement of earth materials. Other processes of the deep-seated environment, such as hydrothermal alteration, may modify the basic relation to rock types. Weathering, erosion, and a variety of other processes in the surface environment will further blur and modify the patterns of the deep-seated environment.

The recognition of patterns related to ore is the aim and function of geochemical exploration. If the effects related to ore are intense and relatively local, the distinction from normal processes is simple; on the other hand, if the effects are weak and related to ore are in a complex manner, the interpretation of geochemical data is correspondingly more difficult and complex. For effective recognition of patterns related to ore, it is necessary first to determine the background of the indicator elements in unmineralised materials.

3.6.1 Normal Background values

The normal abundance of an element in unmineralised earth materials is commonly referred to as background. For any particular element, the normal abundance is likely to differ considerably from one type of earth material to another. The distribution of an element in any particular earth material is rarely uniform. Thus it is usually more realistic to view background as a range rather than as an absolute value, even in a relatively uniform environment. The nature of the environment itself can also have a marked influence on distribution. Whatever type of sample is involved, the range of background values should be determined or reconsidered whenever a new area is studied.

3.6.2 Geochemical anomaly

An anomaly is a deviation from the norm. A geochemical anomaly, more specifically, is a departure from the geochemical patterns that are normal for a given area of geochemical environment. An ore deposit, being a relatively rare or abnormal phenomenon, is itself a geochemical anomaly. In addition, the recognisable patterns of geochemical dispersion related either to the genesis or to the erosion of the ore deposit are anomalies.

Significant anomaly: Anomalies that are related to ore and can be used as guides to ore are termed as significant anomalies. Such anomalies usually consist of values that are higher than background. Negative anomalies are rarely useful in searching for ore.

Non-significant anomaly: High contents of indicator elements can arise from non-economic mineralisation or by geological or geochemical processes unrelated to ore. Such superficially similar anomalies unrelated to ore are termed as non-significant anomalies.

Threshold: The threshold is the concentration of an indicator element above which a sample is considered anomalous. In the simplest case, the threshold is the upper limit of normal background fluctuations. The higher values above the threshold are anomalies, and lower values are considered background. In more complex cases, two or more types of threshold values may be recognized. Recognition of regional and local threshold can be extremely important in prospecting as it may then be possible to limit the detailed search for peak anomalies to the plateaus of high values defined by preliminary wide-spaced regional sampling. Data from orientation surveys at several known deposits may lead to setting a threshold well above the level of normal background fluctuations in order to separate significant anomalies from those related to weak mineralisation or unusual geochemical features. In any case, the threshold is set at a level that is most convenient and efficient in detecting and delimiting ore.

3.7 SAMPLING MEDIA IN GEOCHEMICAL EXPLORATION

The quantitative determination of the anomalous distribution of certain elements in the surface soil and subsurface overburden and comparison with a known background value give an idea of the mineral deposits hidden below the ground. This is the essential principle of geochemical prospecting. The common practice followed in geochemical method is the collection of soil, stream-sediment, water, rock samples at regular intervals, the grid lines being transverse to the strike of the suspected zone of mineralisation. The metal content is determined by rapid geochemical analysis. Geochemical methods are very effective in locating targets of base metal mineralisation.

3.7.1 Soil sampling

Residual soils in temperate and tropical regions carry mineral particles of parent rocks. Soil geochemical sampling aims recognising such values, anomalously high value concentrations indicating of soil capping target.

3.7.2 Stream sediment sampling

This is the most widely used technique in geochemical surveys. Fine stream sediments collected from active stream channels or flood plains carry mineral matter in fine form derived from their original source rock.

3.7.3 Water sampling

Water sampling is of relatively little value except in the case of uranium and in rare cases, Zinc and Copper. Water samples are collected from lakes, rivers, and underground sources.

3.7.4 Rock sampling

Rock samples are collected from visible rock outcrops by cutting out chips of rocks from predetermined grid points.

3.7.5 Volatiles and Airborne Particulates

The gases emanating from ore deposits or oil fields have recently attracted the attention as possible exploration guides. The characteristic smell of a mine dump containing sulphides is a good example. The gases contained in the pore spaces of rocks and soils represent mixtures of atmospheric gases, gases of deep-seated origin, and gases of shallow origin.

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. Explain the geochemical anomaly.

6. What is a Threshold value?

3.8 BIOGEOCHEMICAL AND GEOBOTANICAL EXPLORATION

Chemical analysis of systematically sampled trees and shrubs for traces of ore metals was one of the first geochemical methods to be investigated. In the early 1930s, V.M. Goldschmidt, pioneer in geochemistry, made the observation that the humus of forest soils was very much enriched in most of the minor elements. He deduced that the same trace elements must be correspondingly enriched in the plants from which the humus was derived. He also made the first suggestion that analysis of plant material might be an effective method of prospecting. In later years this method of exploration came to be known as the biogeochemical method.

Visual observation of plants, when used as a guide to buried ore is known as geobotanical prospecting. Whereas biogeochemical methods require chemical analysis of plant organs, the geobotanical methods depend on direct observations of plant morphology and the distribution of plant species. Therefore, geobotanical methods have very great advantages over geochemical methods of prospecting in that the results of the survey are immediately available without further treatment of the samples.

The growth and distribution of a particular plant in a given area are known to be influenced by subsurface geology. Geobotanical survey involves a visual study of the nature and distribution of the vegetative cover, plant distribution, the presence of indicator plants, mutational or morphological changes in species introduced by mineral enrichment etc.

3.8.1 Biogeochemical anomalies

Biogeochemical anomalies are areas where the vegetation contains an abnormally high concentration of metals. If the metal content of a sample of plant material is to be useful in prospecting, it should bear a fairly simple relationship to the metal content of the bedrock. Other factors that affect the background and contrast in biogeochemical surveys include plant species sampled, plant organ sampled, age of plant or organ, depth of root system, health of plant, amount and direction of sun light. The factors of soil pH, Eh, temperature, soil moisture and inferences created by other elements in the soil also affect the background and contrast.

Different species of plants take up different amounts of inorganic material from the soil. The part of the plant selected for analysis is a critical factor. The differences in trace element level from one organ to another, and the stability of element concentration within one organ and location on a single plant are the important considerations. The concentration of trace elements is found to decrease in the order; leaves, twigs, cones, wood, roots, and bark.

Biogeochemical prospecting methods have advantages over other geochemical techniques. The potential for accumulation of elements from considerable depths below the surface, and easy access of vegetation for sampling are the important advantages.

3.8.2 Geobotanical Indicators

Geobotanical survey involves a visual study of the nature and distribution of the vegetative cover, plant distribution, the presence of indicator plants, mutational or morphological changes in species introduced by mineral enrichment etc.

Tracking of indicator plants is more useful in this exploration. Two types of indicator plants are recognised. These are i) **Universal indicators**, and ii) **local indicators**. Universal indicators grow only in a mineralised terrain and are seen the world over in similar set-ups. They are of course rare in their occurrence and distribution. Universal indicators are recognised for Co, Cu, Se, U and V and Zn. Local indicators are more common; More than 60 species of local indicators have been recognised for Co, Cu, Fe, Pb, Mn, Mo, Ni, P, Se, U, Ag, V and Zn. However, opinion is divided about their ultimate practical utility.

Geobotanical indicators have been used in locating and mapping groundwater, saline deposits, hydrocarbons, and rock types, as well as ores.

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.

7. What is biogeochemical anomaly?

8. What are universal indicator plants?

3.9 SUMMARY

Geochemical prospecting for minerals includes any method of mineral exploration based on systematic measurement of one or more chemical properties of a naturally occurring material. The chemical property measured is most commonly the trace content of some element or group of elements.

Geochemical surveys are usually classified as reconnaissance surveys or detailed surveys, according to their purpose and scale. They can also be classified according to the material sampled in the survey viz., soil, vegetation, sediment, water, rock, or vapour.

On the basis of differences in pressure, temperature, and chemistry, the geochemical environment of the earth can be classified into two major groups; deep-seated and surficial. The process, in which atoms and particles move to new locations and geochemical environments, is called geochemical dispersion. The dispersion occurs in dynamic systems in which earth materials are undergoing changes in chemical environment, temperature, pressure, mechanical strain, or other physical conditions.

In geochemical survey an element measured in order to detect an ore body is known as indicator element or pathfinder element. In majority of situations, the indicator element is an economically valuable component of the ore being sought. However, if the valuable component is difficult to analyse, immobile, or yields data, which are difficult to interpret, another element associated with the ore may be more useful. Such an element is called a pathfinder element.

A geochemical anomaly is a departure from the geochemical patterns that are normal for a given area of geochemical environment. Anomalies that are related to ore and can be used as

guides to ore are termed significant anomalies. Such anomalies usually consist of values that are higher than background. The threshold is the concentration of an indicator element above which a sample is considered anomalous. In the simplest case, the threshold is the upper limit of normal background fluctuations. The higher values above the threshold are anomalies, and lower values are considered background.

Visual observation of plants, when used as a guide to buried ore is known as geobotanical prospecting. Whereas biogeochemical methods require chemical analysis of plant organs, the geobotanical methods depend on direct observations of plant morphology and the distribution of plant species.

Therefore, geobotanical methods have very great advantages over geochemical methods of prospecting in that the results of the survey are immediately available without further treatment of the samples.

3.10 CHECK YOUR PROGRESS – MODEL ANSWERS

1. In a reconnaissance survey, the purpose is to search a relatively large area for indications of ore. The spacing and type of samples are chosen to detect the favourable provinces or ore bodies with few samples or at as low a cost as possible.
2. The geochemical environment is defined by pressure, temperature, and availability of the most abundant chemical components.
3. The process, in which atoms and particles move to new locations and geochemical environments, is called geochemical dispersion.
4. If the valuable component is difficult to analyse, immobile, or yields data, which are difficult to interpret, another element associated with the ore may be more useful. Such an element is called a pathfinder element.
5. A geochemical anomaly, more specifically, is a departure from the geochemical patterns that are normal for a given area of geochemical environment.
6. The threshold is the concentration of an indicator element above which a sample is considered anomalous.
7. Biogeochemical anomalies are areas where the vegetation contains an abnormally high concentration of metals.
8. Universal indicator plants grow only in a mineralised terrain and are seen in the world over in similar set-ups. They are rare in their occurrence and distribution.

3.11 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in about 30 lines each.
 1. Explain the reconnaissance and detailed surveys in geochemical exploration.
 2. Explain the geochemical dispersion.
 3. Define the geochemical anomaly and explain the different types of anomalies.

4. Describe the sampling media employed in geochemical surveys.

II Answer the following questions in about 10 lines each.

1. What is deep-seated geochemical environment?
2. Explain the Threshold value.
3. What is biogeochemical anomaly?
4. Explain the pathfinder element.

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UNIT : 4 EXPLORATORY DRILLING

Contents

- 4.0 Objectives
- 4.1 Introduction
- 4.2 Drilling
- 4.3 Drilling Methods - Types of Drills
 - 4.3.1 Diamond Drilling
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- 4.4 Collection and preservation of drill samples
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- 4.7 Average Assay computation.
- 4.8 Summary
- 4.9 Check Your Progress- Model Answers
- 4.10 Model Examination Questions
- 4.11 Glossary

4.0 OBJECTIVES

In this unit, the methods of drilling and types of drills used in mineral exploration are explained.

At the end of this unit, you will be able to

- explain the applications of drilling
- explain the different types of drilling
- explain the methods of analysing the average assay.

4.1 INTRODUCTION

Drill holes make it possible to investigate blocks of ground that by any other means would be accessible only at much greater expense, if at all possible. In some investigations, drill holes are intended merely to secure geological information -the position of a contact, the attitude of a formation, or the sequence in a stratigraphic column. In others they are designed to determine the presence or absence of veins/ or other guides to ore. Drill holes are also used to take samples of the ore and to provide all the information that is required for an estimate of tonnage and grade. At many mines, the resident geologist is in complete charge of drilling, from designing the exploration activity to logging the cuttings and core samples, analysis and interpretation of the data. The geologist usually has the responsibility for recommending the location of drill holes, and of recording the results of the work. He should therefore be familiar with the possibility and limitations of the types of drills most commonly used. It is for this reason that elementary knowledge of exploratory drills is essential.

4.2 DRILLING

Drilling or boring is the process of driving holes into rocks. The material which is cut during the process of drilling may be used for purposes of tests, chemical analysis etc., which is the

prime purpose of drilling in mineral exploration. Simple wash boring can be used if the drilling is for shallow depths. In the case of mineral exploration, sophisticated equipment is required to collect the samples from deeper levels.

Any drilling programme should aim at establishing the strike wise and dip wise continuity or discontinuity. For this purpose, the interval of drilling has to be chosen on the basis of available geological information. This should be kept in view for establishing the continuity of the ore at depth and also for intersecting the ore body at various future mining levels. Drilling also should aim at establishing the various structural projections.

4.3 Drilling Methods -Types of Drills

Five methods of drilling are generally recognized. They are: **percussive, attritive, rotative cutting, rotative shearing and rotative crushing.**

In percussive drilling, the rock is broken by repetitive impaction. In this group five types of drills can be recognised. They are pneumatic rock drills, down-the-hole drills, independent rotation drills, motor drills, and cable churn drills.

In attritive drilling the rock is ground away by abrasive action. Two types of drills are recognised in this group. They are diamond drills and shot calyx drills.

In rotative cutting drilling, the rock is cut or planed away. All auger drills fall within this group. In the rotative shearing method, rocks are fermented by wedge action. This group includes drag -bit holes a rotary percussive drills.

In rotative crushing method also, rocks are broken by wedge action, but the wedge action is used in combination with a thrust. All heavy rotary drills fall within this group.

Of all the drilling methods and types of drills detailed above, diamond drilling is the most versatile and maximum use, in mineral exploration. Churn drilling and rotary drilling also find use in mineral exploration, although their use is rather limited.

4.3.1 Diamond Drilling

Diamond drills can be used for surface as well as sub-surface drilling. In diamond drilling, a cylindrical bit (cutting tool) impregnated with diamonds is connected to a string of hollow jointed tubes and rotated by a mechanical device, which may be a diesel engine or a pneumatic compressor device. Water, drilling mud, and in some cases air are circulated through the hollow tubes to keep the bit cool and wash out the cuttings.

The diamond cutting edge cuts a cylindrical core as it penetrates the various rock strata. Such a core is collected in a core barrel, which is fitted immediately above the bit. From the core barrel the core is collected either by withdrawing the tool string (conventional method) or by removing only the barrel and bit (wire line core barrel). In drilling shallow or moderately deep holes, the time consumed in lowering the drill bit, core barrel etc. into the hole and hoisting them up repeatedly for collecting the core may be less significant than other consideration.

Where time is an important factor, wire line drilling may be resorted to. Wire line drilling differs from conventional drilling in that the inner tube that contains the core can be lifted to

the surface without hoisting the entire drill string, by releasing it from the outer tube of core barrel.

The core so collected forms the sample, which may be subjected to tests or analysis. The core barrel is constructed in such a way that core is retained during rotation. To ensure complete recovery, the core barrel may have an inner stationary tube which retains the core with an outer rotating tube, which transmits the rotation to the bits. Such a core barrel is called double tube core barrel. In a double tube core barrel, water is circulated between the outer and inner walls and the core is not washed by water and, because of this, better core recovery is ensured, particularly in weak and fractured zones. Drilling can also be done without the circulation of water, in which case it is called dry drilling. In dry drilling the core recovery is very high, but the bit losses are also correspondingly high.

Calyx drilling which is of fairly wide application is done on the principle of diamond drilling, but instead of diamond bits, it uses chilled steel shots as a cutting tool.

These days, however, as a substitute to diamond drilling, dry drilling by tungsten carbide bits is resorted to quite extensively by many exploration agencies.

4.3.2 Churn Drilling

In churn drilling, a hollow tube suspended on a cable and attached with a cutting tool is driven into the ground by rectilinear motion. The motion is imparted to the bit by continuous dropping and raising of the tool string. The cuttings so generated are collected periodically by a sludge collector or bailer. The method is not used widely in mineral exploration. However, for exploration in alluvial terrains, this type of drill is excellent.

4.3.3 Rotary Drilling

In cases where the information sought is purely of a confirmative nature and can be interpreted from chips and cuttings, rotary drilling is useful. In mineral exploration, such drilling can be used most effectively in mine exploration stage, when bench drilling becomes necessary. Apart from the drilling methods described above some simple devices like auger drilling are also used while exploring for soft and non-compact material like clays and bauxite.

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. Name the three types of drilling.

A proforma suggested for keeping drill core records is given in Table -1.

Table- 1 Presentation of Drill Hole Data : Suggested Proforma

Name of the Investigation :	Date of commencement :
Borehole No. :	Date of completion :
Angle of inclination :	R.L. at the collar of
Bearing :	of the Borehole :
Location in co-ordinates :	Total depth of borehole :

1. Sample No.
2. Length of run
From
To
3. Total width
4. Recovered length/weight of core/sludge recovery %
5. Core size
6. Sampled section (m)
7. Rock type and lithological description
8. Length of Sampled section
9. Extrapolated Length of Sampled section
10. Specific gravity
11. Assay %
12. Width x Assay
13. Sampled width
14. Average of Ore zones
True width
Average Assay
15. Nomenclature of zones
16. Remarks

4.4 Collection and Preservation of Drill Samples

Three types of samples come out of drilling:

(1) Core samples from diamond drills or various other coring and calyx drills (2) Wet cutting or sludge from churn drill, diamond drill or wet rotary or percussive drilling and (3) dry cutting from air flushed diamond, rotary, auger or percussion drilling.

Among all these, the diamond drill core and the calyx drill core can be considered almost identical with the host rock from which they have been removed. When the core recovery is 100%, the core reflects the strata faithfully. However 100% core recovery is seldom achieved. When core losses occur, the sludge (cuttings), coming out with circulating water, mud or air must be given due weightage. In other forms of drilling, only sludge is obtained. Core to sludge ratios in drill hole samples are computed for a proper understanding of the data.

In core drilling, the core is the principal sample and is collected from the barrel at intervals of 3 or 6 m. (10 to 20 ft). Shorter drill runs and shorter core lengths are preferred in some cases. After recovery from the barrel, the core is dried to remove only the superficial moisture and

kept in a core box. For preserving and indexing the drill cores, the Indian Standards Institution has evolved standard procedure (1-4078: 1967) which may be referred to for proper up keep of drill cores.

Portions of core which are needed for analysis are first split into two by a core splitter. One portion is kept in the box. The other portion is again split into two. One portions sent for assaying. The other is sent for physical and mineralogical studies. When the core recovery is poor, the sludge representing the core loss will have to be assayed and computed with the core portion.

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. Name the three types of samples coming from drilling.

4.5 Collection of Sludge

In collecting sludge during core sampling, a Thompson sludge cutter can be used. In this there is cast aluminum box with an overshot waterwheel type of impeller, in which one or more compartments are open. This impeller has several open compartments and allows the passage of 10% of the sludge to a special paper bag where it is collected. The cutter is directly fitted to the return water house, so that the motion of the water moves the impeller.

In the case of non-coring drills, with water circulation arrangement, the Thompson sludge cutter or a sludge box can be made use of. The box has a water inlet and outlet and is divided longitudinally by three baffle plates. After stopping drilling, the circulating water is connected to the sludge box and the water is allowed to settle. Excess water can be siphoned off. Samples can be removed periodically, dried and sent to assay.

In the case of non-coring drilling using air for removing the cuttings, two arrangements are possible. One is to have a cutting collecting arrangement attached to the tool string, which can be periodically reclaimed and the samples removed. The other is to allow the cutting to accumulate at the mouth of the drill hole and then collect the cuttings sequentially, the top most representing the deepest stratum.

4.6 Sampling of Drill Core, Sludge and Cuttings

It was mentioned earlier that the core sample is split and one is taken for analysis and another for reference. That half selected for sampling is again split into two, longitudinally and is

taken for sampling. Samples may be made from 50 cm, 1 m, 2 m or even 3 m section length of core, or even the whole mineralized band can be taken as one sample, if the mineralization is visibly of uniform quality and distribution. When mineralization is irregular, shorter length of samples are better. However, less than 50 cm length samples are impracticable in most cases. The selected core lengths are sized down to the appropriate sample size and sent for analysis.

4.7 Average Assay Computation

In core drilling, as mentioned earlier, the recoveries are rarely 100%. There is always a loss of core with varying in amount. From the relative proportions of core and cutting, the percentage of core recover has to be worked out. The analysis of such core and the cuttings separately has to be made and a weighted average of the two can be obtained. But if we want to compensate the core loss, analysis of sludge has to be performed, in order to have a representative assay value of the mineral prospect. But the core and sludge assays cannot be combined by mere weighted averages. One easy method, suggested and published by the Indian Bureau is presented here.

$$A = \frac{C}{L} \times \frac{D_1^2}{D_2^2} (A_1 - A_2) \times A_2$$

where A = Average Assay; C = Recovered Core; L = Length of hole (relevant to the calculated portion);

D₁ = Diameter of the hole;

D₂ = Diameter of the core; A₁ = Core Assay; A₂ = Sludge Assay.

In the case of non-coring drilling, sludge or cutting is sampled. Here also, analysis may be of sample 50 cm, 1m or 3 m lengths depending on the type of mineralisation.

4.8 SUMMARY

Drilling or boring is the process of driving holes into rocks. The material which is cut during the process of drilling may be used for purposes of tests, chemical analysis etc., which is the prime purpose of drilling in mineral exploration. Simple wash boring can be used if the drilling is for shallow depths. In the case of mineral exploration, sophisticated equipment is required to collect the samples from deeper levels.

Any drilling programme should aim at establishing the strike wise and dip wise continuity or discontinuity. For this purpose, the interval of drilling has to be chosen on the basis of available geological information. This should be kept in view for establishing the continuity of the ore at depth and also for intersecting the ore body at various future mining levels. Drilling also should aim at establishing the various structural projections. Diamond drilling, churn drilling, rotary drilling etc. are employed to achieve the above objectives in the mineral exploration programmes. The samples obtained from drilling constitute core/sludge or both. They are analyzed and averages are computed as to the values of mineral.

4.9 CHECK YOUR PROGRESS-MODEL ANSWERS

1. Percussive, attritive, rotative cutting, rotative shearing, and rotative crushing.
2.
 - (i) Core samples from diamond drilling & calyx drilling
 - (ii) West cutting from churn drill, diamond drill
 - (iii) Dry cutting from diamond, rotary, auger drilling.

4.10 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in 30 lines each.

1. Describe briefly the importance of drilling in mineral exploration, mention various methods and types of drills.
2. Give a detailed account of diamond drilling, mentioning its importance in exploration.
3. How are drilled samples collected and preserved?

II. Answer the following question in 10 lines each

1. How are core cuttings obtained from drilling?
2. How is sludge collected?
3. How the average assay is computed?
4. Describe the importance of Churn drilling?

4.11 GLOSSARY

Assay

: Assaying means chemical analysis of the sample for finding out Percentage of the metal element. Assay means the percentage of the metal or element.

Sampling

: Drilling samples also require sampling for obtaining a representative sample. This procedure of deciding and picking up of the required sample from drilled material is referred to as sampling.

Tungsten carbide

Tungsten carbide has almost replaced diamond universally due to Exhorbitary cost of industrial diamond and their non- availability

BRAOU

BLOCK – II MINERAL EXPLORATION – II

BRAOU

UNIT : 5 PHYSIOGRAPHIC AND MINERALOGICAL GUIDES

Contents

- 5.0 Objectives
- 5.1 Introduction
- 5.2 Physiographic guides
 - 5.2.1 Topography as a guide
 - 5.2.2 Physiographic environment of ore deposits
- 5.3 Mineralogical guides
 - 5.3.1 Rock alteration
 - 5.3.2 Mineral Zoning as a guide
 - 5.3.3 Oxidation Products
- 5.4 Summary
- 5.5 Check Your Progress -Model Answers.
- 5.6 Model Examination Questions
- 5.7 Glossary

5.0. OBJECTIVES

In this unit, physiographic and mineralogical guides are described.

After completing this unit, you will be able to

- describe the physiographic guides depending on the geomorphic expressions of ore bodies.
- describe the physiographic environment of ore deposits.
- explain the mineralogical guides.
- explain the oxidation products.

5.1 INTRODUCTION

Different geological parameters indicating the presence of mineral deposits at surface are called geological guides. The important among them are physiographic and mineralogical guides, stratigraphic and lithological guides, and structural guides.

The physiographic guides serve in locating ore deposits. These constitute either direct or indirect evidences, based on geomorphic features, as to the presence of ore deposits in an area. The Mineralogical guides are manifested in primary as well as in secondary ore deposits. They are characterised by the presence of zoning, rock alteration and box works. Limonites provide a variety of clues to the presence of mineralised zones at depth.

5.2 PHYSIOGRAPHIC GUIDES

Physiographic features may serve as direct or as indirect evidences of the presence of ore. Direct indications, such as the surface expression of an ore body, are useful immediately. But indirect evidence also may be of value. Such features as fault scarps, hog backs and cuestas serve as clues to the geological structure. Evidence bearing on the physiographic history of

the region may indicate the conditions under which ore was accumulated or enriched and so point to the places on which it may now exist. These historical considerations find their widest use in guiding the selection of broad regions for exploration, but even in problems of ore-search within a restricted area, they contribute to the background for constructive geological thinking.

5.2.1 Topography as a Guide

Eminences and depressions: Topographic features like eminences and depressions serve as guides for ore search. Ridge like out crops result directly due to the presence of ore bodies and are undoubtedly valuable guides in ore search. Topographical maps often show peculiarities of relief eg. elongated narrow depressions, cone shaped or terraced elevations. These are worth investigating by the prospector; Aerial photographs may indicate additional topographic criteria.

Topographic expressions are quite helpful in prospecting for many metals and in particular for Iron ores. In India, all the important hematite iron deposits form hills or chains of hills. In Salem district, Tamil Nadu, the magnetite ore bodies form continuous resistant bands on hilltops which are easily recognised from a distance. Surface topography depends upon the nature of mineral ingredients present in the crustal rocks and their relative resistance to physical disintegration and chemical solution. So the presence of quartz veins or iron rich gossans in a terrain lead to eminences, while calcite veins or carbonate gangue may result in depressions because of solution. The erosion or solution may contribute to depressions.

Oxidational Subsidence: The depressions could also result in yet another way, i.e. by oxidational subsidence. Removal of support through shrinkage of ore bodies during oxidation causes subsidence. This aspect has received careful attention at Bisbee, in Arizona, where the effects are somewhat similar to those of mine subsidence. This oxidational subsidence gave rise to numerous marginal cracks, which reached, to the surface level covered by the limestones. The cracks in the limestone were cemented by calcite. According to Mc Kinstry, the significance of these cracks and oxidation subsidence at Bisbee copper deposits, recognised much later in the Bisbee history, should educate mineral prospectors to take note of such important criteria in mineral prospecting.

5.2.2 Physiographic Environment of Ore Deposits

The important physiographic aspects for identification of ore deposits are geomorphological features, canyons, pediments, placers, pay streaks, residual ores and supergene enrichment zones.

Geomorphological Criteria: Physiographic conditions vary so widely, depending on the type of deposit and its associated rocks. They express themselves in such a variety of land forms, depending on the climate and geomorphic history, that is impossible to formulate any general proposition to the effect, that hills, valleys, peneplanes, monadnocks, or any other geomorphic features are either favourable or unfavourable. But a given region, a study on the relation of specific deposits to their geomorphic setting can often lead to the recognition of useful guides.

Canyons: Where ores are associated with rocks which have thick cover of resistant material, the ores can only be found in deep canyons, in highly dissected region, which cut through the top resistant rock and expose the productive rock in the canyons. Thus, in the Sierra Madre

of Western Mexico, where young volcanic rocks cap the high plateaus, the silver ores are found chiefly if not solely in the canyons, which cut through the siliceous lavas and expose the productive rock beneath them.

Pediments: Pediments are especially favourable situations for vein deposits. A mountain pediment, according to Bryan, is a rock floored plain of combined erosion and transportation at the foot of a desert mountain range. The normal pediment has a smooth slapping surface more or less covered by alluvium and broken only by scattered hills, which rise abruptly from its surface. Whereas the mountains represent in general the more massive and resistant rocks, the pediments develop on those parts of the rock mass where faulting, fracturing and chemical decay have rendered vulnerable to erosion. Hydrothermal ore deposits are expected in these places since the zones of structural disturbances are hospitable to localise ores and the hydrothermal solutions also promote weathering. Most of the gold placers throughout Arizona, USA are related to pediments.

Physiography In Relation To Placer Deposits: Physiographic events play a critical role in the accumulation of placer deposits of gold and other durable heavy minerals. The most favourable conditions are those in which the sequence of events has been conducive to (1) preparation (2) concentration and (3) preservation. The best preparation is a long period of deep weathering on a surface of mature or sub-mature topography. This liberates the individual particles of metal or heavy mineral from their enclosing material and prepares a deep layer of residual soil for concentration by the action of sorting agents. Upliftment and vigorous erosion causes streams to cut channels into the old surfaces transporting debris and depositing the heavy minerals in favourable places. Placers formed in this stage are valuable, but they may be short-lived because of continued or accelerated erosion which will destroy them. Destruction is prevented, however, if the placers are covered by younger deposits, as by aggradations of the stream channels or by outpouring of lava which fills the valleys either partly or completely. If a second rejuvenation takes place and new streams exhumed, the old placer deposits can be extremely rich due to resorting and reconcentration.

In the case of buried placers, a detailed study of geology and geomorphology, particularly with the aid of aerial photographs, may serve to locate these deposits with success. A few pits or drill holes in the selected areas will reveal their true nature. Alternatively, as all placers contain certain magnetite, the shape of buried channel may easily be determined with the magnetic method of prospecting.

Location of Pay Streaks: In placer deposits the major ore-locus is the stream channel, but subsidiary loci determine the position of pay streaks within the channel. As gold tends to accumulate in place of slackened stream velocity, the portions of the profile in which the gradient flattens are more favourable than those where it is steep.

Places in which the stream emerged from rapids into quiet water are favourable because of reduced velocity and increased opportunity for deposition. A broader valley below a narrow gorge presents an opportunity for shifting of channels with consequent resorting of earlier gravels. The resulting multiplicity of channels affords more potential sites for pay streaks. The broader valley permits meandering with development of curving channels and ox-bow loops, and it is well known that the inner sides of the curves are especially favourable.

The efficiency of bedrock in catching heavy minerals is an important determining factor. Some of the richest California stream placers are on limestone whose pitted and pinacled surface has provided ideal setting places. In contrast, diorite, which wears to a smooth

streambed, is inferior to either limestone or schist, although rich local accumulations have been found in potholes and among nests of boulders and diorite. Where streams cross highly inclined or vertically layered rocks, such as quartzites, slates, schists or alternating hard and soft beds, the harder layers tend to project upward and softer ones to be cut away. This forms natural riffles, which are excellent traps for placer minerals and may give rise to bonanzas or exceptionally rich streaks. According to Mc Kinstry, bedrock riffles parallel to the direction of stream flow surprisingly seem to be more effective than riffles crossing it at a large angle. Therefore, portions of channels which are roughly parallel to the strike of schistose rocks are favoured.

Thus, it may be seen that physiographic events exert a dominant control in the formation of placer deposits. In interpreting the previous history, the nature of the alluvial material may be of assistance. The size and shape of the gold particles, whether coarse or fine and whether fought or water worn, is an index to the distance of travel; the shape, arrangement, petrologic nature of the accompanying pebbles give a clue to the course, in some cases to the age of gravel in respective channels. Thus, reconstruction of the history of erosion and deposition, using principles of geomorphology and sedimentation gives an insight into the arrangement of channels and the probable position of pay streaks.

Physiography In Relation To Oxidation and Enrichment Residual Ores: Since rock weathering is controlled partly by topography, those types of ore, which owe their value to, the removal or undesirable elements through processes of weathering occupy definite positions with respect to erosion surfaces, past and present. This is true of nickel sulphates, bauxite, some manganese ores and lateritic iron ores, which are formed through weathering processes under tropical conditions. It is also true of gossans, such as those minable for their content in gold, silver, lead or iron, although lateritic weathering or tropical climates are not essential in these cases.

The processes of weathering which produce ores of these types proceed slowly and reach completion to worth while depths only where the water table is relatively deep and where time has been available for a long period of weathering. This, in general, calls for topographic surface in a state of maturity or old age. Raised peneplains and plateau surfaces, which have not yet been seriously dissected, offer the appropriate combination of condition.

Deep and long continued weathering under tropical condition of certain rock types like basaltic traps (Madhya Pradesh, Maharashtra and Bihar), feldspathic gneisses and granulites (Andhra Pradesh, Orissa and Tamil Nadu), Clays and clayey limestones (Jammu and Kashmir), produce bauxite deposits. Source rocks must be subjected to continued erosion, and bauxite deposits characteristically lie on gently undulating erosion surfaces, and most deposits mark unconformities. The pocket deposits are restricted to limestone and dolomite on karst topography, erosion surfaces and unconformities. Many bauxite deposits are associated with peneplains and old base level surfaces. Residual manganese ores are also related to peneplains. Nickel silicate deposits form on erosion surface. •

The above examples make it amply clear the influence of physiography and the importance of geomorphological criteria in the location of residual ore deposits. The reconstruction of the history of erosion facilitates prediction of productive areas.

Supergene Sulphides: Physiographic conditions favourable to supergene sulphide enrichment of copper and silver ores are rather similar to those, which produce the residual deposits described earlier. Under warm and humid climatic conditional sulphide ores oxidise

on the surface and copper or silver is leached below in solution to be redeposited below the water table to form supergene sulphides. The more the water table sinks below, the thicker is the zone of secondary enrichment, but it should neither sink too slow nor too fast as in that case no enrichment is possible. When continued erosion takes place at a slow rate, a slow and gradual lowering of water table takes place and a balance between erosion and enrichment is possible with a physiographic surface in the state of mature or old age. Thus, enriched ores are likely to be related to former erosion cycles. As such in the search for supergene sulphide ores, a study of the physiographic history of the region, serves as a useful guide.

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. List out the physiographic guides used in locating new deposits.

5.3 MINERALOGICAL GUIDES

The minerals that are present and their relative abundance serve as practical guides in ore search. Variations in the proportions of minerals, whether in the wall rock or in vein matter, and apparent in plan or in vertical sections, may constitute target rings. Oxidised minerals at the surface serve as an indication of what lies beneath.

Mineralogical variations in wall rock, unless inherent in the original rock-mass, are usually the result of alteration of rock by mineral-bringing solutions; variations within the vein matter may reflect local variations in conditions of ore deposition and subsequent influence of descending solutions.

5.3.1 Rock Alteration

The mineralogical changes that are so common in rocks surrounding epigenetic ore deposits usually involve the introduction of certain chemical elements and the removal of others. Occasionally the chemical change is negligible and the elements that were present originally merely rearrange themselves into new assemblages of minerals in monomineralic rocks, such as pure limestones and sandstones.

Few elements present do not provide the making of new minerals, in the absence of introduced material, alteration is recognisable only by difference in colour or texture. In most rocks, however, both chemical and mineralogical changes take place.

Common alteration minerals characteristic of various types of hydrothermal mineralisation are:

With hypothermal mineralization	: Garnet, amphiboles, pyroxenes, tourmaline, biotite.
With Mesothermal mineralisation (and also in many deposits classed as hypothermal or epithermal)	: Sericite, Chlorite, Carbonates and silica.
With Epithermal mineralisation	: Some sericite, often much chlorite and carbonate, adularia or alunite

Replacement of rock minerals by any of these alteration products jointly or severally and especially by pyrite, as one the commonest minerals of hydrothermal alteration, may produce an altered rock so conspicuous that the minerals themselves recognise it as a guide to ore. Alternatively, the altered rock may be scarcely distinguishable by naked eye from its fresh equivalent although it can always be recognised readily in thin section under the microscope.

Like other guides to ore, rock alteration is most serviceable if it is neither too restricted nor too wide-spread. The outer limits of a zone of alteration form the outer rings of a target for exploration. Within the outer ring, internal rings may be drawn by outlining different types of altered rock or by plotting successive degrees of intensity.

Let us examine some of the typical hypothermal and mesothermal mineral deposits of India in this context. In the Kolar Gold Fields, gold occurs in the native form generally as fine and invisible disseminations within the quartz, sulphides and silicates and rarely as thin streaks, films and granular lenses. The glassy vitreous nature of quartz, presence of minerals like pyrrhotite, scheelite, magnetite, diopside and cummingtonite and the diopside hornblende-biotite wall rock alteration are not only indications of highest temperature hypothermal ore mineralisation known in the world but serve as practical mineralogical guides for search of gold.

Regarding the mesothermal deposits, typical mineralogy of veins constitute native gold and pyrite (with minor pyrrhotite, arsenopyrite and chalcopyrite) in the case of gold-quartz veins, and chalcopyrite and bornite with minor pyrite and galena and subordinate sphalerite in the case of copper deposits. The quartz is partly milky white and less vitreous. The common wall rock alteration is chloritisation, sericitisation, silicification, carbonatisation etc.

The above examples illustrate how the nature of mineralisation, relative proportions of minerals present and the typical associated minerals along with characteristic wallrock alteration will be useful as practical guides for ore search.

5.3.2 Mineral Zoning As a Guide

The mineralogical variations might be regarded as aspects of hypogene zoning, but zoning in the stricter sense is the progressive change in mineralisation along channel ways from source to surface or outward from a central axis is serviceable in a somewhat different way. It finds its chief utility in the epithermal and the shallower of mesothermal deposits, where noticeable changes may take place either laterally within the limits of a single company's holding or in depth within the limits accessible to mining.

Zonal arrangement of hypogene minerals around the intensive masses is an important form of ore control. High temperature minerals lie close to the magmatic source and the low temperature minerals lie in zones away from the intrusives. Zoning may be horizontal,

vertical or both, ore of same metal or different metals may form the different zones. The zoning, based upon size, may be (i) regional large scale zoning or (ii) restricted zoning shown by closely grouped mines, or (iii) local ore zoning with changes in the character of mineralisation within a single ore body or a single ore shoot.

Based on observation, Emmons suggested an ideal sequence from the parent intrusive outward (1) barren zone with quartz (2) tin (3) tungsten (4) bismuth and molybdenum (5) gold (6) copper (7) zinc (and some lead) and lead (with some zinc, copper, silver and manganese) (8) silver (9) barren zone (10) gold and silver (11) antimony (12) mercury (13) upper barren zone.

Mineral zoning can be recognised by geological and geochemical study. Even if non-commercial ores occur at the surface or away from the intrusive, search for other minerals should be made deeper or near to the intrusive. Even where regional zoning is present, careful and more closer search may lead to the discovery of economic deposits.

Where supergene sulphide ores are formed, there is distinct, primary mineralisation may serve as a guide to richer supergene ore. If primary copper or silver mineralisation is first discovered at depth, there is a possibility that higher working may find a zone of enrichment especially under the remnant of an old erosion surface.

The supergene ore may be richest where precipitating minerals were present in the primary ore.

5.3.3 Oxidation Products

The oxidation products of an ore body constitute a type of guide that has been used effectively by miners and prospectors since times immemorial, but modern thinking of chemistry and geology of oxidation have made it even more effective.

Whether or not the oxidised material is of commercial interest for its own sake, it always prompts the question. What is underneath? What primary (or secondary) minerals were the parents, the oxidised gossan or capping? Will the unoxidised material in depth be richer or leaner? What minerals will it contain? These questions apply to oxidised ores of all sorts but particularly to those derived from sulphides.

In the oxidised zone, sulphides are decomposed, their sulphur is converted to sulphate and their metal content carried away in solution or else fixed, wholly or in part, as stable compounds, chiefly oxides, carbonates, and silicates. The relative stability of metal compounds in the zone of oxidation is a decisive factor here. Most of the gangue minerals succumb to weathering, carbonates dissolve readily and ultimately the silicates break down. Of the original gangue minerals quartz is the sole survivor, others are represented by the decomposition products of iron and manganese oxides, clay minerals, and some of the most stable minerals of the other metallic compounds. The chemical changes reach completion in some cases and hence, varying amounts of original minerals and transition mineral products may remain. The nature of such material and the textures preserved in silica and limonite are the chief clues to the composition of the original ore.

Gossans as a Guide to Ore Deposits: Gossan is a Cornish word used to designate oxidised out cropping cellular mass of limonite and gangue overlying aggregated sulphide deposits. Gossans are welcoming sign boards for a prospector to point out what lies beneath. However,

it requires caution, since there are true gossans and false gossans. True gossans containing indigenous limonite, usually indicate the site of former iron bearing sulphide minerals, which carry the possibility and hope that an economic deposit may be present underneath. The size of the gossan, colour and structure of limonite, voids etc. give clues for ore search. A false gossan containing transported limonite is formed by iron or copper transported by a strong neutraliser. Iron of sulphide derivation, if it is insoluble ferric stage gets fixed as indigenous limonite at the site of former sulphide forming true gossans, or if present in the soluble ferrous state gets transported and precipitated as transported limonite forming false gossans. Therefore, false gossans do not indicate sulphides beneath the surface; however depending on the degree of transportation the possibility of finding them at a distance beneath, may not be ruled out. False gossans can be distinguished by the absence of indigenous limonite, lack of sulphide voids and the nature of transported limonite. Transported limonite points to the preponderance of pyrite or an absence of copper minerals.

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. Define the term "Gossan".

Limonite in Gossans As a Guide: In outcrop derived from the leaching of semi massive and massive sulphides, as contrasted with the disseminated porphyry type, a greater variety of limonite products usually is in evidence; particular varieties, such as cellular pseudomorphs, are developed on a large scale and generally stand out more conspicuously to the unaided eye. There is also greater tendency for the merging of one variety with another, owing to the interplay of solutions of different origin during the oxidation.

The cellular pseudomorphs find their most extensive and persistent development in outcrops of this type. Where the structure is guided in its formation by cleavage of fracture planes, cellular boxwork, of sharply angular pattern and with cell walls intious in a straight line past several cells, is the usual development. Where the structure is guided in its formation by the boundaries of coarse and irregularly shaped grains, cellular sponge is the usual development, with the cell walls more rounded, more irregular and heterogeneous in pattern and with no defined cell orientation of formal structure.

Thus the colour, texture and structure of cellular boxwork, size and arrangement of limonite grains etc. serve as useful guides for mineral prospecting.

Colours of Limonite: Familiar colours of limonite are yellow, brown mushroom and red. Many investigators have established a correlation between limonite and the sulphide from which it is derived. According to Bateman (1960), the following colours of limonite indicate the presence of the mineral shown against each.

Ochreous - Chalcopyrite;
Light brown and brownish - sphalerite;
yellow and orange - bornite, chalcopyrite;
maroon - chalcocite, covellite, bornite;
dark brown to black - chalcocite;
ochreous orange - galena;
maroon - molybdenite.

It must be stressed that the colours of limonite do not always indicate the presence of specific minerals. But when this criterion is used along with the structure of the limonite (box work), it helps locating economic mineral deposits.

Boxwork Structure of Limonite: As outlined earlier, during the oxidation of a grain of sulphide mineral, residual limonite remains in the cavity, assumes a honeycomb cellular pattern called boxwork and persists in the limonite caprock with its original pattern. Like colour, boxwork pattern indicates the presence of specific sulphide mineral. The following boxwork patterns aid diagnosis of mineral shown against each.

Coarse cellular - chalcopyrite, sphalerite;
fine cellular - bornite, chalcopyrite, sphalerite;
cellular - sphalerite;
triangular - bornite;
contour - tetrahedrite;
columnar and botrvoidel - pyrite;
diamond mesh pyramidal - galena, molybdenite;
honey-comb - chromite.

Voids in Leached Outcrops: Leached outcrops of lodes containing voids may serve as useful guides in ore search. Such voids created by the leaching of predecessor minerals may be of sulphide or non-sulphide derivation. Abundance of voids of sulphide derivation indicates the abundance of preexisting sulphides. Shape of such sulphide voids may indicate the characteristic predecessor miner, eg. terraced cubic outlines indicate galena, spear shapes -arsenopyrite blades -enargite; plates -molybdenite, rhombs -rhodocrosite; plates -covellite etc. The identification of these moulds of the prospector may aid location of the above sulphide minerals.

5.4 SUMMARY

The Physiographic guides serve in locating ore deposits. These constitute either direct or indirect evidences, based on geomorphic features, as to the presence of ore deposits in an area. Such features as fault scarps, hog backs and cuestas serve as clues to the geological structure. Evidence bearing on the physiographic history of the region may indicate the conditions under which ore was accumulated or enriched and so point to the places on which it may now exist. These historical considerations find their widest use in guiding the selection of broad regions for exploration, but even in problems of ore-search within a restricted area, they contribute to the background for constructive geological thinking. The Mineralogical guides are manifested in primary as well as in secondary ore deposits. They are characterised by presence of zoning, rock alteration and boxworks. Limonites provide a variety of clues to the presence of mineralised zones at depth. The minerals that are present and their relative abundance serve as practical guides in ore search. Variations in the

proportions of minerals, whether in the wall rock or in vein matter, and apparent in plan or in vertical sections, may constitute target rings. Oxidised minerals at the surface serve as an indication of what lies beneath. Mineralogical variations in wall rock, unless inherent in the original rock-mass, are usually the result of alteration of rock by mineral-bringing solutions; variations within the vein matter may reflect local variations in conditions of ore deposition and subsequent influence of descending solutions.

5.5 CHECK YOUR PROGRESS - MODEL ANSWERS

1.
 - (i) Geomorphological criteria, canyons pediments.
 - (ii) Physiography in relation to placer deposits.
 - (iii) Location of pay streaks.
 - (iv) Physiography in relation to oxidation and enrichment residual ores.
 - (v) Supergene sulphides.
2. Gossan is a Conish word used to designate the oxidized out cropping cellular mass of limonite and gangue overlying aggregated sulphide deposits. Gossan not limited to the surface but may extend some distance below the surface. Gossans are sign boards that point to what lies beneath the surfaces.

5.6 MODEL EXAMINATION QUESTIONS

- I. Answer the following question in 30 lines each.
 1. "Physiographic features may serve as direct evidence of the presence of ore" - Discuss.
 2. Describe the role of Physiography as a guide in respect of the following:
 - (a) Placer deposits
 - (b) Residual ores
 - (c) Supergene sulphides.
 3. Minerals that are present, and their relative proportions serve as practical guides in ore search. Discuss.
 4. What are gossans? How are they useful in mineral exploration?
- II. Answer the following questions in 10 lines each.
 1. How Rock alteration characteristic of hydrothermal mineralisation is manifested.
 2. What is mineral zoning?
 3. What is Limonite Boxwork?
 4. Explain the Voids in Leached outcrops.

5.7 GLOSSARY

Adularia	A variety of orthoclase, pure or nearly pure potassium aluminium silicate, often with a pearly lustre (when called as moon stone). Original name derived from Adular region in Switzerland.
Alunite	Basic hydrous sulphate of aluminium and potassium, most commonly associated with acid volcanic rocks.

- Boxwork** : When a grain of sulphide is oxidised and residual limonite remains in cavity, the limonite assumes a honey comb pattern called boxwork.
- Canyon** : A large gorge, formed due to rapid down cutting of streams, Eg- Grand Canyon of Colorado.
- Geomorphology** : A branch of geology relating to the study of land forms including their history and processes of formation.
- Hogbacks and Cuestas** : A hogback is an erosional surface with a long, relatively gentle slope on one side and a sharp, steep or precipitous slope on the other side. Such a ridge develops when rock formations are moderately tilted with a hard layer lying between two soft layers.
- A cuesta is a sort of a ridge of resistant rock formation with a slope on one side being very steep forming an escarpment and on the other side with a very long and gentle slope called dip slope. Hence cuesta is a feature combining an escarpment and its dip slope.
- Karst topography** : In certain regions the sink holes and caverns are so numerous that they combine to form a peculiar topography, characterised by the presence of small basins. In such topography the drainage pattern is quite, irregular, with streams abruptly disappearing into the ground and then reappearing elsewhere as large springs. It is named after the Karst region in Yugoslavia, where it is strikingly developed.
- Monadnock** : Monadnock is a special kind of erosional landform which represents a residual mass of a country rock of any shape, which has not been reduced to the general level of the peneplain during the late stage in the erosional history of a region.
- Potholes** : Highly turbulent streams excavate potholes and rocky channels. These are cylindrical holes drilled in bed rock by abrasion, where an eddy swirls pebbles and sand grains in spiral paths.
- Scheelite** : Tungsten ore, a fluorescent mineral.
- Sericite** : Fine scaly muscovite, united in fibrous aggregates and characterised by silky lustre.
- Zoning of minerals** : Spatial distribution (both horizontal and vertical) of minerals around a primary source.

UNIT : 6 STRATIGRAPHIC AND LITHOLOGICAL GUIDES

Contents

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- 6.1 Introduction
- 6.2 Stratigraphic and lithological guides
 - 6.2.1 Syngenetic and Epigenetic Criteria
 - 6.2.2 Reasons for favourability
 - 6.2.3 Competent Vs Incompetent Formations
 - 6.2.4 Indian Examples of favourable formations
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 - 6.3.1 Mechanical Principles of Fracturing
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 - 6.3.7 Contacts
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- 6.4 Summary
- 6.5 Check Your Progress -Model Answers
- 6.6 Model Examination Questions
- 6.7 Glossary

6.0 OBJECTIVES

In this Unit, the stratigraphic and lithological guides in mineral exploration are described.

After completing this unit, you will able to

- explain the stratigraphic and lithological guides
- describe the techniques to search for ore deposits by Lithological and Stratigraphic guides.
- explain the differences between the syngenetic and epigenetic criteria.

6.1 INTRODUCTION

If ore occurs exclusively in a given sedimentary bed, the bed constitutes an ideal stratigraphic guide. If the host rock is not a sedimentary formation but an intrusive body or a volcanic flow, the same principles are applicable so far as ore search is concerned, but, since in such cases the guide cannot properly be called stratigraphic, the term lithologic is more appropriate.

Therefore if ore occurs in a sedimentary bed or alternatively in an igneous intrusive at a place, they serve as excellent stratigraphic or lithologic guides for ore search. The stratigraphic sequence of the sedimentary bed can be easily determined either from the geological map or by actual field work and the presence of the bed elsewhere can be predicted and search may be made for the ore. For instance, in India, economic deposits of hematite iron ores are found in rocks of Iron ore series in different parts of the country. Iron

ore series, therefore, serves as a good stratigraphic guide. Stratiform igneous rocks like pyroxenite intrusive body of Jojohatu, Singbhum, Bihar contain chromite seams of varying size. Such layered ultrabasic intrusives serve as valuable lithological guides in ore search.

6.2 SYNGENETIC AND EPIGENETIC CRITERIA

The ore may be syngenetic (an integral part of the body of rock) or epigenetic (introduced into the rocks subsequently). This distinction is not only of academic interest, but also important from the practical point of view of a prospector, because of its economic implications. Often the prospector is obliged to judge the degree of confidence, that a given stratigraphic guide inspired and (still more important) to predict what places within the favourable formation are most likely to be ore bearing. Economic considerations require answers to such questions, which depend on the mode of emplacement of the ore and the factors that have determined its present position. In this respect the syngenetic and epigenetic cases are in sharp contrast with each other and consequently require separate consideration

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. Bring out the differences between syngenetic and epigenetic deposits.

6.2.1 Syngenetic Deposits

Exploration in syngenetic deposits is relatively less complicated, compared to epigenetic deposits. If the ore is an integral part of a body of rock, the rock itself serves as a guide, that is, the ore search is limited or confined to that particular rock formation. The localisation is most precise in layered rocks, especially in sediments, but it is useful even in homogenous, igneous rocks. If the ore consists of a bed in sedimentary formation, one need only to know the stratigraphic sequence and the structure of the beds in order to predict where the outcrop will be found or at what depth will the ore will be at a given place.

For this purpose, a structure contour map is the most convenient device for depicting the shape of the ore bed and projecting its positions. The problem is simple in beds that have suffered little folding, but intricacy arises, when the structure becomes more complex, so that ore search may require the solution of difficult problems in post-ore folding and faulting. In the case of syngenetic deposits, localisation of ore is not controlled by intersecting loci such as shear zones, breccia zones etc. (which are so important in epigenetic deposits) but is determined by the conditions of sedimentation, that prevailed when the beds were deposited. Such conditions include not only the shape and extent of basins of accumulation but also the position of unconformities. Syngenetic deposits of igneous origin are usually less regular than sedimentary beds. However, in some thick sills and lopoliths, the rock constituents have

a very regular stratiform arrangement, as been in the case of some chromite occurrences. In less regularly shaped intrusives, syngenetic ore deposits may be erratic in distribution, but even then, the fact that they are confined within the igneous body, serves as a useful guide in delimiting the field of search. For instance chromite ores are confined to bodies of mafic rocks or to serpentines derived from them. One need not search for chromite in other rocks, nor in serpentine of other origin.

In pegmatites the metallic minerals (if they can be truly described as syngenetic) are probably erratic in distribution. However, in many pegmatites the constituent minerals form rude zones from a micaceous cleavage adjoining the host rock through graphic granite and/or perthitic feldspar to a central core of quartz. Pegmatites of Nellore belt, Andhra Pradesh and Gudalur belt, Tamilnadu which occur as dykes, vein like injections and lenticular segregations, contain valuable industrial minerals like mica, apatite, topaz, tourmaline etc. and minerals containing rare metals like beryl, columbite-tantalite, wolframite, scheelite, molybdenite, lepidolite, spodumene, samarskite, allanite, monazite, zircon etc. They are both unzoned (homogenous) and zoned. The mica pegmatites of Nellore belt occur in Dharwar hornblende schists and amphibolites and associated mica schists. If pegmatite rock serves as a lithologic guide, Dharwars serve as a stratigraphic guide in prospecting for mica here. Mica pegmatites of Gudalur belt, Tamilnadu occur on the Wynad plateau also are localised within Dharwar mica schists. The mica in the zoned pegmatite is generally localised as disseminated books in the intermediate zone of coarse feldspar between the quartz core and outer fine grained quartz-feldspar zone and in the case of unzoned pegmatite, it occurs as disseminations in the homogenous pegmatite rock.

6.2.2 Epigenetic Deposits

Ore that has been introduced into rocks may show strong partiality to certain formations, whether the ore flows fractures or replaces formations bodily. Replacement ore bodies differ from most sedimentary (syngenetic) deposits in that not all of the favourable stratum is ore replacement within the bed is often controlled by some additional loci which may consist of fold axes, fractures or veins.

The favourable formation need not be sedimentary in origin, volcanic flows or thin brecciated tops may play the same role as waterlaid strata or need the formation be stratiform at all. Igneous dykes or sills or in fact intrusives of any shape may constitute favourable formations

6.3 REASONS FOR FAVOURABILITY

The reason why one rock is more receptive to ore than another is not always evident. On theoretical grounds, two conditions are expected to be favourable: (1) permeability which allows passage of solutions, and (2) chemical reactivity, to induce precipitation of ore minerals. The two conditions may be combined in the case of a soluble rock through which solutions can eat their own way by chemical reaction. Permeability may be either a primary property of a rock as in sandstones, conglomerates or vesicular lava tops or it may be imposed by fracturing or shearing. The influence of physical properties (especially permeability) or chemical properties (especially reactivity) is rarely predictable in advance of exploration.

Thus, if a porphyry and a limestone occur together, the ore may favour the porphyry, because of more open fractures in it, or it may favour the limestone, which is more hospitable chemically. Although limestones are normally very receptive to ore, there are cases in which

ore shuns them and deposits in rocks, which might ordinarily be considered as poor hosts. Thus at Mount Isa (Queensland) the great lead-zinc deposits occur in shale while limestones in the region have not been mineralised.

There is some indication that certain host rocks show preference for specific metals. Limestones are especially hospitable to lead and zinc but relatively unreceptive to gold. Quartzite is also a good carrier of lead-zinc ores in some places. Even here between the two metals, instances quoted by Mc Kinstry show that lead prefers more siliceous rocks namely quartzites in contrast to zinc confining to slates, when both types of rocks exist in an area. There may be a chemical reason for this preference. The rocks most receptive to gold seem to be those containing chlorite or other minerals of similar composition. There are more gold deposits in chloritic slates and phyllites and basic to intermediate igneous rocks than in quartzites, rhyolites or limestones.

Susceptibility to replacement is often a matter of delicate if not obscure control. Why replacement should, for example, single out certain beds within apparently uniform limestones is a question that has aroused much inquiry but has received no conclusive answer. Some consider that dolomites are more favourable than calcareous limestones, but this relationship is not universal. In silicified limestones, a proportion of silicate to carbonate of 1:1 is more favourable than either pure carbonate on the one hand or highly silicified rock on the other. An optimum size of pore space, neither too large nor too small is a determining factor.

It is probable, however, that the mineralogy and the texture of the rock, though important, do not tell the whole story, and the manner in which individual beds behaved during the folding may hold part of the secret. Delicate differences in relative competency could control the manner in which individual beds are prepared to receive the ore solutions.

6.4 COMPETENT VERSUS INCOMPETENT FORMATIONS

In some areas, at least, competent rocks are more hospitable to ore than incompetent ones, and surely this is what would be expected from their mode of failure in fracturing. The term 'competent' refers to rocks which are relatively strong but, when they fail, break as though they are brittle in nature. 'Incompetent' refers to rocks which are weak and have a tendency to deform plastically or by flow. Quartzites, conglomerates and fresh igneous rocks are competent rocks. Incompetent rocks are shales, slates, schist and limestones, also igneous rocks that have been altered to sericite, chlorite or serpentine. These generalisations, however, are subject to some modifications with varying circumstances. In the first place, competence is a relative matter. A limestone between shale beds is likely to behave as a competent rock, an identical limestone between beds of quartzite is likely to behave incompetently. In addition, the manner of failure depends in some degree on the manner in which the rocks were deformed. A limestone under light load may behave as a competent rock, but under high confining pressure, especially in the presence of solvent and with the rate of deformation slow enough to give time for recrystallisation, it may behave as incompetent material.

Competent rocks, in addition to their tendency to fail by fracture rather than by shear, have an advantage to yield to fracturing in such a way as to provide permeable channel ways. When competent rocks shatter, they produce either a network of interconnected cracks or a permeable breccia free from gouge. In spite of the superior mode of failure of competent

rocks, it is not everywhere true that they are the most hospitable to ore deposition. At Bengigo (Victroia), incompetent slate beds have localised slipping, on the limbs of anticlines where they overlie competent quartzite beds, and form the sites for quartz veins which carry visible gold.

6. 5 INDIAN EXAMPLES OF FAVOURABLE FORMATIONS

A brief review of the favourable formations from Indian context would show how they could serve as stratigraphic or lithological guides, besides throwing light on the possibility of certain host rocks showing preference for specific metals.

Typical sedimentary mineral deposits occurring within the Precambrian rocks of South India are the limestones (cement, flux and chemical grade) and dolomites (flux and refractory grade) occurring in the Cuddapah and Kurnool formations in the Cuddapah basin of A.P. The main horizons are the dolomites of Vempalli stage (Lower Cuddapah) and the Nargi limestones of Jammalamadugu stage (Kurnool) distributed in Cuddapah, Kurnool, Mahaboobnagar, Guntur and Krishna districts. The dolomites of the Pakhal system in Khammam district, A.P and the limestones and dolomites of Bhima series in Ranga Reddy district, A.P and Gulbarga (Karnataka) districts also come under this category. The Auk shale stage at the base of Paniam quartzites (Kurnool) in Kurnool district, A.P also carries at many places sedimentary clays and ochers of economic value. Recent studies in the Cuddapah basin have also shown places of phosphorite in the Cherty Vempalle dolomites and an intensive search is now under way for possible occurrences of phosphorite in the limestones and dolomites of other basins.

Another important sedimentary deposit in South India is the occurrence of diamonds in the Banganapalle conglomerates at the basal part of Kurnool system in Kurnool and parts of Mahaboobnagar, Prakasham, Guntur and Krishna Districts in A.P. Though diamonds are known in these conglomerates all over the Cuddapah basin, there are two important E-W trending diamondiferous belts: (1) between Banganapalle and Munimadugu, and (2) between Ramalakota and Yembayi in Kurnool district where ancient mining for diamonds was concentrated.

Some of the lead-zinc and copper deposits namely Agnigundala, Vummidivaram, Varikunta at Zangamarajupalle occurring in the Cuddapah basin of A.P show excellent stratigraphic, lithological and structural control in ore deposition. The most typical of these is the Agnigundala lead and copper deposits in Guntur district. There are three major deposits of base metals in the belt consisting of the Bandalamottu lead copper deposits, Nallakonda copper deposit and Dhukonda copper lead deposits, in addition to minor deposits of mainly lead ore at Karampudi and other places. The deposits reveal good stratigraphic and lithologic controls which conformable to bedding planes in greyish white, partly cherty, non-argillaceous dolomites in the case of Bandalamottu and other lead deposits, and coarse, grained, calcareous quartzites within fine grained non-calcareous quartzites in the case of Nallakonda and Dhukonda copper deposits. Locally the ore follows shear fracture and breccia zone cutting across bedding. In the case of Vummidivara lead deposits, the ore is localised along stratigraphic horizons of narrow beds of quartz-breccia intercalated within fine grained massive quartzites, occurring in Cumbum phyllites and argillites. At Varikunta and Zangamarajupalle, the mineralisation is restricted to the narrow stratigraphic horizon dolomite and is completely absent in the underlying and overlying Cumbum shales and argillites.

The favourable formations and their associate metals reveal certain interesting and fascinating aspects for further study, besides merely serving as stratigraphic and lithologic guides for ore search. Either the occurrence of lead in cherty and nonargillaceous dolomites and its absence in shales and argillites or the adherence of copper to calcareous quartzites within the non-calcareous quartzites is in accordance with some of the earlier observations made by J.S. Brown.

Preference of dolomite to pure limestone or preference of silicated limestone (or calcareous quartzite as here) to pure limestone or quartzite by ore bearing solutions seems to be also true in the localisation of above mentioned base metals of Indian origin. A further study on some of these geochemical affinities might throw more light in disputed origin of some of these base metal deposits.

6.6 SUMMARY

In this Unit, we have discussed the stratigraphic and lithological guides in mineral exploration. Association of ore deposits with a specific lithological unit belonging to a particular stratigraphic sequence constitute lithological and stratigraphic guides for exploration of mineral deposits. The deposits may be either syngenetic or epigenetic in nature. Each type has its own identifiable features. A few Indian ore occurrences have been cited as examples of manifestation of lithological and structural controls.

6.7 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Syngenetic deposits are those formed at the same time as the enclosing rock. Where as the epigenetic deposits are those formed later than the enclosing rock.
2.
 - (i) Width of opening
 - (ii) Surface area
 - (iii) Rate at which hydrothermal solutions would pass through.
 - (iv) Hutti gold field
 - (v) Copper -Quartz vein of Gani-Kalava, Kurnool district., A.P .
 - (vi) Agnigundala Copper deposits Guntur, A.P.
 - (vii) Jaduguda, Singbhum Uranium mineralisation.
 - (viii) Lead deposits of Varikunta and Zangamrajupalem.

6.8 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in 30 lines each.

1. Described how syngenetic criteria could be useful in mineral exploration.
2. Give brief account of stratigraphic and lithological guides with Indian examples.
3. Describe the reasons for favourability.

II. Answer the following questions in 10 lines each.

1. Competent and Incompetent beds.
2. Preference of host rocks to specific metals.
3. Epigenetic deposits

6.9 GLOSSARY

- Allanite : Rare earth silicate with certain metals Ce, Di, La, and with minor amounts of Yttrium group, characteristically found in deep seated igneous rocks and pegmatites.
- Columbite -Tantalite : Niobate and Tantalate of iron and manganese passing by insensible gradations from normal columbite to normal tantalite. Iron and manganese also vary widely; commonly occurs in pegmatite veins.
- Epigenetic Deposit : A mineral deposit which is formed subsequent to the enclosing rock or geological formation.
- Lepidolite : Lithium Mica
- Samarskite : A rare mineral, radioactive, containing rare earths of cerium and yttrium and also uranium oxide associated with pegmatites.
- Syngenetic Deposit : A mineral deposit which is formed along with the enclosing rock or geological information.

UNIT : 7 STRUCTURAL GUIDES

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- 7.12 Model Examination Questions
- 7.13 Glossary

7.0 OBJECTIVES

In this Unit, structural guides, fracture patterns, contacts and folds as guides in mineral exploration. Are described.

By the end of this unit, you will be able to

- explain the mechanical principles of fracturing.
- describe the vein patterns as guides.
- describe the different structures as guides - enechelon, cymoid and horsetail structures.
- explain the role of contacts and folds in the localisation of ores and their importance as guides in mineral exploration.
- explain the folds of different ages, which have considerable influence on the occurrence of ore deposits.

7.1 INTRODUCTION

Fractures form the channel ways for entry of solutions, the receptacles for deposition, and the starting places for replacement. In vein deposits, fractures are the dominant control, but even in most disseminated and replacement deposits, fractures have exerted a noticeable influence

on the forms of ore bodies. The shapes of fractures and of fracture systems, therefore, provide the key to the structure of many types of deposits.

Fractures are not just accidental. They are the result of failure in a rock mass that has experienced stress. Therefore they are formed in response to physical laws. Unfortunately there is much that we have yet to learn about the operation of these laws, and we are still unable to explain why, under apparently identical stress conditions, some materials fail in one way and some in another. In other words, we do not have a satisfactory theory of rupture. Nevertheless, we do know both from experiment and from observation that the surfaces along which materials fail have at least qualitative relation to the orientation of the stress.

Complete data regarding the acting stress and also the knowledge regarding the strength distribution in the rock, would enable us to predict the general shape and in some cases the detailed shape of the pattern of fractures. But we rarely have this full information, yet some of the data can be deduced from observation. Interpreted with the knowledge of how rocks are known to fail, it often permits the completion of a partly concealed pattern and a prediction as to which portions of the pattern will be most productive.

7.2 MECHANICAL PRINCIPLES OF FRACTURING

Stress, the pattern of principal stress planes, uniform versus non-uniform stress, relation of fractures to stress and causes for variation in fracture patterns are described here.

7.2.1 Stress

If a body of material is deformed within the elastic limit, each part of it exerts force on the adjoining part. This internal force is called stress, and it can be resolved into shearing and normal components. If we select any point within the body and pass through this point an imaginary plane, there will be a component of the force, which tends to make the material on one side of the plane slide over the material on the other side, i.e., a shearing component.

There is also a component, which tends either to press the sides of the plane together or to pull them apart, i.e., a normal component. If the tendency of the normal component is to pull apart, it is called tensile stress. If it is to squeeze together, the normal component is called compressive stress.

7.2.2. The Pattern of Principal Stress Planes

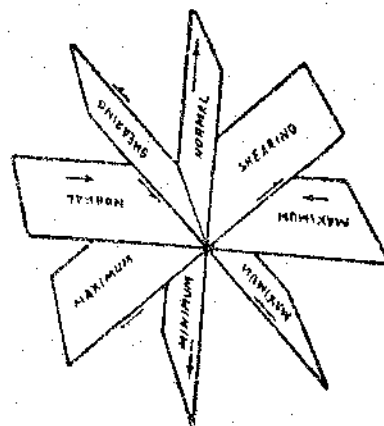


Fig. 7.1 Planes of Principal Stress (idealised diagram after Mc Kinstry)

Every point in a stressed body has four critical planes. Two of maximum shear, one of maximum normal stress and one of minimum normal stress (refer idealised diagram in Fig. 7.1). The four planes all intersect in a common line and stand at 45° at each other. This is true regardless of the manner in which the body is loaded (whether it is acted on by compression, by tension or by a shearing couple). It is also true regardless of whether the body is homogenous or heterogeneous and regardless of whether the stress is uniform or non-uniform.

7.2.3 Uniform Versus Non-Uniform Stress

If the stress is uniform, the critical planes have the same orientation at all points within the body, therefore the state of stress for the body as a whole can be represented by a single diagram. If the stress is not uniform, the orientation of the assemblage of the stress planes varies from point to point. Yet, at anyone point they are always at 45° to each other. Of non-uniform stress, there are infinite modifications. Two familiar varieties, whose distribution is systematic, are known as bending and torsion. These are not, in effect, different kinds of stress, but merely different types of variation of the stress orientation, for at anyone point, the stress can be resolved into its normal and shearing components. Of these two, torsion requires some elaboration. Torsion is a special type of loading which is best described by the simple example of a rod held in a vice at one end and twisted by a pipe wrench attached to the other end. Loading analogous to this can hardly be very common under geological conditions although it must be involved in some large scale warping of the earth's crust and in the kind of deformation that causes scissors-fault movements.

7.2.4 Relation of Fractures to Stress

With this background of mechanical principles, let us turn to our rocks and see what relation the fractures bear to the stresses that cause them. There are two typical modes of failure by fracture tension and shear. The resulting fractures are thus named after the stresses and we have the shear fractures and tension fractures. Whether a rock fails by one or the other or by a combination of the two depends on the nature of the rock and the conditions of deformation, although not enough is known about the governing laws to permit exact predictions.

7.2.5 Causes for Variation in Fracture Patterns

Since fractures can be expected to correspond to the pattern of stress only if the material is homogenous, it follows that any inhomogeneity in the rock will cause irregularities in the fracture pattern or add new elements to it. Of course, no rocks are truly homogenous in the physical sense; the nearest approach that we can expect is 'statistical homogeneity', in which irregularities such as grains or crystals are small in proportion to the dimensions under observation and are oriented at random so that the directional properties of individual grains tend to cancel out each other. It is significant that the closest resemblances to ideal fracture patterns are found in large masses of igneous rocks, as these come nearer to being statistically homogenous than do bedded sediments or metamorphics. The most conspicuous feature which interrupt homogeneity are (1) surfaces of weakness (pre-existing fractures, bedding planes, and igneous contacts). (2) members of a rock mass having contrasting strength characteristics (beds, dykes, sills) and (3) anisotropic rocks (slates, schists, gneisses).

7.3 VEIN-PATTERNS AS GUIDES

A proper understanding of the vein patterns is a must for mineral exploration. Once the vein pattern is clearly understood, the next step is to see whether it can be analysed in terms of a

stress pattern, using not only the space relations of the veins but indications of any pre-displacement, however small, that may have taken place along them and any details of vein structure indicating shear or tension phenomena. Most important of all is to correlate the pattern with geological features, rock formations that have been particularly hospitable or inhospitable to fracturing, surfaces of weakness that have deflected veins from their general course, and attitude of fractures with relation to bedding and folds. An understanding of the origin and mechanics of the vein pattern not only inspires greater confidence in the conclusions but permits more intelligent predictions. To quote Mc Kinstry, if we know why a vein makes are under certain conditions, we are in abetter position to predict where it will make ore again.

7.3.1 Typical Vein Patterns

The various types of vein patterns are described by Bateman (1960); and Mc Kinstry (1948). When a fracture or fissure is filled up with mineral matter, it is called as vein. Veins are tabular bodies, long in two dimensions and short in the third and are formed along cracks and fissure zones and are favourable loci of ore deposition. Individual varieties of fissure veins include, simple, composite, linked, sheeted, dilated and chambered. Each of these may be massive or crustified (Fig. 7.2).

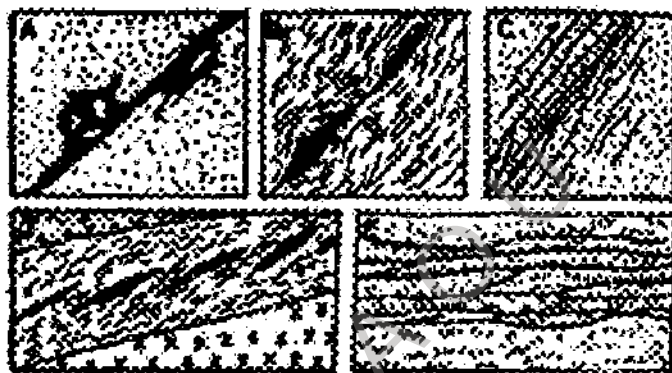


Fig. 7.2 Varieties of Fissure Veins. A. Chambered Vein (After Becker); B. Dilated Veins in Schist; C. Sheeted Vein; D. En echelon Veins in Schist; E. Linked Vein (after Bateman)

The simple fissure vein occupies a single fissure whose walls are relatively straight and parallel. Where the walls are irregular and brecciated, particularly the hanging wall, owing to formation under light load near the surface, it is often called a chambered vein. Dilated or lenticular veins are fat lenses in schists. Generally several occur together, like a string of sausages, or they may be disconnected en echelon lenses. They are thought to be caused by the bulging or dilation of schistose rocks due to pressure transmitted by the mineralising solutions. Some are due to the pulling apart of a pre-existing vein during later metamorphism of the enclosing rock. In width they range from a few inches to several tens of feet. A group of closely spaced, distance, parallel fractures is a sheeted vein. Each fracture is filled with mineral matter and is separated by layers of barren rock, and the whole is mined as single deposit lode, whose width may be several tens of feet. If individual fractures are linked by diagonal veinlets a linked vein is formed. A composite vein or lode is a large fracture zone, upto many tens of feet in width, consisting of several approximately parallel ore-filled fissures and connecting diagonals, whose walls and intervening country rock have undergone some replacement.

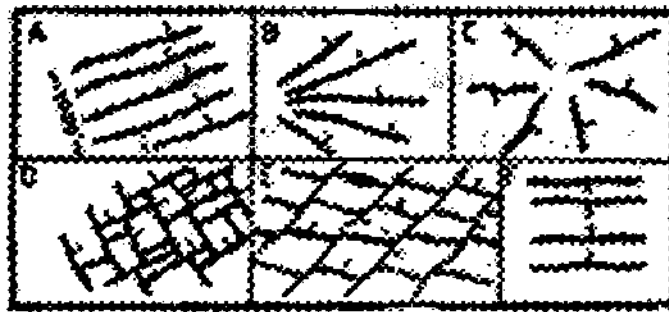


Fig. 7.3 Classes of Fissure Systems. A. Parallel System; B. Fan shaped; C. Radial; D. Intersecting Cognate; E. Intersecting Systems, F. Conjugated (after Bateman)

Fissures seldom occur one but tend to occur in groups (Fig. 7.3), giving rise to the various vein patterns. If the fissures of a group are of the same age and have approximately parallel strike and dip, they constitute a fissure system or vein pattern. Fissures formed at the same time are cognate fissures, those with parallel strike but intersecting dip are said to be conjugated. Different systems may intersect each other, there are instances where as many as seven such systems have been recognised. Two intersecting systems may differ in age or they may be cognate and of the same age. Those differing in age generally displace each other, carry different ores, those of the same age carry similar ores and do not fault each other. To distinguish between them is most important.

Sometimes two sets of veins may intersect each other in the form of a grid, which may be rudely rectangular or oblique. Instead of crossing each other, the veins may form a Y-shaped pattern or they may form a linked system consisting of parallel veins joined by diagonal branches. Some what similar are braided systems in which two veins run parallel for a space, then join, then separate and become parallel once again after the design of a chickenwire mesh.

Some what less common than patterns marked by two dominant trends are patterns of three or more at places, where the system is highly complex, yet has some aspects of symmetry. In some patterns the veins are curving rather than even approximately straight, swinging from one direction to another. From these patterns, in which some resembles of orderly arrangement is discernible, there are all gradations into patterns in which the veins seem to lie helter-skelter with no recognisable scheme.

7.3.2 Vein Structure within the Pattern

Within the broad framework of the pattern of a district, the individual veins are vein groups have their own characteristic shapes. Like the major patterns, they vary from one district to another, but a few typical structures are familiar through repetition.

Eg. En-echelon cymoid and horsetail structures (Fig. 7.4). The shape of veins controls localisation of ore in them.

Deposition of ore in veins will depend up on (1) width of opening, so that sufficient ore bearing fluids may pass through freely, (2) Surface area so as to enable the solutions to come into contact for reaction with host rocks and induce precipitation, (3) rate at which hydrothermal solutions would pass through. Ore bearing fluids pass at a comparatively slower rate through zig-zag or curved fractures in comparison to straight ones and thus the opportunity of the fluids to react with the wall rock is more and hence the chances of

Jaduguda, Singbhum uranium mineralisation appears to have been controlled by minor cross folds, thicker and richer lodes have developed in their synclinal portions while the lean and very poor ones occur in their anticlinal warps.

In the lead deposits of Varikunta and Zangamarajupalle, Cuddapah district, A.P., the ore bodies resemble typical 'pitch and flat' type deposits, localised in the vicinity of steep dipping en-echelon shear-fracture zones in the folded dolomite.

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. Give five examples of Indian deposits, which are controlled by structure.

7.10 SUMMARY

In this Unit, we have discussed about the structural guides, fracture patterns, contacts and folds as guides.

Fractures produced under the action of stress are of different types. They depend also on the nature of the rock masses i.e. homogenous or heterogeneous. Fracture systems are classified on the basis of their pattern or shape. They are good receptacles for ore deposition and hence constitute guides to ore deposits.

The contacts of various rock formations with intensives or within themselves will form potential zones for localisation. The folds, major as well as minor, act as channel ways for solutions as well as sites of deposition. The recognition of these features will enable to locate the ore deposits.

7.11 CHECK YOUR PROGRESS - MODEL ANSWERS

1.
 - (i) Width of opening
 - (ii) Surface area
 - (iii) Rate at which hydrothermal solution would pass through.
2.
 - (i) Hutti gold field
 - (ii) Copper -Quartz vein of Gani & Kalava, Kurnool district., A.P.
 - (iii) Agnigundala Copper deposits Guntur A.P.
 - (iv) Jaduguda, Singbhum Uranium mineralisation.
 - (v) Lead deposits of Varikunta & Zangamarajupalle.

7.12 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in 30 lines each.
1. "Fractures are not purely accidental, but are formed in response to physical laws" - Discuss.
 2. Describe the importance of vein patterns as guides to ore search.
 3. Describe how contacts could be useful as guides in mineral exploration. Mention a few Indian examples.
 4. Describe how folds could serve as practical guides in exploration of syngenetic and epigenetic deposits, with suitable examples.
- II. Answer the following in 10 lines each.
1. Write short notes on the following indicating their importance in mineral exploration.
(a) En-echelon Structure
(b) Cymoid Structure
(c) Faults of minor displacement
 2. What is the significance of folding of epigenetic ore formation?
 3. What are the structural guides for gold deposits of Kolar Goldfield?

7.13 GLOSSARY

- Anisotropic rocks** : Some rocks such as uniform slates and schists, are homogenous in the sense that they lack contrasting layers. However, they are weaker in some directions than in others. In such rocks, which may be termed anisotropic, a uniform stress produces non-uniform strain.
- Braided system of Pattern** : Vein pattern similar to a braided stream which flows in two or more interconnected channels - Braided pattern is one where two veins run parallel for a space, then join, then separate and become parallel again resembling a chicken-wire mesh.
- Contact-metasomatic deposits** : Contact effects of intrusive magmas have been divided into two types. (1) Effects of heat without appreciable magmatic accessions giving rise to contact metamorphic deposits (2) effects of heat combined with magmatic accessions giving rise to contact metasomatic deposits, where new minerals are formed (Bateman, 1960). Lindgren uses the term pyrometasomatic for contact metasomatic deposits.
According to Mc Kinstrey, the effects do not seem to be restricted or localised to contacts but extend for over long distances.

Cymoid Lens

: Cymoid structures commonly occur in pairs, forming a cymoid loop. That is a vein splits, one branch swerving aside to execute a reverse curve while the other branch continues straight for a short distance and then executes a similar curve to rejoin the first branch. The two branches thus enclose a lens of wall rock shaped somewhat like the cam of a stamp mill-called cymoid lens.

Pitches and Flats

: Deposits formed in induced cavities created due to folding and warping. Such deposits lie on inclined limbs and flat portions of the folds. Pitches, which are highly inclined and flats are openings formed by the parting of beds under gentle slumping.

Saddle-reef

: Deposits formed due to induced cavities created by folding and warping. Eg: Bendigo Saddle Reefs, Australia. Induced openings, created by alternating competent and incompetent beds such as quartzite and slate, which are closely folded, when filled by ore resemble the cross section of a saddle hence their name.

Shears

: In the elementary sense of the word, a shear is a plane (or curved) surface on which one wall has moved past the other. Shears, when closely spaced, constitute a shear zone, which consists of slabs of silvers of rock.

Tensile Stress

: Normal component of stress, which pulls the body apart.

UNIT : 8 SAMPLING AND ESTIMATION OF ORE RESERVES

Contents

- 8.0 Objectives
- 8.1 Introduction
- 8.2 • Methods of sampling
 - 8.2.1 Channel or Groove sampling
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 - 8.2.3 Muck or Grab Sampling
 - 8.2.4 Wagon Sampling
 - 8.2.5 Drill hole sampling
- 8.3 Reduction of Bulk Samples
- 8.4 Errors in sampling
- 8.5 Theory of sample weighing
- 8.6 Estimation of ore reserves
 - 8.6.1 Geometric methods
 - 8.6.2 Graphic methods
- 8.7 Summary
- 8.8 Check Your Progress - Model Answers
- 8.9 Model Examination Questions
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8.0 OBJECTIVES

In this unit, different methods of sampling and estimation of ore reserves by geometric and graphic methods are described.

After completing this unit, you will be able to

- explain sampling and its methods
- describe the errors in sampling
- explain the methods of estimation of ore reserves

8.1 INTRODUCTION

The evaluation of a mineral prospect or mining property requires examination of chemical and physical characteristics of the ore or mineral as accurately as possible. The value of the prospect or prosperity depends upon the value of the ore. 'Sampling' generally makes this determination. Sampling is the process of taking a small portion which shall be representative of the whole. The consistency is generally known as the assay value of the ore. Although the usual reason for sampling a mine or a mineral property is primarily economic, the resulting assay returns constitute data of a truly geologic character. The results of sampling are much more quantitative in their nature than most other available geological data. If geology benefits from sampling, it also contributes to it, for sampling can never be reduced to blind rules of thumb, but must be carried out in conformity with geological principles.

In an actual ore body, the accuracy of sampling depends not only on the number of samples but also on proper distribution of them throughout the ore body, because it would obviously

be incorrect to take all of the samples either in a rich part or lean part. Therefore, it is important to select the places in such a way that all parts of the ore body will be represented.

The kind and amount of sampling depend upon the type of deposit and the degree of development, whether the property is a prospect, an exploration or partly or fully developed mine. Sampling may be done at any exposed surface of the ore body, such as outcrops, shafts, drifts, crosscut or rises in the ore. Test pits or drill holes may be sunk for the express purpose of obtaining samples. Because of the weathering, samples taken from outcrops are rarely representative of the unaltered ore.

The theory of sampling is that, if enough small portions of an article, properly spaced, are taken, their average value of consistency will approximate that of the whole very closely. Sampling should be, as nearly as possible, a mathematical - mechanical process, and a mechanical collection of material at mathematically spaced intervals. It is not and never should be considered a haphazard procedure.

8.2 METHODS OF SAMPLING

The purpose of sampling includes:

- 1) Determination of average grade for a particular tonnage
- 2) Study of economic viability of a mineral prospect and
- 3) Estimation of reserves in proved deposit.

Whatever be the purpose, care should be taken to see the changes in chemical and mineralogical nature of the ore, structure, texture, size of individual particles, degree of variation in the distribution of values from point to point. These vary so greatly that no set procedure can be prescribed. Each deposit presents an individual problem.

The following conventional methods of sampling are used for different purposes.

- a) Channel or groove sampling
- b) Chip sampling
- c) Muck or Grab sampling
- d) Car or Wagon sampling
- e) Pit /trench /borehole or drill hole sampling.

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 are the different purposes of sampling?

8.2.1 Channel or Groove Sampling

This method consists of cutting channel across the face of exposed ore and collecting chips, fragments and dust from each channel to makeup a sample. Channelling consists of cutting grooves of uniform section across the face, usually at right angles to the formation. The customary size of the groove is from 1.5 to 4" wide and about 1" deep, depending on the nature of the material. Hammer and Moil are generally used to cut the sample

The spacing of channels is highly important; the intervals must be close enough to yield a representative part of the whole. In general, the sample spacing will be closer for irregular ore deposits and for uniform ore deposits, the greater may be the sample interval.

8.2.2 Chip Sampling

In chip sampling a series of chips of rock is taken either in a continuous line across the exposure or at random intervals. It is less laborious than channel sampling and is usually adopted when 1) quick preliminary results are needed or 2) the ores are hard and uniform, and difficult to cut a channel.

8.2.3 Muck or Grab Sampling

A grab sample of the muck pile after blasting is sometimes taken instead of a channel sample of a face. Pieces of rock of convenient size are picked up in this method. This method gives correct results in some ores, whose values are evenly distributed or are independent of breaking qualities.

8.2.4 Wagon Sampling

A shovel full of ore or a series of pieces selected at random or according to a pre-arranged system is taken from each car that comes from the mine. A check may be obtained by averaging all car samples for a day and comparing with the mill head sample, which is likely to be more correct, especially if taken by automatic methods after crushing.

8.2.5 Pit/Trench/Bore hole or Drill hole Sampling

In mineral exploration, pitting, trenching and putting bore holes or drill holes are quite common and samples have to be taken carefully. Depending upon the nature of the deposit different methods of excavation are needed to expose the ore body for study.

If pitting or trenching is adapted to bedded deposits, deposits extending in depth, require bore holes or drill holes. In the case of drill holes one has to study the core, chips as well as sludge samples to get an average.

8.3 REDUCTION OF BULK SAMPLES (CONING AND QUARTERING)

By whatever method the samples are collected, they can be reduced to the required size by the process called coning and quartering. Loose and powdered samples are heaped to form a cone. The cone is quartered by means of two plates. One set of opposite quadrants is taken and the other is rejected.

The process is repeated every time alternating the quadrants until the required size is obtained. The one obtained at the end will represent the total bulk sample taken.

8.4 ERRORS IN SAMPLING

Sampling results may go wrong at anyone of the several points during the process of estimating ore values, for one or more of the following reasons.

1. Salted or erroneous samples.
2. In-sufficient number of samples.
3. Improper location of samples.
4. Improper or 'salted' chemical analysis.
5. Incorrect weighing of samples.

Many of these are self explanatory, except 1 and 2, which require elaboration. Salting is the act of raising the value of the sample above that of the ore exposure from which it was taken. It may be intentional or unintentional. Weighing of samples and their assay values is most important and is described below separately.

8.5 THEORY OF SAMPLE WEIGHING

Samples are generally picked up at regular intervals. But this is not always possible because of richer and leaner concentrations and erratic distribution of values in places. Samples therefore may have to be picked up at semi regular intervals (i.e. in one direction it may be regular but irregular in the other) or at irregular intervals. Assay value of each of these samples may be determined. If we merely add up these assay values in a prospect, without looking into the representation of each sample (the samples may represent different lengths or areas) it only becomes an arithmetic average but not the weighted one to represent the true average of the prospect. Each one of these values is limited to the relative length/area it represents and a weighted average has to be obtained by taking the length/area into consideration. Unless a weighted average is obtained, the estimation of the value of the prospect will go wrong.

8.6 ESTIMATION OF ORE RESERVES

It is necessary to compute the reserves of a mineral deposit for its economic appraisal. Ore reserves represent the quantity of ore available in the deposit in tonnes. Estimation of tonnage involves two factors: weight of ore and volume of ore.

The weight of ore is obtained by determining the specific gravity of substances. Specific gravity or density is synonymous terms used to express the weights of substances relative to that of pure water at 4°C. In estimating total values, the specific gravity figure for an ore is not ordinarily used as such, but is converted into a figure representing cubic feet of ore per ton, called the tonnage factor. In the calculation of tonnage factor the unit customarily used for various ores is an item, which must be considered. Iron ore is sold on a long ton (2240 lb) basis, coal particularly anthracite is estimated and sold both on long ton and short ton (2000 lb) basis, whereas the short ton is generally used as the unit for other minerals. The ores are usually estimated on metric ton (2204.6 lb) basis. The tonnage factor of a given ore, of course, varies for each of these units.

The volume of the ore deposit is computed from plan and section maps by the use of planimeter areas or by arithmetical calculation. Multiplication of volume in CGS system by the specific gravity gives directly the tonnage in metric tonnes (since 1 cu cm of water weighs

1 gm). When the total volume is in cubic feet (i.e. in FPS system) it is to be multiplied by tonnage factor (since 1 cu ft of water weighs 62.5 lb). The tonnage factor is determined by the following formula

$$Tf = \frac{2000}{62.5} \times G$$

2000 lbs (on short ton basis)

G = specific gravity of ore

62.5 is the wt. of the Cu ft of water

Thus tonnage = Tf x volume (in cu ft) of ore

Methods for volume determination of ore deposits may be broadly grouped as 1) Geometric methods and 2) Graphic methods.

8.6.1 Geometric Methods

Geometric methods include two categories i.e. uniform spacing on rectangular co-ordinates and uniform spacing on 60 co-ordinates.

A. Uniform spacing on rectangular co-ordinates

There are two methods in this spacing. One is extended or unlimited area method, and the other is included or limited area method.

1. Extended area method: 16 samples are picked up at regular intervals and the area of influence of each sample is 150' x 150'. The total area is 1200' x 1200'. The area multiplied by the average thickness gives the volume (Fig. 8.1).

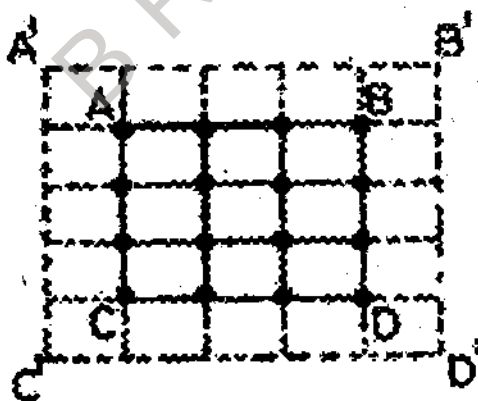


Fig. 8. 1 Extended area method

2. Included area method: In this case the area is limited and the representation of samples vary. The corner samples represent only one quadrant, the side sample 2 quadrants while the interior samples 4 quadrants. In this case the volume is obtained. By multiplying the area 900' x 900' by weighted average thickness and not simple arithmetic average (Fig. 8.2).

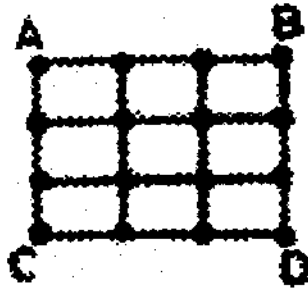


Fig. 8. 2 Included area method

B. Uniform spacing on 60 co-ordinates

When samples are picked up on 60 co-ordinates the area of influence of each sample is a regular hexagon. The representation of samples do not vary. So volume is obtained by multiplying the total area of hexagons with the average thickness of deposits.

C. Semi-regular spacing

When samples are picked up at semi-regular intervals, the area may be extended or included. For the volume calculation in this case, weighted thickness should be taken since there will be variation in representation of samples.

D. Irregular spacing

When the spacing is irregular the volume can be measured in two ways. These are 1) Area of influence method (polygon method), 2) Triangular grouping (arbitrary choice of triangles).

1. Polygon method: When samples are picked up at irregular intervals, the influence of each sample is obtained by drawing perpendicular bisectors to the joining points. These in turn form different polygons representing the areas of influence of each sample.

The areas are computed by planimeter or dividing them into triangles. Area multiplied by weighted average thickness gives volume (Fig. 8.3).

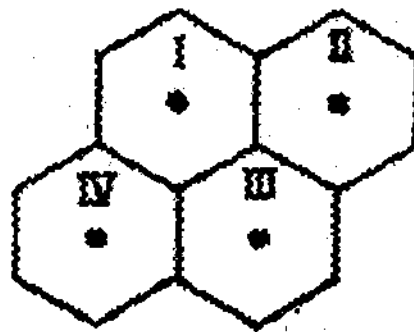


Fig. 8. 3 Polygon method

2) Triangular method: In this case, the sample points are joined arbitrarily to form triangles and their areas are computed. The area multiplied by weighted thickness gives volume (Fig. 8.4).

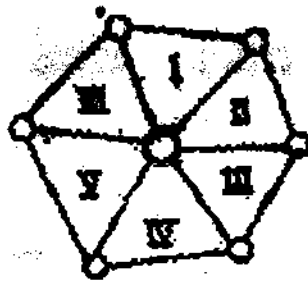


Fig. 8. 4 Triangular method

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 are the different Geometric methods of reserve estimation?

8.6.2 Graphic Methods

The graphic methods include

- Isocore maps
- Stratum contours
- Transverse sections

a) Isocore maps:

Isocore map is one where contour lines represent points of equal vertical thickness. In the figure (8.5) isocore lines having values of 5 m, 7 m and 8 m are shown. The area between the contours 5 and 6 m will have an average vertical thickness of 5.5 m and so on. The areas between two contours are measured separately with the help of planimeter. Each of these areas is multiplied by the average vertical thickness to obtain the volume.

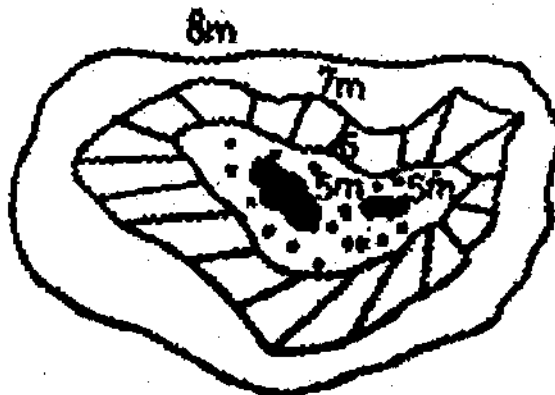


Fig. 8. 5 Calculation of reserves. Isochore Plan

b) Stratum contours:

Stratum contours are the lines joining the equal elevations of bed either for upper or lower surfaces. The figure (8.6) represents upper and lower contacts of a coal bed. The thickness (10 m) is multiplied by the area of the bed to obtain volume.

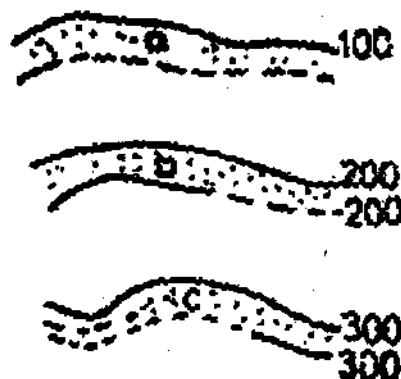


Fig. 8.6 Stratum contours

c) Transverse sections:

Transverse sections are prepared from the data obtained from a number of bore holes, and for each sectional area the reserves are estimated separately (Fig. 8.7). The area of each section is measured by a planimeter and it is multiplied by the thickness of that section to get the volume.

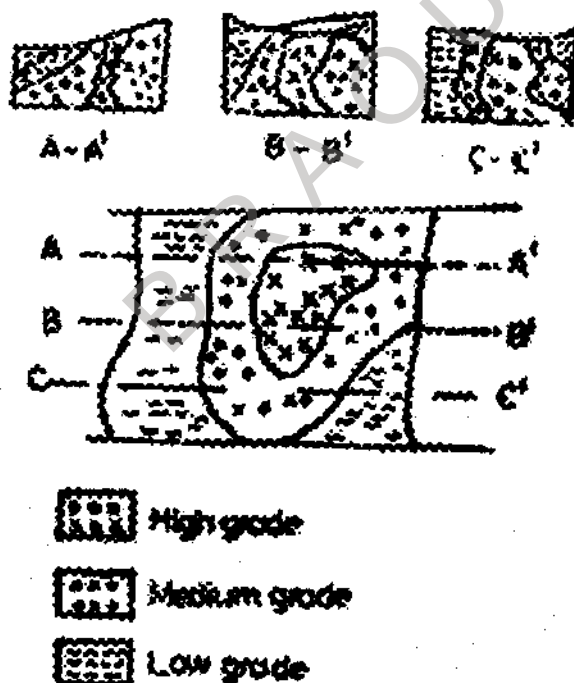


Fig. 8.7 Calculation of reserves by transverse section

8.7 SUMMARY

Sampling is the process of taking a small portion, which shall be representative of the whole. The different sampling methods employed are chip sampling, muck or grab sampling, car or

wagon sampling, pit/trench/bore hole or drill hole sampling. The consistency is generally known as the assay value of the ore. The results of sampling are much more quantitative in their nature than most other available geological data. It is important to select the places in such a way that all parts of the ore body will be represented. By whatever method the samples are collected, they can be reduced to the required size by the process called coning and quartering.

Sampling is carried out for the determination of average grade for a particular tonnage, study of economic viability of a mineral prospect, and estimation of reserves in proved deposits.

It is necessary to compute the reserves of a mineral deposit for its economic appraisal. Ore reserves represent the quantity of ore available in the deposit in tonnes. Estimation of tonnage involves two factors; weight of ore and volume of ore. The weight of ore is obtained by determining the specific gravity of substances. Geometric methods and graphic methods are used for volume determination of ore deposits.

8.8 CHECK YOUR PROGRESS - MODEL ANSWERS

- 1
 - (i) Determination of average grade for a particular tonnage.
 - (ii) Study of economic viability of a mineral prospectively.
 - (iii) Estimation of reserves in proved deposits.
- 2
 - (i) Extended area method
 - (ii) Included area method.

8.9 MODEL EXAMINATION QUESTIONS

I. Answer the following in 30 lines each

1. Describe various methods of sampling techniques
2. What is tonnage factor? Discuss how it is calculated?
3. Describe the different methods in practice for estimating the volume of a given deposit.

II. Answer the following in 10 lines each

1. Significance of sampling
2. Isocore maps
3. Errors in sampling
4. Coning and quartering

8.10 GLOSSARY

Sampling	:	Sampling is the process of taking a small portion of an article, such that the consistency of the portion shall be representative of the whole.
Consistency	:	A term used to denote uniformity in sample characteristics, generally represented by assay

- value of ore.
- Tonnage factor** : Number of cubic feet in one tonne of ore is denoted as tonnage factor.
- Salting** : Salting is the act of raising the value of the sample intentionally.
- Weighting of sample** : The true representative sample so as to represent the whole.

BRAOU

BLOCK -- III MINERAL ECONOMICS -- I

BRAOU

UNIT: 9 PRINCIPLES OF MINERAL ECONOMICS

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9.0 OBJECTIVES

In this unit, the principles of mineral economics are described.

After completion of this unit, you will be able to

- describe the principles of mineral economics
- explain the concept and scope of mineral economics
- describe the minerals and industry

9.1 INTRODUCTION

Minerals constitute wealth of a nation. As early as 300 BC, Kautilya in his classical Sanskrit treatise on Economics (Arthashastra) highlighted that minerals are the source of treasure. The concept of minerals in human history is as old as that of the human civilisation. The names of minerals and the their products have been used to christen various eras of civilization such as the Stone age, the Bronze age, the Iron age and the Nuclear age. The use of minerals has been instrumental in raising the standards of living of mankind. The sophisticated world of today is largely the result of the enlarged use of minerals for various purposes e.g. fertilisers, food, coal, petroleum, natural gas and atomic energy as sources of power, necessities like automobiles, aeroplanes, ships, modern communications and a host of chemicals which are derived from the use of minerals. All engineering and structural materials, machinery, plants, equipment and anything from pins to planes are manufactured from metals and their varied alloys.

The tremendous growth of science and technology has not only led to the discovery of new mineral deposits, but also contributed to the varied uses of the same old known minerals to suit modern needs. Let us take the example of beryl. Only precious varieties of beryl crystals were used by our ancestors as emeralds, leaving the rest. Emerald is one of the nine precious gemstones. With the discovery and isolation of beryllium metal, beryl is today used as a

neutron moderator and is governed by the dynamic energy mineral act. Beryllium oxide is used as a good refractory. Similarly bauxite was known and used in a limited way. The discovery of electrolytic process of extraction of aluminium from bauxite has resulted in the large-scale production of aluminium metal in the world. This, in turn, has contributed to a massive use of the metal for a variety of purposes, in particular as substitute for others in short supply like tin and copper. Today mineral resources have become almost synonymous with industrial power. Industrial power in turn dependent upon ownership of, or access to, large quantities of mineral resources that have become the back-bone of the industrial revolution. Mineral resources have much to do with man, and man with mineral resources. It is surprising to realise that the rise of the industrial age has so accelerated the demand for minerals that the world has dug up and consumed more of its mineral resources in the period shortly before and after World War II and than in all preceding ages. This insatiable demand for minerals to feed industry has made some sources of supply that we used to think were adequate, now look rather small, and sources capable of meeting large demand are being depleted rapidly.

The quest for the wealth of minerals wrested from the earth for man's vanity, necessities or comforts has ever been a powerful incentive to discovery, exploration and trade. Their search has given rise to voyages of discovery and settlement of new lands. Their ownership has resulted in industrial development and in commercial or political supremacy, and has also caused strife and war. A glance at the history development of leading industrial nations reveals that their rise has coincided with the utilisation of their mineral resources, initially coal and iron, for coal is one energy that makes the wheels go around and the wheels are made of iron. Those countries supplied with diversified mineral resources are the ones that become the great industrial nations and the politically and militarily strong ones. Additional nations are joining this group based on their petroleum resources such as the middle east countries; or by purchasing new resources such as Japan; or by the development of vast mineral resources, such as Russia, Australia and Brazil.

9.2 THE CONCEPT AND SCOPE OF MINERAL ECONOMICS

Certain inherent peculiarities of the naturally occurring minerals and their impact on industrial economics have paved the way for the emergence of mineral economics, as a special branch of geology. Certain basic axioms universally recognised have laid the foundation stone for the formulation of national mineral policy. These are:

1. Minerals are depleting assets,
2. Modern industrial economics is based on minerals and mineral products,
3. The boundaries of countries bear no relation to mineral geography and
4. No nation has domestic resources sufficient for its industrial needs.

The pressing needs of mineral production, the intricacies of assuring future supplies, economic evaluation of the deposits, the economics of location of plants in relation to domestic and imported raw materials have become the subject matter of special study. Mineral economics has therefore identified itself to form a special branch of geological discipline requiring special study of the deposits, reserves, utilisation, ore dressing practices, research, planning and development of mineral based industries, trade in minerals and other related problems. Mineral economics can thus be defined as the synthesis of such theories and practices of geological science, political science and economics that are involved in or attracted to the balanced development and management of the country's mineral resources.

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. List out the main axioms for national mineral policy.

9.3 MINERALS AND INDUSTRY

By virtue of their origin, minerals inherit distinct characteristics, which distinguish them from other natural resources. The most important peculiarity is their non-renewable character, unlike fauna and flora. It takes millions of years of time for geological processes to form any useful mineral. Minerals are depleting assets and once mined out, the deposits get exhausted without any chance of replacement. Some of these peculiarities which have serious impact on mineral-based industries are given below.

9.3.1 Localisation

The mineral deposits are not only unevenly distributed in various parts of the earth, but a particular mineral deposit is highly localised in any region in which it occurs. For example, Canada produces about 50% of the world's production of Nickel and comes from the single nickel producing area in the world near Sudbury (Ontario), which is only 24 km long and 32 km wide. Similarly about half of the world's molybdenum production comes from a single large deposit of molybdenite at Climax mine in Colorado, U.S.A.

This uneven distribution of mineral deposits in the crust reflects in the relative self-sufficiency of nations with respect to mineral resources for industrial needs. Even continents and hemispheres on the globe differ greatly in respect of essential mineral resources. A study of the mineral distribution in the world shows that the mineral resources of the Eastern hemisphere excel than those of the Western hemisphere, like ores of manganese, chromium, tungsten, tin and bauxite, petroleum, etc. Similarly the Northern Hemisphere and therefore it includes the most industrialised nations with the best-developed energy resources and the steel industry, which constitute the so-called power belt of the world.

9.3.2 International Character

As a logical consequence of localisation, naturally occurring minerals are not confined to man made political boundaries. In this process, no nation is self-sufficient in respect of mineral resources. This is true of the even most industrially advanced countries like USA and USSR, not to speak of others. They are thus of international character. The unequal distribution of minerals makes certain countries to acquire monopolistic rights in respect of certain deposits, which results in geopolitics and rivalry. This unequal distribution also makes

trade in minerals inevitable and involves political and economic discussion between the countries.

9.3.3 Exhaustibility

Mineral wealth is exhaustible. Once it is mined and consumed, it is lost forever. This gives a characteristic life cycle to a mine. One can find these three distinct life cycles to a mine namely youth (development stage), maturity (firmly established stage) and old age (declining stage). Some of the deposits, originally considered to be of enormous size, have in this process lost their importance due to depletion of the reserves. The only natural cryolite mine at Ivigtut, Greenland, which was under production for a hundred years was closed down in 1962, as the reserves were exhausted. The Cornish tin mines, which was the world's most important source for about 1000 years, is not active now. Many others like the copper deposits of Michigan, USA and Silver mines of Potosi in Mexico have lost their importance.

The practical exhaustion of cryolite, a crucial mineral indispensable in aluminium industry, has led to the discovery of synthetic cryolite by Germans. Similarly the relative paucity of pivotal industrial minerals in nations has led to the development of mineral substitutes in industry. This inherent feature of exhaustibility therefore highlights the crucial importance of mineral conservation in the management of resources.

9.3.4 Mining Problems and Unpredictable Character

Unlike other industries, mineral industry involves mining operation. Depending on the mode of occurrence of the mineral deposit, the mining may be open cast or underground. Mining has its own problems. The unpredictable nature of mineral occurrences, mineralisation, considerable variation in grade in a given deposit, uncertainties of extent and persistence in depth, and the increasing cost of mining with the increase in its depth, make it altogether different from any other industry. In the case of underground mining, the sinking of shafts, development, drifting, haulage, ventilation, drainage, safety and several other factors are to be taken into account to run a mine efficiently, economically and at the same time with safety. Deeper mining beyond 150-meter depths involve temperature and pressure effects.

While higher temperature results in burning, increased rock pressures due to super imposed load creates rock bursts. These are quite common in deep mines like Kolar Gold mines, where the depth is around 3 km.

9.3.5 Environmental Requirements

Environmental regulations happen to be one more constraint to face in the mineral industry. Mining problems include different types of hazards. Abnormal peculiarities of temperature and pressure variation coupled with rock bursts, free and gas hazards, collapse of roof and sidewalls are encountered in mining industry.

The recent strides in industrialisation have brought new challenges to mankind. One of them is environmental pollution. In industrially advanced countries like USA, the mineral industry has faced severe restrictions than it ever had before on the effect of ground prospecting, development, mining, refining and smelting on the environment. Nevertheless, the subject is volatile and emotional but understandable when rational. One thing is obvious, unless regulations pertaining to mining and mineral industries are strictly followed, environmental problems do occur. While institutions like Department of Environment Regulations (DER) in USA monitor this aspect, we in a developing country like India are yet to go a long way in

adopting these procedures. Environmental impact of the mines did not receive much attention till 1970. However, the following central laws have been framed which relate to the impact of mines.

- 1) The water Prevention and control of pollution Act, 1974.
- 2) The Forest (conservation) Act, 1980.
- 3) The Air protection Act, 1986.

9.3.6 Impact of New Discoveries and Technological Developments

Production of minerals in mineral industry is affected by changing needs of manufacturing industries, accumulation of stock, fluctuation in prices and refuse of metallic scrap. Discovery of new deposits and advancement in recovery and metallurgy of new finds also affect the mining activities adversely. A country less advanced in technology, possessing poorer grades, may reduce the cost of production considerably by adopting improved methods of mining and processing. For instance, Florida has only low grade beach sands containing 2 to 3 % ilmenite. But the processing technology has practically squeezed Indian ilmenite market, which has rich concentrations as high as 80% in Kerala and Tamil Nadu beaches. Similarly discovery of new deposits in a country reflects the pattern of international trade in respect of pricing. Take for instance, the iron and manganese ores, which enter the world market in bulk quantities.

The emergence of large number of countries in Latin America and Africa besides Australia as iron and manganese ore producers has affected competitive position in the export trade. The steep fall of prices in respect of manganese ores, particularly after Korean War in 1954, has resulted in the closure of several manganese mines in the country.

9.3.7 The Grading and Specifications

Trade in minerals is entirely different from other commodities, because considerable variations may take place in the quality of the same deposit. Variations in the quality in mineral industry affect pricing and also the grade and the required specifications necessary for supply.

Therefore, selective mining, blending and processing for grading and marketing and special problems are encountered in mining. The price is fixed on the basis of tenor and commercial grades on whose basis the minerals are supplied. To add to this, penalty also is imposed for any deleterious constituents, if present, since they affect the manufacturing process.

9.3.8 Huge Capital Investment and Risk Factors

Exploration and development of mineral deposit involves massive investment of huge capital. Ore bodies buried deep underground could be unearthed only by application of geological, geochemical and geophysical methods followed by deep drilling. Sometimes unforeseen geological factors like faulting, pinching out of the ore bodies, deterioration of quality at depth etc., may ultimately affect the life of mineral industry, by way of prospecting, development, mechanisation and exploitation is therefore quite different in nature.

It involves massive investment of capital expenditure, uncertainties, risk and hazard resulting from depletion of reserves, unpredictable character of mineralisation, practically negligible salvage value of machinery employed and variable working conditions underground. Some of

these uncertainties lead to liquidation of the mineral industries. Mineral industry for the above reasons is placed altogether on a different footing.

9.4 MINERALS AND NATIONAL ECONOMY

With the achievement of freedom in 1947, Indian Government has realised the crucial importance of minerals in national economy and took steps for planned mineral production and with it concurrent industrial expansion. The creation of department of planning and Development in the central government and the establishment of several agencies concerned with the minerals have started a new chapter in our outlook for minerals. The country has realised that a national mineral policy is essential for planned mineral exploration, exploitation and utilisation. Adequate emphasis and care have been initiated with the consideration of the following aspects in the 1st five-year Plan.

1. Systematic exploration for proper assessment of extent and value of mineral deposits.
2. Systematic mining by scientific methods.
3. Conservation of minerals without wastage.
4. Explorations for strategic minerals like sulphur, tungsten, tin etc.
5. Making of finished products from raw minerals and their export.
6. Beneficiation of low-grade ores by scientific research.
7. Substitution of deficient minerals by scientific research.
8. Collection of industrial mineral statistics through Bureau of Mines.

This new approach has resulted in the establishment of many new organisations like Indian Bureau of Mines (1948), Department of Atomic Energy (1954), National Coal Development Corporation (1956), Oil and Natural Gas Commission (1956), National Mineral Development Corporation (1958), State Trading Corporation (1956) and subsequently Minerals and Metals Trading Corporation (1963) and Mineral Exploration Corporation (1972). Many National Research Laboratories like National Metallurgical Laboratory, National Geophysical Research Institute, National Remote Sensing Agency, Central Ground water Board for development of groundwater resources, National Institute of Oceanography etc., have contributed to the necessary scientific research relating to the minerals both on land and in high seas.

9.4.1 Present Status

Indian economy is growing fast. In the year 2000-2001, the GDP growth rate was 5.2% less when compared to the GDP growth rate (6.4%) in year 1999-2000. The growth rate of mining and quarrying is increased to 5.4% as compared to the 4% growth rate in the year 2000.

The Government of India in 1991-92 removed many restrictions on imports and exports through Liberalized Exchange Rate Management System (LERMS). Indian mineral industry contributes sufficient amount to the National Economy through production of fuels, metallic, non-metallic and minor minerals.

According to the amended Exim Policy 2000-02, and General Agreements on Tariffs and Trade (GATT), which is the part of the World Trade Organisation in WTO Agreement, imports can be controlled only through tariffs or customs duties not through any Quantitative Restrictions (QR'S) such as quotas and licenses. Therefore the Indian mineral industry will survive globally only through competitive quality and price.

Government of India has created a department of dis-investments in December 1999, to dis-invest the public sector enterprises (PSE's). Bharat Aluminium Company (BALCO), which is the first mineral based industry was privatised by selling 51% of share to Sterlite Industries for RS 551.50 crores.

Government of India is also setting Special Economic Zones (SEZ) in the place of export processing zones (EPZ) to promote exports and also established export-import Bank of India (Exim Bank) in 1982.

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. Write about the peculiarities of mineral industry?

3. What is LERMS?

9.5 SUMMARY

The concept of minerals in human history is as old as that of the human civilisation. The use of minerals in any country indicates the rising standards of developments. Mineral resources have become almost synonymous with industrial power. A Glance at the history of development of leading industrial nations reveals that their rise has coincided with the utilisation of the mineral resources. The countries, which are rich in diversified mineral resources, have become strong industrial nations.

Certain universally recognised basic axioms of mineral policy are; minerals are depleting assets, modern industrial economics is based on minerals and mineral products, the boundaries of countries bear no relation to mineral geography, and no nation has domestic resources sufficient for its industrial needs.

Mineral economics can thus be defined as the synthesis of such theories and practices of geological science, political science and economics that are involved in on attracted to the

balanced development and management of the country's mineral resources. Some of the peculiarities which have serious impact on mineral based industries are localisation, international character, exhaustibility, mining problems and unpredictable character, environmental requirements, impact of new discoveries and technologies, the grading and specifications, huge capital investment and risk factor.

In our country, Government of India has formulated a national mineral policy essential for planned mineral exploration, exploitation and utilisation. The policy states systematic exploration, systematic mining conservation, exploration of strategic minerals, beneficiation of low-grade minerals, substitution, collection of mineral statistics etc. Recently government has changed some policies and allowing private companies in the exploration work.

9.6 CHECK YOUR PROGRESS - MODEL ANSWERS

1.
 - a) minerals are depleting assets
 - b) modern industrial economics is based on minerals and mineral products
 - c) the boundaries of the countries bear no relation to mineral geography
 - d) No nation has domestic resources sufficient for its industrial needs
2. Localisation, International character, Exhaustibility, Mining problems, Environmental requirements, Impact of new discoveries and technological development, The grading and specification, Capital investment.
3. Liberalised Exchange Rate Management Systems.

9.7 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in about 30 lines each.
 1. Elaborate the basic principles underline in mineral economics and show its importance in national economy.
 2. How is mineral industry different from other industries? Give brief account of its peculiarities.
- II. Answer the following questions in about 10 lines each.
 1. Minerals are depleting assets. Explain?
 2. Explain the Localisation of mineral deposits.
 3. Explain the Mining problems in mineral industry.
 4. What is the Concept of mineral economics?

UNIT: 10 INDIAN MINERAL RESOURCES

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- 10.7 Model Examination Questions

10.0 OBJECTIVES

Mineral resources of India are described in this unit.

After studying this unit, you will be able to

- describe the distribution of metallic minerals
- explain the distribution of non-metallic minerals
- describe the distribution of fuels

10.1 INTRODUCTION

India possesses number of metallic and non-metallic minerals and fuel deposits of various grades distributed in different states. India is in self - sufficient in mineral production such as iron ore, manganese, vanadium, titanium, magnesium, chromium, aluminium, cadmium, zirconium, germanium and beryllium, amongst metallic minerals; limestone, gypsum, china clay, mica and fluorspar amongst non-metallic minerals and coal and petroleum in fuels.

10.2 METALLIC MINERAL DEPOSITS

Important metallic deposits are manganese deposits, copper deposits, lead and zinc deposits, chromite deposits, iron ore deposits and bauxite deposits.

10.2.1 Manganese deposits

The Indian manganese (Mn) ores are hard, lumpy and suitable for metallurgical industries.

These deposits are classified, based on their mode of occurrences as,

- a) Syngenetic gonditic deposits which are distributed in Bandara and Nagpur districts of Maharashtra and in Balghat district of Madhya Pradesh as Saucer series
- b) Syngenetic reef deposits which are associated with Kodurite suite of rocks of Visakhapatnam, Srikakulam, Adilabad and Hyderabad districts of Andhra Pradesh and in Koraput and Bolangir districts of Orissa
- c) Replacement deposits of iron ore which are distributed in Keonjhar and Sundargarh districts of Orissa, and Belgaum, Tumkur, North Konara and Chitradurga districts of Karnataka and
- d) Lateritoid and supergene deposits which are associated with all the above deposits.

The two major consuming industries of manganese ore are iron and steel, and Ferro-manganese. Low-grade ore of 30-35% Mn may be used for pig iron, but Ferro-manganese requires better grade (38% Mn) and preferably of 46% Mn content. Rate of manganese ore consumption for one ton of pig iron production is 57 kg. Rate of consumption of Ferro-manganese is 9 to 21 kg per ton of steel output.

According to the National Mineral Inventory (Indian Minerals Year Book, 2001), the total recoverable reserves of manganese ore (as on 1995) are placed at 167 million tonnes. The production of manganese ore at 1.56 million tonnes during 2000-2001 marginally decreased by about 2% as compared to that of 1999-2000.

10.2.2 Copper deposits

Copper (Cu) deposits are generally disseminated massive irregular or / vein type of deposits and are distributed with

- a) Singhbhum Copper Thrust belt in Bihar which extends through Rakha, Mosabani, Tanapahar districts
- b) Khetri deposit which extends from Singhana to Raghunatha Garh in Rajasthan
- c) Malanjkhand-Cu mineralisation, which is associated with long brecciated quartz veins and all the copper deposits are associated with Dharwar rocks.

In Agnigundala belt, Cu mineralisation is found in calcareous quartzites and are distributed in Agnigundala, Nallakonda and Dhukonda regions in Andhra Pradesh, Betla in Maharashtra and Kalyadi in Karnataka are the main deposits.

According to the National Mineral Inventory (as on 1997) there are about 461 million tonnes recoverable reserves of copper ore in the country containing about 4.7 million tonnes of copper metal (1.02%). Production of copper ore are at 3.48 million tonnes during 2000-2001 was higher by 13% as compared to that in the previous year.

10.2.3 Lead and Zinc deposits

Main producers of lead and zinc are Zawar mines of Rajasthan, in which Mochia, Balaria, Zawarmala and Udiapur are important deposits. Rajpura-Daraba (Rajsamand dt.), Rampura-Agucha deposit (Bilwara dt.); Bhotang mine (Sikkim); Ghugra-lead-zinc deposit in Ajmer dt. of Rajasthan, lead ore deposits of Bandalamottu (Guntur dt.) of Andhra Pradesh and Sargipalli, Sundergarh districts (Orissa) are the important deposits

India has about 176 million tonnes of recoverable reserves of lead and zinc ore containing about 2.2 million tonnes of zinc metal (as on 1997). The production of primary lead during

2000-2001 decreased to 34,480 tonnes from 35,120 tonnes in 1999-2000. The production of zinc metal at 1,78,015 tonnes in 2000-2001 increased marginally by about 2% as compared to that in 1999-2000.

10.2.4 Chromite deposits

The chromite deposits are mainly concentrated in the state of Andhra Pradesh, Bihar, Kamataka, Maharashtra, Manipur, Orissa and Tamil Nadu. In Orissa, the chromite is concentrated in the Sukinda ultrabasic complex of Cuttack dt., in quartzite with enstatite - Peridotites; in the Nausahi, (Keonjhar dt.) and Maraubil Maulabhaja (Dhenkanel) areas, the chromite is associated with quartzites, siliceous dolomites, slates etc. In kamataka high-grade chromite deposits are reported in the Hassan district (from Jambur to Arsikene) in the ultrabasic rocks. Two chromite lenses confined to shear zones were traced in Byrapur area. In addition to these deposits, Pauni in Bhandara dt. of Maharashtra; Signhabhum dt. of Bihar, Kondapalli in Krishna dt. of Andhra Pradesh, and in Sitampundi of Tamil Nadu, have good chromite deposits.

Chromite is chiefly used for the manufacture of ferro-chrome, basic refractory bricks and chrome chemicals.

The total recoverable reserves of chromite in the country (as on 1995) are placed at 86.23 million tonnes. Production of chromite at 1952 thousand tonnes during 2000-2001 registered an increase of 12% compared to that of the previous year.

10.2.5 Iron ore deposits

Iron ores are very essential raw materials for all modern industries. In Madhya Pradesh iron ore occurs mainly in Bailadilla, Durg, Jabalpur and Sindhvi districts. All the deposits are associated with banded hematite quartzites of Dharwarian age. They are massive deposits of hematite ores. In Goa iron ore deposits are associated with pink phyllites. The principal ore types are massive/bedded and powdery type of haematite, and some amount of magnetite.

In Orissa iron ore deposits occur in the districts of Cuttack, Keonjhar, Sundargarh, Mayurbhanj, Koraput and Dhenkanal. The principal ore is hematite, which is associated with both, banded hematite quartzite (BHQ) and banded hematite Jasper (BHJ). In Bihar iron ores are associated with iron ore series with hematite quartzite shales. In Andhra Pradesh, important deposits are located in Warangal, Khammammettu and Veldurti. The iron ores of Kamataka are associated with Bababudan hill sand Sandur hills of Thumkur, Chitradurg and Shimoga district. The magnetite deposits in India are mainly distributed as apatite- magnetite formations of Singhbhum shear zone (Bihar), titaniferous and vanadiferous magnetite in Mayurbhanj district of Orissa and banded magnetite silica deposits of Salem and Tiruchirapalli districts in Tamilnadu and Kudremukh deposits of Kamataka and Guntur district of Andhra Pradesh.

The total recoverable reserves of haematite in the country (as on 1995) are placed at 10 billion tonnes. But, the high-grade reserves (65% Fe and above) are 0.81 billion tonnes. The present rate of production is about 70 million tonnes per annum.

10.2.6 Bauxite deposits

Bauxite deposits mainly occur in Orissa, Andhra Pradesh, Madhya Pradesh, Gujarat, Maharashtra and Bihar. Major bauxite deposit reserves are confined to the Eastern Ghat group

of rocks in Orissa and Andhra Pradesh states. The in-situ reserves are 3,037 M.T and recoverable reserves are 2,525 million tones (1991-1992). Most of the Indian bauxite reserves are metallurgical grade.

The total recoverable reserves of bauxite in the country (as on 1995) are placed at 2,462 million tonnes. About 86% of the recoverable reserves are of metallurgical grade. The reserves of refractory and chemical grades account for only 1% and 0.36% respectively.

Table 10.1 Recoverable Reserves of Bauxite (1991-1992) in '000 tones

Andhra Pradesh	592001
Bihar	61104
Goa	28089
Gujarat	107744
Jammu & Kashmir	1783
Karnataka	27416
Kerala	7923
Madhya Pradesh	140791
Maharashtra	87250
Meghalaya	896
Orissa	1442276
Rajasthan	318
Tamil Nadu	18327
Uttar Pradesh	9420

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 are the important iron ore deposits in India?

2. List the states, which have bauxite deposits in India?

10.3 NON-METALLIC DEPOSITS

Important non-metallic deposits are mica, barytes, diamond, placer mineral deposits etc.

10.3.1 Mica deposits

Mica bearing pegmatites occur in Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Kerala, Maharastra, Orissa, Rajasthan, Tamil Nadu and West Bengal. Archaean and schistose belts of Nellore in Andhra Pradesh contain vermiculite mica deposits. In Bihar, Champagnar-Chakai pegmatite belt passes through Gaya, Hazaribagh and Monghyr districts, and the host rocks are Precambrian metasediments. In Rajasthan, the mica belt extends from Molambad (Jaipur dt.) to Kankroli (Udiapur dt.). The ruby mica and spotted mica (Jaipur dt.) rich pegmatites are intruded in to the gneiss and schistose rocks. The recoverable resources of mica in India are 1,09,022 tons (1990) and the production of crude mica was considerably declined to 3,592 tons (1991-92) from 7,934 tons (1980).

The recoverable reserves of mica (as on 1995) are; Andhra Pradesh 44,837 tonnes, Bihar 12,161 tonnes, Jharkhand 1393 tonnes and Rajasthan 1,589 tonnes.

10.3.2 Diamond deposits

Diamond deposits in India are mainly confined to Kimberlite (volcanic pipes), conglomerate rocks and alluvial placers. Majhgawan - volcanic pipe, Hatpur (Panna dt.) is chief source in Madhya Pradesh, and Puyalinkhand (Rajasthan). Diamonds are also recovered from the basal conglomerate beds of Kaimur, Rewa and Bhandar belts of Vindhyan system, Bangananapalle conglomerate of Kurnool system, Veladikkottapalem, Gravel of Krishna river basin in Andhra Pradesh. In Kesarapura- Chitradurga districts, diamondiferous conglomerate beds are identified.

The country possesses diamond recoverable reserves of 11,96,154 carats (1991-92) and production of diamonds was at 18,213 carats in 1991-92.

The total recoverable reserves of diamond in the country (as on 1995) are placed at 9,81,515 carats.

10.3.3 Barytes

Baryte deposits occur in India in the states of Andhra Pradesh, Madhya Pradesh, Himachal Pradesh and Rajasthan. The Mangampet deposit in Cuddapah dt. of Andhra Pradesh is the largest deposit of the world. Other deposits in Andhra Pradesh are located in several places between Guvvalacheruvu and Boraram, which occur in Vempalli limestone deposits. Bedded deposits contain granular barytes and radial platy aggregates of barytes accompanied with volcanic vesicular tuff.

In India, the total recoverable reserves are estimated as 70.15 M.T (1991-92) and the production of barytes was at 6,35,000 tons (1991-92).

The total recoverable reserves of barytes in the country (as on 1995) are placed at 87 million tonnes of which 61% are in proved, 32% in probable and 7% in possible categories.

About 98% of reserves are in Andhra Pradesh. Rajasthan, the second largest producer, has 1.24 million tonnes.

10.3.4 Placer mineral deposits

India has 6100-km long coastline. Most of the coastal regions have important heavy mineral concentrations in the form of beaches, dune and offshore deposits. Atomic Minerals Division of Government of India is carrying out mineral exploration programme in the West Coast and East Coast of India. The important coastal sand placer mineral deposits are

- a) Kerala Deposits: These deposits contain mainly ilmenite, rutile, zircon, monazite, sillimanite and garnet. Chemically, the ilmenites of the Chavara are one of the best ilmenite deposits with 60% of TiO_2 content.
- b) Tamil Nadu Deposits: These are the oldest deposits located in India and have a total heavy mineral content of 39%. The important minerals are ilmenite, rutile, leucoxene, zircon, monazite, sillimanite and garnet. Indian Rare Earth Ltd. (IREL) is operating several mines in this area.
- c) Maharashtra Deposits (Ratnagiri): The main source rocks for these deposits are Deccan Traps and abundant minerals are ilmenite and magnetite.
- d) Andhra Coast (Bhimunipatnam): The total heavy minerals content is 19.58% in this deposit and contain ilmenite, rutile, monazite, zircon, garnet and sillimanite. The provenance for this deposit is Eastern Ghats.
- e) Orissa Deposit (Chatrapur): This deposit has 18 km length and has 20.5% total heavy mineral content. The most abundant heavy minerals are garnet, sillimanite, monazite, rutile, ilmenite etc.

Table 10. 2 Reserves of Placer mineral deposits in India

Mineral	Reserves (M.T)
Ilmenite	348
Garnet	107
Zircon	21
Rutile	18
Monazite	8
Sillimanite	130
Total	632

In addition to the above dune and beach deposits some off-shore deposits are also identified off east and west coasts of India. Presently Atomic Mineral Division, IRE limited, Rare Metal and Rare Earth Ltd., Geological Survey of India, and academic institutions are engaged in placer mineral exploration and exploitation. Chavara (Kerala), Manavalakurichi (Tamil Nadu) and Chatrapur (Orissa) have been exploited by the IRE Ltd.

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 important mica deposits in India?

4. Describe the Mangampet barytes deposit.

10.4 FUELS

Important fuels are coal, lignite, petroleum and natural gas which are described below.

10.4.1 Coal and Lignite

Coal occupies an important position in the Indian Mineral Industry. It is the main raw material for thermal energy. Coal deposits are of either Permian age (lower Gondwana, Damuda Formation) or Tertiary age and very few occurrences are of Jurassic and Cretaceous age (Kutch and Assam). Coal deposits of India are associated with sandstone and shales of fresh water origin and very few coal formations are also associated with limestone. The coal resources of Gondwana basin in south India are 214 billion tones and the lignite reserves are 100 billion tones.

The Gondwana coal deposits in India are mainly Godavari Valley coal seams (Andhra Pradesh), Singlimali (Assam); Jharia, East & West, Bokaro, North & South Karanpur, Daltonganj, Rajmahal (Bihar) etc.; Unaria, Johila, Bislampur, Lakhanpur Tatapani-Ramkota and part of Singrauli coal field (Madhya Pradesh) etc.; Chande-Wardha, Kamptee, Umrer, Bander, NandBokhara (Maharashtra) etc. Talcher coal field (Orissa); Raniganj, Barjora, Deocha and Darjeeling (Uttar Pradesh) etc.; The Tertiary coal fields are distributed in the states of Arunachal Pradesh, Assam, Meghalaya and Nagaland.

10.4.2 Petroleum and Natural gas

The petroleum and natural gas bearing sedimentary basins of India are not only confined to the onshore but also extends to offshore regions. The 26 sedimentary basins of India are not alike with respect to the petroleum and natural gas occurrence and distribution. The main petroliferous basins are Assam shelf, Cambay basin, Kutch, Saurashtra, Bombay, Konkan, Kerala, Laccadives, Andaman Nicobar, Cauvery, Krishna - Godavari and Mahanadi. Based on degree of exploration and assurance, the basins are divided into two categories.

- (a) high prospective basins: Bombay offshore, Cambay, Upper Assam, Assam-Arakan, Krishna- Godavari and Cauvery basins and
- (b) Low prospective basins: Ganga, Vindhyan, Kerala-Konkan, Mahanadi and Bengal basins.

Based on the degree of exploration, basin status may be changed.

Total hydrocarbon resources of the country for on land and including deep waters of east and west coasts is approximately 30 billion tonnes. The in place geological reserves are 6.85 billion tones. The domestic crude production in 1999-2000 was about 32 M.T and gas production was 28.5 billion cubic meters. The domestic crude is mainly distributed in the Mumbai off shore, Gujarat and Assam basins and lesser quantity from Andhra Pradesh, Tamil

Nadu and Arunachal Pradesh states.

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 are the different stratigraphic horizons of coal deposits in India?

6. List the petroliferous basins in India?

10.4 SUMMARY

India is rich in mineral resources and self sufficient in the mineral production of iron, manganese, vanadium, titanium, magnesium, chromium, aluminium, cadmium, zirconium, germanium, beryllium, limestone, gypsum, china clay, mica, fluorspar, coal, natural gas etc.

Manganese ores are distributed in Maharashtra, Madhya Pradesh, Andhra Pradesh, Karnataka, and Orissa. Copper deposits are located in Bihar, Orissa, Rajasthan, Andhra Pradesh, Maharashtra and Karnataka. Lead and Zinc deposits occur in Rajasthan, Sikkim, Andhra Pradesh, and Orissa. Chromite deposits are mainly concentrated in the states of Andhra Pradesh, Bihar, Karnataka, Maharashtra, Manipur, Orissa and Tamil Nadu. Iron ore deposits are distributed through out India, mainly in the states of Bihar, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Orissa Goa and Tamil Nadu. Bauxite deposits are mainly located in Orissa, Andhra Pradesh, Madhya Pradesh, Gujarat, Maharashtra and Bihar.

Mica bearing pegmatites occur in Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Kerala, Orissa, Rajasthan, Tamil Nadu and West Bengal. Diamond deposits occur in the kimberlite pipes of Madhya Pradesh and Andhra Pradesh.

Barytes occur in the states of Andhra Pradesh, Madhya Pradesh, Himachal Pradesh and Rajasthan. Placer deposits, mainly, atomic minerals occur in the beach sands of Andhra Pradesh, Orissa and Kerala. Coal deposits occur from the Gondwana formations. These are distributed in the states of Bihar, West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Maharashtra, Madhya Pradesh, Assam, Uttar Pradesh, Meghalaya and Nagaland. Petroleum

deposits are spread over in Assam, Gujarat, Bombay and in Krishna-Godavari Basin. Rich deposits of Natural gas occur in Andhra Pradesh from Krishna-Godavari Basin.

10.5 CHECK YOUR PROGRESS – MODEL ANSWERS

1. Bailadilla, M.P., iron ore series of Bihar, Bababudana hills of Karnataka, Salem of Tamil Nadu, Kudremukh deposits of Karnataka.
2. Andhra Pradesh, Orissa, Bihar, Maharastra, Jammu & Kashmir.
3. Pegmatites of Nellore, Champanar pegmatites of Bihar and Molambad pegmatites of Rajasthan.
4. Mangampet barytes of Andhra Pradesh is associated with Vempalli limestones of Cuddapah system. It is bedded deposit of volcanic origin.
5. Permo-carboniferous rocks of Gondwana system and Tertiary rocks of Assam.
6. Krishna - Godavari basin, Mahanadi basin, Assam shelf, Bamba high and Kutch.

10.6 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in about 30 lines each
 1. Describe in detail about copper, lead and zinc deposits of India.
 2. Give an account on placer deposits of India.
 3. Briefly describe the chromite distribution in India.
- II. Answer the following questions in about 10 lines each
 1. Coal
 2. Bauxite
 3. Diamonds
 4. Petroleum

UNIT:11 MINERAL RESOURCES OF ANDHRA PRADESH

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- 11.5 Summary
- 11.6 Check Your Progress - Model Answers
- 11.7 Model Examination Questions

11.0 OBJECTIVES

In this unit, mineral resources of Andhra Pradesh are described.

After completion of this unit, you will be able to

- describe the non-metallic resources of Andhra Pradesh.
- explain the fuel resources of Andhra Pradesh.
- explain the metallic mineral resources of Andhra Pradesh.

11.1 INTRODUCTION

Andhra Pradesh, part of the peninsular India, is endowed with good number of mineral deposits distributed in various geological formations of Archaean to recent in age. The

important minerals are limestone, coal, bauxite, dolomite, iron ore, barytes, quartz and silica sand, clays, ilmenite, steatite, staurolite, other heavy minerals, copper, manganese, graphite, apatite, asbestos, mica and gold. Ball clay, calcite, china clay, chromite, feldspar, fire clay, fuller's earth, gypsum, corundum, kyanite, lead and zinc, ochre, pyrite, pyrophyllite, tungsten, diamonds, semi-precious stones and dimensional stones.

11.2 METALLIC MINERAL DEPOSITS

The important metallic deposits of Andhra Pradesh are bauxite, iron ores, manganese ores, copper ores, lead and zinc ores, chromite ores and gold.

11.2.1 Bauxite

Bauxite is an important aluminium mineral, which is formed by residual processes. The parent rocks for bauxite are mainly khondalites and charnockites of Eastern Ghats. The deposits are highly dissected and small, and occur mostly on gentle to moderately slopping landforms. The thickness of bauxite deposits ranges from 1.22 - 52 m and belong to post Mio-Pliocene age.

In Andhra Pradesh, the recoverable reserves (as on 1995) are placed at 551.5 million tonnes. The bauxite reserves occur in the Eastern Ghat hill ranges of East Godavari, Visakhapatnam and Vizianagaram districts. The important mineral deposits are located in Addatigala, Chidipalem, Gurteedu and Y. Ramavaram, Anatagiri, Araku, Chintapalli and Sunkarimetta. Based on the chemical composition, bauxite ore is classified into different grades (Table 11.1).

Table 11.1 Specifications of Bauxite Ore

Grade	Al ₂ O ₃ Min - max	Fe ₂ O ₃ Min - max	SiO ₂ max
1. Metallurgical grade			
Grade-I	45%- 50 %	0 -4%	5%
Grade-II	40%- 45 %	0- 4%	5%
2. Refractory grade	55 %	0 -4.5%	-
3. Abrasive grade	50 %	-	4%
Chemical grade	58%	2.5 %	-

11.2.2 Iron ore

Iron is the second most abundant metal and widely distributed in the Earth's crust. The important iron minerals are hematite, magnetite, limonite and siderite. In Andhra Pradesh, the iron ore is mainly associated with stratigraphic units of Dharwars, Cuddapahs and Gondwana super groups. Iron ores (Banded Hematite -Quartzite) of Anantapur and Chittoor districts are associated with the Dharwars. Magnetite-hematite-quartzite occurs at Yerabali (Karimnagar). Khammam and Warangal deposits are in Phakal and Dharwar strata. Upper Gondwana rocks of Adilabad district have iron ores. Banded magnetite - quartzite are located in Prakasam and East Godavari districts. Magnetite deposits are also mined at Kasipatnam (Visakhapatnam) along with apatite and vermiculite. In situ reserves of magnetite and hematite in Andhra Pradesh are 1381 M.T and production was increased to 1,88,000 tons

(1996-97) from 1,39,000 (1989).

11.2.3 Manganese ore

The Manganese (Mn) ore deposits of Andhra Pradesh occur mainly in Vizianagaram, Srikakulam and Adilabad districts. The Mn -ores are localised with crests and troughs of drag folds in metamorphic granulites and garnetiferous quartzites. Psilomalene and pyrolusite are the main minerals in these deposits. The important deposits are located in Garividi, Garbham, Koduru, Duvvum, Devada, Chipurupalli etc. The ore has Mn (32.12-41.60 %), SiO_2 (4.02-6.22 %), Fe (3.68-34.81 %) and P (0.13-0.55 %). The main occurrences of manganese are in Adilabad district (Gaulighat Gudaand, Tasmu and Jamadpur). These are associated with Penganga formations. The main Mn mineral in these deposits is wad, pyrolusite and magnetite. The minor occurrences are also reported from Prakasam and Nellore districts.

In situ reserves of manganese ore in Andhra Pradesh are placed at 12.8 M.T of which 7.5 M.T is considered as recoverable reserve. The production of Mn ore is 83340 tons (1996-97).

11.2.4 Copper Ore

Copper is an important non-ferrous metal, which is used in electrical, alloy, and agricultural sectors. In Andhra Pradesh the Cu deposits occur in Guntur, Khammam, Kumool, Mahabubnagar, Nalgonda and Nellore districts. In the Agnigundala belt of Guntur district, the host rocks are calcareous quartzites, dolomites, and dolomitic limestones. The important regions are Bandlamottu (Pb and Cu), Nallakonda (Cu) and Dhukonda (Cu and Pb). Mineralisation is essentially disseminated type and as veins, stringers and breccia fillings. Copper minerals are more associated with quartzites. The important Cu minerals in these areas are galena (PbS), chalcopyrite (CuFeS_2), sphalerite (ZnS), pyrite (FeS_2) and pyrrhotite (Fe_7S_8). The Mailaram (khammam dt.) Cu deposit is associated with quartz-chlorite schist. Stringers of chalcopyrite, pyrrhotite and pyrite are noticed in Venkatapuram and Yellambailu. Other minor occurrences of copper are reported in Cuddapah, Karimnagar, Medak and Warangal districts.

In situ reserves of 1,20,29,000 tonnes (1993) of copper were reported in Andhra Pradesh and the production is 58,000 tons (1987).

11.2.5 Lead and Zinc

In Andhra Pradesh, lead ores occur in Chittoor, Cuddapah, Guntur, Hyderabad, Khammam, Kumool, Nalgonda and West Godavari districts. The lead deposits in Bandlamottu and Dhukonda blocks of the Agnigundala deposit in the Guntur district are the most important. Galena occurs as veins and stringers in dolomites and dolomitic limestone in these deposits along with small amounts of chalcopyrite, sphalerite and pyrite. In the Bandlamottu block the mineralisation is noticed over a strike length of 1200 m. In the Dhukonda block, galena occurs as dissemination and fracture fillings in quartzites and dolomites. In Karampudi, the occurrences of Pb-Zn ores do not appear to be a sizable one as the average width of the ore body is reported to diminish with depth. In the Cuddapah district, lead ores have been reported to occur near Zangamrajupalle, Varikunta, Chinnarampadu, and Nagasakapalli areas. In these areas the galena is found in limestones. In the Kumool district a possible good occurrence of galena is near Giddalur and near Kidlakonda close to Chityala.

Old workings for argentiferous galena are found near Koilakuntla and Basavapuram. In the Nalgonda district 'float' ores of Galena are found at Malepalle and near Pedda Adisarlapalli.

Argentiferous galena, in association with pink granites, occurs near Chintakunda in this district. The grain size of Galena ranges from a pea to a walnut. Near Amadubodu traces of galena are noticed in crystalline limestone. In Prakasam district a number of old workings of lead are located near Vermmidivaram. The lead is used in the manufacture of storage batteries, cable sheaf, thin sheets, tubes and lead pipes. It is alloyed with a number of other materials.

11.2.6 Chromite Ore

Chromite deposits are mainly confined to the Eastern Ghats. In Krishna district, Kondapalle, Ebrahimpattanam, Gangineni and in Khammam district Bhimavaram, Dendukuru, Jannavaram, Lingampet, Madira, Palvanona, are the main occurrences of chromite deposits.

The chromite deposits occur as north south trending en echelon lenses. The chromite is associated with orthopyroxenite and anorthosite. In West Godavari district, chromite occurs near Enukonda in association with peridotites and pyroxenites.

11.2.7 Gold

Gold deposits in Andhra Pradesh are situated in Ramagiri Area. The main host rocks in this area are schistose greenstone, sericite, chlorite, phyllites, quartz, sericite schist, and ferruginous quartzite. Gold bearing quartz veins are intruded in to these country rocks. Echelon drag folds, shear fracture zones etc., control the gold mineralisation.

Five locations are important for gold occurrences viz., Chennabhavi, Yeppamana, main, east and Gibutil. Gold occurrences in this area are in the native form. Some gold occurrences are also reported in the metamorphosed basalt and acid tuff of Chigaragunta area of Chittoor district, in Meta-basalt along the shear zones of Jonnagiri schist belt. In Kurnool district, auriferous smoky quartz vines are also reported.

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 the metal in bauxite ore?

2. List the manganese minerals?

11.3 NON - METALLIC DEPOSITS

The important non-metallic Minerals viz., limestone, placer minerals, dolomite, barytes, quartz, quartzite and silica Sands, graphite, mica, diamond, clay, corundum, apatite, asbestos and semi-precious stones are described.

11.3.1 Limestones

The composition of limestone is 56% of CaO, and 44% of CO₂ and general impurities are arenaceous, argillaceous and magnesium etc. Large reserves of limestone exist in Cuddapah Super group and Kurnool group. Palnadu, Pakhal, Sullavai and Bhima basins have limestones and crystalline limestone of Borra in Visakhapatnam district is also an important deposit.

The recoverable reserves of limestone in Andhra Pradesh are estimated at 14,295 M.T and the production is 9,685,000 tons (1996-97). Depending on the chemical composition and grade of limestone, it is used in cement, metallurgical, chemical, glass industries and in the manufacturing processes of paper, sugar, ceramics, soap, and rubber etc. It is also essential in water and sewage treatment, poultry feed and in agriculture industry.

11.3.2 Placer minerals

Andhra Pradesh has number of river sand deposits, which are used for building constructions. Inland dunes and beaches are source of many black sand deposits, which contains ilmenite, garnet, sillimanite, zircon, rutile, magnetite and monazite etc.

Important deposits are Bhavanapadu, Kalingapatnam and Srikurmam (high tonnage), Donkuru- Baruva, Koyyam, Bhimunipatnam and Pentakota (medium tonnage) in north Andhra Pradesh coast. (Total heavy mineral concentration is 10%-25%).

The palaeo beach ridges were identified in the southern Andhra Pradesh coast (Nellore and Prakasam districts) and the total heavy mineral concentration is 3-12%. The dominant minerals are ilmenite, magnetite and garnets etc. (Table 11.2).

Table 11.2 Heavy mineral reserves of Andhra Pradesh

Mineral	reserves (million tones)
Ilmenite	103.15
Garnet	48.99
Sillimanite	47.02
Zircon	4.43
Rutile	4.42
Magnetite	10.84
Monazite	2.29
Others	29.25

Ilmenite and rutile are the chief ores of titanium. Garnets are used in water filtration, water test culturing, electronic industry and abrasive industry. Sillimanite is used as refractory mineral. Monazite is source of many rare earth elements. Zircon is the principal ore mineral of zirconium and ground zircon is used in refractory paints.

11.3.3 Dolomite

Dolomite deposits of the state are mainly associated with the Proterozoic group of rocks. Vempalli formation of Papagni group in the Cuddapah Super group and Enchencheruvu formation of Mulug group in the Pakhal basin is dolomite bearing.

The main dolomite producing regions in the state are Dhone and Veldurti of Kumool district and in the Cuddapah district, Guvvalacheruvu and Vempalle areas and Dandegundal, Madharam, Puba and Takalagudem of Khammam district and Chillavaripalle, Rayalacheruvu and Timmapuram areas of Ananthapur district.

The reserves of dolomite in Andhra Pradesh are 172.972 M.T and production was 302683 tones (1996-97).

11.3.4 Barytes

Andhra Pradesh alone is contributing barytes more than 98% of India's production. It is mainly used as drilling mud in oil and gas drilling. The Mangampet barytes occur as mainly bedded and lapilli types of deposits and confined to the Pullampet formation of the Nallamalai group (Middle upper Proterozoic) of Cuddapah super group. Vinjamuru deposits in Nellore District (Archean age), small deposits of Anantapur district, small lenses of barytes near Gopalpur and Ballapet in Khammam districts are associated with dolomites of Pakhal sediments (upper Proterozoic).

In situ reserves of barytes was estimated as 78.8 M. T and production was 3,37,952 tons (1996-97).

11.3.5 Quartz, Quartzite and Silica sands

Quartz is used in electrical industry and for making silicon alloys and ceramics. Quartzites are used in refractories and in iron and steel industry. Silica sand is used in glass and sodium silicate industry, and in foundries. Crystalline quartz is mainly occurs in pegmatites and veins of quartz are found in granite gneisses of Hyderabad area. Quartzites occur mainly in Vizianagaram district and silica sand is found along the coastal tracts of Prakasam, Nellore, and Guntur districts. The main glassy sands come from Bapatla (Guntur dt.) to Chinaganjam (Prakasam dt.). The in situ reserves of quartz and silica sand in the state is 35.9 M.T. Production of quartz and silica sands was 65925 tones and 153808 tones respectively (1996-97).

11.3.6 Graphite

Graphite is also called as black lead, which is used for several purposes such as foundry, batteries, lubricating paint, refractories, paints etc. Graphite mineralisation is reported in East Godavari (Marripalem, Potaram, Vullapalem, Ramavaram etc, West Godavari (Reddi Bodair,) Khammam (Balapalle, Ipalpadu, Ravigudem, Sidharam), Visakhapatnam (Endapalle, Paidikonda), Vizianagaram (Nullapalem, Ramabhadrapuram, Tyeda), Srikakulam (Alluru, Kesari, Pachipenta) districts. Graphite occurs as a constituent of graphitic schists/gneisses belonging to the khondalite group of rocks. It also occurs as veins,

lenses/pockets associated with pegmatites traversing in khondalites of the Eastern Ghat metamorphic complex.

11.3.7 Mica

Mica group minerals are hydrous aluminosilicates. Mica is used in various uses industries like electrical appliances, roofing, wallpaper, rubber, paints etc. Main occurrences of mica are pegmatites, which cut across the country rocks of mica schists and hornblend schists. The Nellore mica belt is extended to Gudur, Rapur, Atmakur, and Kavali areas. The main mica minerals Nellore - Gudur belt are muscovite and Vermiculite. In addition to the Nellore mica belt, Phlogopite- Vermiculite occurrences have been reported in Borra, Kasipatnam areas in Visakhapatnam district. Occurrences of muscovite and biotite are also reported in Anantapur, East Godavari, Karimnagar, Khammam, Kumool and Srikakulam districts.

11.3.8 Diamond

Diamond is a pure carbon. It has high index of refraction and hardness. Diamond is highly resistant to chemical reagents even the strongest acids have no action on it. Diamond is the most valued gemstone. Diamond occurrences in Andhra Pradesh are reported from Anantapur, Cuddapah, Kumool, Prakasam, Mahaboobnagar, Krishna and Guntur Districts. Based on the mode of occurrence diamonds may be broadly categorized into three types. These are associated with

- a) The kimberlite, micaceous kimberlite and lamproite of late Proterozoic age (840-1020 my) located in Wajrakarur, Lattavaram, Venkatapalle and Ramagiri gold field areas of Anantapur district and Maddur -Mahaboobnagar sites of Mahaboobnagar district.
- b) Proterozoic Banganapalle basal conglomerate and conglomerate inter veining in sandstone or Banganapalle quartzite. (Banganapalle -Racherla and Muninnadurga area).
- c) The Krishna (Ustapalli -Paritala), Pennar (Hindupur- Sangam), and Sagileru (Giddluru -porumamille) riverbeds have diamonds.

The state in situ reserves of diamonds are placed at 194990 carats.

11.3.9 Clays

Clay is a natural mineral substance consisting essentially of hydrated aluminosilicates and plastic when sufficiently fine grained and wet, rigid when dry and vitrifying when fired at a sufficiently high temperature.

- (a) Clays are classified by their commercial application, these are (a) High grade clays (china clay, ball clay, paper clay, glass-pot clay, flint clay, plastic fire clay, graphitic fire clay, pottery clay, medicinal clay etc.), and
- (b) Low grade clays (loess clay, glacial clay, slip clay, adobe clay, gumbo clay etc.).

In Andhra Pradesh, important clay deposits are distributed in Adilabad district (Butermal, Chanaka, Dhanora, and kattarala) which are essentially sedimentary associated with the Kamthi formation of Gondwana Super group. In Srikakulam district (Eguvasembi, Nimmalapadu), clay beds are associated with the coastal Gondwanas. In West Godavari (Dwaraka- Tirumala, Kotlapalle, Kuchipudi, Yerrakalva, Venkata Krishnapuram), clays are associated with the Raghavapuram formation of Upper Gondwana rocks. In East Godavari district (Dowlaiswaram, Errapalem, Gurupalem, Jaggampeta, Razole etc), clays are associated with the Rajahmundry sandstone of Tertiary formations. In Hyderabad and

Rangareddy district (Alipur, Godamguda, Marepalli and Rudravaram etc.), clays are associated with the Deccan traps. In Ananthapur district (Balapuram, Vengannapalle, Uravakonda and Cherlopalle etc.) the clays are residual types. In Cuddapah district (Tellapaka, Vallurupalli and Anantarajupeta etc), clays are the result of weathering of shales especially the Pullampeta formation. Lakshmipuram, Madigunta clays are formed by the residual weathering of granite gneisses.

Resorting to levitation and sedimentation usually washes crude/raw clay. China clay is essentially a raw material in ceramic industry. Clays are used in High-low tension insulators, spark plugs, switches, white wares, sanitary-ware, glass tiles, stone wares, pipes, and rubber industry. It is also used in cosmetic, pharmaceutical and insecticide industries. Fuller's earth is mainly used after activation for decolorizing vanaspati oil and refining crude petroleum. Fire clay is mainly consumed in refractory industry. It is also used in ceramic industry.

11.3.10 Corundum

In Andhra Pradesh, corundum occurrences are found in the districts of Anantapur, Khammam, Chittoor and Nalgonda. It is found in several localities in the Atmakuru, Nutimadugu belt in Anantapur district. In Chittoor district, it is found near Yerracheruvupalle and Polichettipalli. In Khammam district, it is associated with Nepheline syenite at Rangapur and near Gobbugurti with ultrabasic rocks. In the Nalgonda district, it occurs in number of villages around Pargi and near Pedagudem. Timmapur, Ligampalle etc.

Corundum occurs in association with ultra basic and Nepheline syenitic rocks. The recovered pieces are however, from the weathered zones as also transported ones from their source rocks. They are associated with kyanite and fuchsite-muscovite sericite rocks near Tadkalpudi in Khammam district. Corundum is used as an abrasive, basic refractory and as semi- precious stone. The reserves of corundum are 1071 tons and production is 666 kg (1996-97).

11.3.11 Apatite

The main apatite deposits in Andhra Pradesh are situated near Kasipatnam of Visakhapatnam district. The average grade of apatite being produced is 34-36% of P_2O_5 . Apatite occurrences are reported from Nellore and Srikakulam districts (Garbham, Ramabhadrapuram and Devada), Visakhapatnam district, (Kasipatnam, Sitarampuram, Budi, Sithampeta, Regulavalasa).

Apatite-magnetite-vermiculite veins occur as 'fillings' en echelon. Shear fractures and shear joints, confined to the domal structure and the veins are radioactive and associated with vermiculite and titaniferous magnetite. These veins are characterised by a distinct zoning with an outer sheath of magnetite inner shell of vermiculite, and a core of apatite. Apatite is an essential constituent of the manganese bearing kodurites found in Srikakulam district. Apatite occurrences are also known to be associated with the pegmatite veins traversing the schist in Nellore mica belt. Apatite is used in the manufacture of fertilisers, phosphoric acid and extraction of elemental phosphorus. The in situ reserves of apatite in the state are placed at 0.4 M.T and production is 3150 tonnes (1997-98).

11.3.12 Asbestos

The main asbestos deposits in Andhra Pradesh occur in Pulivendla area of Cuddapah district, known popularly as the Pulivendla asbestos belt. It is traced over a length of about 24 km

between Velidendla and Brahmanapalli. Asbestos is located in the zones of serpentinisation along the contacts of dolerite sills in the dolomitic limestones belonging to Vempalli formation of Cuddapah Super group. These asbestos veins are of cross fiber type. Their colour ranges from translucent golden yellow to pure white silky fiber. The quality of the fiber varies from flexible to stiff and brittle. Chrysotile, the most important commercial variety of asbestos is a fibrous form of serpentine. The commercial use of chrysotile owes to its remarkable and unique properties like spinnability, combustibility, resistance to heat, acids and alkalis, filtration property, tensile strength and property to absorb cements. The physical properties of asbestos govern its utility. It is used in making yarns, paper blocks, cement products, brake lining and other automobile spare parts, special packing gaskets, insulating materials, painting, roofing etc.

11.3.13 Semi Precious stones

In Andhra Pradesh, alexandrite and chrysoberyl occur in pegmatitic veins in khondalite and leptynite of Eastern Ghat formations in parts of Srikakulam, Visakhapatnam, Vizianagaram and East Godavari districts. Many numbers of such pocket deposits are identified in recent times. Alexandrite is the costliest gemstone in the world market. Ruby, a variety of corundum is known to occur in association with granites in parts of Lakshmipuram, Tallada of Khammam district, Atmakuru, Pargi, Sivapuram of Anaparthi district in the hostage of pegmatite, nepheline syenite and anorthosite. Tourmaline, apatite, garnet, monazite, amethyst, rose quartz, rock crystal, opal, smoky quartz, topaz and zircon occur in the pegmatitic veins associated with Eastern Ghat formations of north central Andhra Pradesh.

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 clays?

4. Diamonds are associated with

11.4 FUELS

Coal, petroleum and natural gas are described here:

11.4.1 Coal

Coal occurs in four types viz., anthracite, bituminous, sub-bituminous and lignite. In Andhra Pradesh coal seams are mainly confined to the Barakar and Kamthi formations of Gondwana Group of rocks in Godavari valley. Thick coal seams are distributed in parts of Adilabad, Karimnagar, Warangal, Khammam and West Godavari districts. The coal deposits of Andhra Pradesh are non-metallurgical grade, and have low ash content and high moisture content. The Singareni Collieries Company Ltd. is carrying out exploration and mining activity in the areas of Ramagundam, Manuguru, Sattupalli, Pakalagudem, Allipalli, Mulkalapalli etc.

The in situ reserves of coal in Andhra Pradesh is estimated at 10,771 M.T and the production of coal has been increased to 28.7 M.T (1996-97) from 20.584 M.T (1991-92).

Petroleum and Natural gas

In Andhra Pradesh, Krishna - Godavari (K-G) sedimentary basin is one of the important petroleum and natural gas prospecting regions in India. Since 1977, the Oil and Natural Gas Corporation (ONGC) has been continuing its exploration programme in Andhra Pradesh. The important natural gas producing sites in K-G basin are Pasarlapudi, Tatipaka, Yandamuru, Mandapeta, Yalamanchali Adavipalem and Ponnumunda etc. The gas production in these reservoirs is 5 million cubic meters per day. Kesanapalli west and east, Lingala, Kaikaluru, Moore, Suryaraopet, Gopavaram, are the main petroleum producing wells and production of these wells is 800 tons per day.

In the offshore region GS-15 and GS-23 are producing natural gas and Ravva structure is producing both petroleum (50,000 barrels per day) and natural gas (7 lakh cubic meters per day).

The total reserves of petroleum and natural gas in Krishna - Godavari basin are 56.5 M.T

Chek 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 are the different coal mines in Andhra Pradesh?

6. Give the details of petroleum reserves of K-G basin.

11.5 SUMMARY

Andhra Pradesh is endowed with good number of mineral deposits distributed in various parts of the state. These minerals are grouped into three categories namely metallic, non-metallic and fuel.

The Bauxite is an important aluminium mineral, which is formed by the residual process. In Andhra Pradesh 657 million tons of Bauxite is available along the Eastern Ghat hill ranges. Iron ore is the second most abundant mineral in Andhra Pradesh. These deposits are associated with Dharawar, Cuddapah and Gondwana formations, and located in Ananthapur, Chittoor, Khammam, Warangal, Adilabad, Prakasam and East Godavari districts. The Manganese ore deposits mainly occur in Vijanagaram, Srikakulam and Adilabad districts. Copper deposits are distributed in Guntur, Khammam, Kurnool, Mahaboobnagar, Nalgonda, and Nellore districts. Lead and Zinc ores are occurring in Chittoor, Cuddaph, Guntur, Hyderabad, Khammam, Nalgonda and West Godavari districts. Chromite is available in Khammam, Krishna and West Godavari districts. Gold deposits are situated near Ramagiri in Ananthapur district.

Among the non-metallic deposits limestone is available in the districts of Cuddaph, Kurnool, Visakapatnam. Placer deposits like ilmenite, garnet, sillimanite; zircon, rutile, magnetite and monozite are distributed along the beach sand of north Andhra Pradesh. The dolomite rocks are situated in the district of Cuddaph, Kurnool, Warangal and Ananthapur. Baryte deposits occur in Cuddapah, Ananthapur and Khammam districts. Quartz, quartzites and silica sands are mainly occurring in the districts of Hyderabad, Vijayanagaram, Prakasam, Nellore, Guntur. Graphite deposits are situated in East and West Godavari, Vijayanagaram and Srikakulam districts. Mica minerals are located in Nellore district.

Diamonds are reported from Ananthapur, Cuddaph, Chittoor, Kurnool, Prakasam, Mahaboobnagar, Krishna and Guntur districts. Clay deposits are distributed in Adilabad, Ranga Reddy, Srikakulam, East and West Godavari districts. Corundum occurs from Ananthapur, Khammam, Chittoor and Nalgonda districts. Apatite deposits are situated in the districts of Nellore, Srikakulam, Visakhapatnam; Asbestos is available in Cudappah district.

Coal occurs in parts of Adilabad, Karimnagar, Warangal, Khammam and West Godavari districts. Petroleum and natural gas occurs in the Krishna-Godavari Basin.

11.6 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Aluminium
2. Psilomalene and pyrolucite
3. High grade clay - china clay, Ball clay; Low grade clay - loess clay, glacial clay
4. Kimberlites
5. Ramagundam, Manuguru, Sattupalli, Pakalagudem, Allipalli, and Mulkallapalli.
6. A total of 56.5 million tons of petrol and natural gas are available in K-G basin.

11.7 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Explain the mineral resources of Andhra Pradesh.

2. Explain the non-metallic deposits of Andhra Pradesh.

II. Answer the following questions in about 10 lines each.

1. Iron ores of Andhra Pradesh.
2. Coal deposits of Andhra Pradesh.
3. Mica deposits of Andhra Pradesh.
4. Baryte deposits of Andhra Pradesh.

BRAOU

UNIT: 12 MARINE MINERAL RESOURCES

Contents

- 12.0 Objectives
- 12.1 Introduction
- 12.2 Minerals dissolved or suspended in sea water
- 12.3 Minerals on the sea floor
 - 12.3.1 Placers and aggregates
 - 12.3.2 Phosphorites
 - 12.3.3 Metalliferous Sediments
 - 12.3.4 Manganese Nodules
 - 12.3.5 Coral Reefs
 - 12.3.6 Barite
 - 12.3.7 Zeolites
- 12.4 Minerals below the Sea Floor
 - 12.4.1 Petroleum and Natural Gas
 - 12.4.2 Gas Hydrates
 - 12.4.3 Coal
 - 12.4.4 Evaporites
 - 12.4.5 Minerals
- 12.5 Summary
- 12.6 Check Your Progress - Model Answers
- 12.7 Model Examination Questions.

12.0 OBJECTIVES

In this unit marine mineral resources are described.

After studying this unit you will be able to

- explain the minerals available on the sea floor
- describe the minerals below the sea floor

12.1 INTRODUCTION

Population growth demands use of minerals for various purposes. Many mineral deposits on land are depleting. Hence, search for minerals on other environments gains momentum. Marine environment is one such region, which covers 71% of the global area. The concentration of mineral deposits in the marine region is through different processes like transportation and deposition of continental sediments such as detrital grains, colloidal and solution phases; sub marine volcanic activity; outer space and biological activity.

These marine mineral resources are unevenly distributed on the ocean floor and marine mineral deposits are grouped in to A) those dissolved or suspended in the sea water B) those on the sea floor and C) those in the bed rock below the sea floor.

12.2 MINERALS DISSOLVED OR SUSPENDED IN THE SEA WATER

The elements dissolved in seawater are sodium, chloride, magnesium and its compounds,

bromine, gypsum and potash. These are the main products extracted from seawater.

12.3 MINERALS ON THE SEA FLOOR

In India, common salt and gypsum are produced from seawater on commercial basis.

12.3.1 Placers and aggregates

These are mechanical concentration detrital deposits. In general, they are formed in near shore regions. Placers are valuable heavy minerals and these are distributed on sea floor as well as in the form of buried relict (continental shelf) sands in addition to their occurrence in riverbeds and beaches. These placers contain mainly gold, platinum, ilmenite, tin, diamond, rutile, zircon, garnet, magnetite, monazite, corundum, cassiterite etc. These are mainly distributed off North America in the Pacific Northwest (platinum), off East and West Africa (diamond, ilmenite and associated minerals) off Indonesia, Malaysia and Thailand (cassiterite), off Sri Lanka (rutile and zircon), off Eastern and Western coasts of Peninsular India (light heavy minerals), off East Australia (rutile and zircon), Southeast Australia (gold and tin).

Aggregates are deposits of sands, gravel's and shells. Quantitatively these aggregates are more abundant and are used in construction industry.

12.3.2 Phosphorites

Phosphorite is a sedimentary deposit composed mainly with phosphatic minerals such as carbonate fluorapatite, francolite. These are chemical precipitates containing phosphates mixed with other phases and occur in shallow marine environment. In marine environment apatite can occur in various forms like fish debris, reptile bones, shells, coprolites and microcrystalline aggregates. Phosphorites are formed by two processes i.e., a) direct inorganic precipitation and b) the replacement of CO_3 by PO_4 in CaCO_3 .

Most of the Phosphorites are distributed on the western continental margins and water depths less than 1000 m. These deposits are mainly associated with the regions of upwelling and higher biological productivity. There are two regions in the world where phosphorites are thought to be forming today. They are off southwest Africa and off Peru-Chile, off southern California, southeastern USA, and western Mexico, east of New Zealand.

12.3.3 Metalliferous sediments

Sediments rich in iron, manganese and other elements associated with sub marine volcanic activity are considered as metalliferous sediments. Sedimentary deposits along mid oceanic ridge system, island arc system and flanks of all major oceanic ridges are of this type.

Metalliferous sediments are polygenetic in origin such as terrigenous, biogenic, authigenic, hydrothermal, magmatic and halmyolytic processes. These sediments are distributed in the red sea, along mid oceanic ridges, Bauer deep on the Nazca plate between the East Pacific Rise and the Galapagos Rise in the south eastern Pacific ocean and at off Mid oceanic ridges.

12.3.4 Manganese Nodules

These are also called as polymetallic nodules and chemically and mineralogically very complex in nature and exhibit mamillated appearance (hemi spherical-protrusions). Simple

chemical precipitation, absorption and biological activity are different mechanisms by which manganese nodules extract elements from seawater.

The manganese nodules occur in various sizes and shapes, and distributed through out oceans. They are having nuclei of one sort or another. These are mainly composed of authigenic iron and manganese minerals like magnetite, todorokite, pyrolusite and cryptomelane etc. The abundant elements are Mn, Fe, Ni, Co and Cu, and other elements such as K, Si, Ti, Ga, Zr, Mo, Pb, V and rare earths.

The polymetallic distribution on the ocean floor is controlled by the several factors such as (a) degree of oxidation of the depositional environment (b) nature and age of substrata (c) the proximity of sources of element (d) sedimentation rates (e) influence of organisms and (f) bottom current activity.

• Manganese nodule distribution is more irregular in the south Pacific than North Pacific Ocean, extensive nodule distribution is to the south of equator in the Indian ocean, Central Indian Basin, Southern Indian Ocean Basins and off Australia. In the Atlantic Ocean, nodules are distributed on either side of the Mid Atlantic Ridges.

12.3.5 Coral Reefs

The coral reef structure built by organisms such as mollusca, echinodermata hermatypic corals, the coralline algae, and hydrocorals, along with foraminifera, coral reefs with massive platform of limestone containing the calcareous skeletons. Coral reefs, which are built close to the shore and they fringes to the shoreline, are called as Fringing reefs. The width of these may be several hundred meters and formed below 30 m water depths. If there is a lagoon between the inner edge of the reef and the shoreline the structure is called as Barrier reef. These are much larger than fringing reefs and depending up on the lagoonal depth and much of it is quite shallow. Atoll is generally circular in plan and consists of a central lagoon and is surrounded by a narrow carbonate reef dotted with islands. Table reefs rise above the adjacent seafloor as plateau with out any appreciable rim. Coral Knolls are patch reefs rising above lagoonal floor inside the barrier reefs.

The Great Barrier reef off the coast of northeast Australia, Fringing reefs are in Florida, New Hebrides islands and major atoll is in New Mexico, west Carolina; Atolls are distributed mostly in Pacific and Indian Oceans. In India atolls are distributed in Karnikobar islands and Laksha in Maldives.

12.3.6 Barite (BaSO_4)

Barite is one of the wide spread marine minerals and it forms as pellets, euhedral crystals and microcrystalline aggregates. The barite may be formed through authigenitic, volcanic and biological processes.

12.3.7 Zeolites

Zeolites are minor constituents of marine environment. Commonly occurring varieties are phillipsite and clinoptilolite and minor constituents are laumontite, mordenite and thomsite etc. Phillipsite occurs at low sedimentation zones and below calcium carbonate compensation depth and is associated with red clays. This mineral is weathered product of submarine volcanic material. Clinoptilolite occurs in older sediments of marginal areas of the oceans. It is alternate product of silicic volcanic glass.

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 are metalliferous sediments?

2. Describe the Phosphorites.

12.4 MINERALS BELOW THE SEA FLOOR

The minerals in the bedrock below the sea floor are petroleum, natural gas, potash and other saline minerals, sulphur, coal, iron ore and barites. Natural gas and petroleum are extracted from below sea floor in the Bombay high in Indian west coast and Krishna - Godavari basin in the east coast, North sea projects of U.K. Molten sulphur is recovered from the off shore drill holes off Gulf of Mexico. Coal is being mined off Canada, U.K, Chile, Japan, Taiwan and Terlay. Iron ore is extracted from off Finland and off Canada. High-density brines are located in the Red Sea and underlying sediments are the source for Co, Mn, Zn, Pb, Cu, Ag, and Au.

12.4.1 Petroleum and Natural Gas

A complex mixture of liquid hydrocarbons is called petroleum. The petroleum reservoirs are confined to the sedimentary basins and they are distributed onshore as well as off shore regions. These reservoirs are mainly found in the continental shelf and slope regions, and small ocean basins have thick tertiary sediment columns. The main offshore petroliferous basins are found in Brazil, Gulf of Mexico, West Coast of Africa and East Coast of India. Marine production of petroleum began in 1930 at Venezuela and at present the world resources of petroleum (offshore) is around 85 million barrels.

12.4.1 Gas Hydrates

Gas hydrates are formed in water depths below 800 m, when gas and water mixtures are subjected to high pressure and low temperature in the sea. These are also formed in permafrost regions. Gas hydrates act as cap under which natural gas can get accumulated.

These are future hydrocarbon energy resources.

12.4.2 Coal

The most important and longest mined off shore bedded coal deposit, first mined, is in Scotland. Coal deposits are known to occur from many other continental shelf areas. Under sea coal production had accounted maximum in Japan (600 million tons). Many more under sea coal seams have been found off shore of Eastern Hokkaido and Western Kyreshe.

Coal Bed Methane (CBM): Depending upon the depth of burial, carbonaceous matter and geotectonical setting of coal and lignite beds contain variable amounts of methane. Australia, China and USA are producing CBM. India is in the exploration stage.

12.4.4 Evaporates

Evaporates (potash) are occurring very widely in continental shelf areas in salt pillows and in salt domes. The important deposit is Permian Zechstein salt deposit under the North Sea.

12.4.3 Metallic Minerals

Iron, copper and tin metallic deposits are also occurring in submarine bedrocks of continental shelf areas. Ex: Tin ore of Carnival (UK), Magnetite deposits of Jussaro Island of Finland, Copper deposit of Lake Superior.

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 important minerals below the sea floor?

4. Name the metallic minerals, which occur below the sea floor.

12.5 SUMMARY

Many mineral deposits on land are getting depleted. This results in searching minerals on

marine environment. This is one important region, which covers 71% of the global area. The concentration of mineral deposits in oceans may occur through transportation with rivers, submarine volcanic activity and biological activity. The marine resources are classified into three groups viz., minerals dissolved in seawater, those on the sea floor, and those in the bedrock below the sea floor.

The elements occurring in seawater in dissolved state are sodium, chloride, manganese, bromine, gypsum and potash. The minerals existing on the sea floor are placers, phosphorites, metalliferous sediments, manganese nodules, coral reefs, barites, zeolites etc. Placer deposits are mainly mechanical concentrations formed in near shore regions like gold, platinum, ilmenite, tin, diamond, rutile, zircon garnet, magnetite, monazite, corundum, cassiterite, etc.

Phosphorite is a secondary deposit formed mainly from fish debris, reptile bones, shells, coprolites etc. Sediments rich in iron, manganese and other element are associated with submarine volcanic activity. Metalliferous sediments are polygenetic in origin such as terrigenous, biogenic, authigenic, and hydrothermal, magmatic process. Manganese nodules are also called as polymetallic nodules formed by chemical precipitation, absorption and biological activity on seawater. The manganese nodules are in various sizes and shapes, distributed throughout the ocean floor. Coral reefs are also important marine resources. Barite is one of the wide spread marine mineral formed with authigenic volcanic and biological process. Zeolites are the minor constituents of marine environment.

Minerals, which occur below the sea floor, are the petroleum and natural gas, gas hydrates, coal, coal bed methane, evaporites and metallic minerals.

12.6 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Metalliferous sediments are rich in iron, manganese and other elements also cited with submarine volcanic activity.
2. Phosphorites are sedimentary deposits occurs in various forms like fish debris, reptile bones, shells, coprolites etc.
3. The important minerals below sea floor are petroleum and natural gas, coal, evaporates, metallic minerals etc.
4. Iron, copper, and tin occur as metallic minerals below seafloor.

12.7 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in about ^{lines} 10 each.
 1. Describe the marine mineral resources.
 2. Explain the following marine resources of seafloor.
- II. Answer the following questions in about 10 lines each.
 1. Phosphorites.
 2. Gas hydrates.
 3. Coral reefs.
 4. Manganese nodules.

BRAOU

BLOCK – IV MINERAL ECONOMICS – II

BRAOU

UNIT:13 CLASSIFICATION OF WAR MINERALS

Contents

- 13.0 Objectives
- 13.1 Introduction
- 13.2 War Minerals
- 13.3 War supporting Minerals
- 13.4 Classification
- 13.5 Strategic Minerals
 - 13.5.1 Application of strategic minerals in war
 - 13.5.2 Present position of strategic minerals
- 13.6 Critical minerals
 - 13.6.1 Application of critical minerals in war
 - 13.6.2 Present position of critical minerals
- 13.7 Essential Minerals
 - 13.7.1 Application of essential minerals in war
 - 13.7.2 Present position of essential minerals
- 13.8 Summary
- 13.9 Check Your Progress - Model Answers
- 13.10 Model Examination Question

13.0 OBJECTIVES

In this unit, classification of war minerals is described.

After studying this unit, you will be able to

- explain the classification of war minerals
- define the strategic minerals
- describe the critical minerals and essential minerals

13.1 INTRODUCTION

Industrial revolution has contributed to the massive search and application of minerals to industry and national prosperity. Where as the incidence of war on the globe has lead to unimaginable exhaustion of minerals and chaos. The tremendous consumption of minerals and metals used during wars for fighting on land, sea and in air has thoroughly revolutionised the human outlook and created a new awareness in a nation's perspective for mineral planning. The terms strategic, critical and essential minerals are the resultant outcome of war emergency in relative adequacy or otherwise for winning a war. Military preparedness has thus become an integral part of nation's responsibility to defend the country and ward off territorial infringement. A war requires quick mobilisation of men, money and material. Material provides the fighting power and it comes from minerals alone. It is, therefore, the policy of all governments now to maintain up to date inventories of domestic resources and also to take such measures of procurement and stockpiling programmes that would deter the hostile countries from a possible invasion.

13.2 WAR MINERALS

War requires an encyclopaedic list of minerals for fighting power. War minerals are

absolutely essential for warfare, communication and transport. In fact, there is hardly any mineral that is not needed for welfare or war supporting civilian needs. The role of minerals, unlike in peace time economy, assumes much greater significance in times of national crisis, because lack of adequate resources even in a very small quantity may prove grave hazard to the security of the nation.

A brief list of war minerals includes Iron ore for iron and steel, manganese ore for ferromanganese, ores of different alloy metals like tungsten, molybdenum, vanadium, chromium, titanium, nickel, antimony, magnesium, cadmium, zirconium, ores of aluminium, copper, lead, zinc and tin for their metal contents. Beryl for beryllium oxide, piezoelectric quartz, germanium, sulphur, phosphorus, lithium, strontium, graphite, uranium, coal and petroleum also constitute war minerals.

13.2 WAR SUPPORTING MINERALS

A host of other minerals needed to produce the above mentioned metals and alloys, and also for the manufacture of certain supplementary material for war efforts are categorised as war supporting minerals. They include refractory minerals, limestone for flux and cement, gypsum for plaster of Paris and cement, arsenic ore for poisonous and chemical warfare, asbestos for isolation, china clay for insulation and spark plug; fluorspar, industrial diamond, borax and mercury.

13.3 CLASSIFICATION OF MINERALS

Taking the relative adequacy of mineral position in a country as the basis, war minerals are further classified as strategic, critical and essential minerals. Let us examine the real significance of these terms in detail.

A strategic mineral is one, in which a country has more or less negligible resources available and for which it depends on outside sources. A critical mineral is one, in which a country is deficient in supply position, but known occurrences are such that they can be exploited, irrespective of cost, as a wartime measure. An essential mineral is one in which known resources are quite large and produced in sufficient quantities.

It must be clearly noticed that all the three terms strategic, critical and essential are relevant only with reference to an individual country and for a given time. A strategic mineral to India need not be a strategic mineral to other country. Similarly a strategic mineral of today may become a critical mineral tomorrow or even an essential mineral in course of time. The reverse is also possible. The term 'sufficient' or 'adequate' seems to be more appropriate than essential, since such a term will be more meaningful and also eliminates the possible misconception, that the other categories are non essential. Let us now take stock of the present mineral resource position in the country to see what are our deficiencies, our insufficiencies and our adequacies in this lesson. Incidentally, it is also necessary to have some idea of how important they are in war applications.

13.5 STRATEGIC MINERALS

Ores of tungsten, molybdenum, nickel, tin, antimony, arsenic, strontium and mercury, piezoelectric quartz crystals, sulphur, asbestos, industrial diamonds, borax and petroleum may be classified as strategic minerals of India from the available knowledge of current resources and

supply positions.

13.5.1 Application of Strategic minerals in War

Metal and Alloys: Tungsten is used in the manufacture of ammunition, armour plates and heavy guns. Tungsten steel is necessary for making of armour piercing bullets. High-speed tools require adequate amount of tungsten metal to the tune of 18% W. Tungsten is used as a very good refractory metal with 2610°C as melting point and is one of the most important alloying metals used in steel and other non-ferrous alloys. Even 0.25% of the metal imparts sufficient hardness to alloy steel. Molybdenum is a good substitute for tungsten. Nickel is used in the making of stainless steel and high nickel alloys. These are necessary for crankshaft, marine, electronic, nuclear power and aerospace applications. One other important application of nickel is in the form of chrome-nickel alloy, which is made to throttle the flow of electricity to convert it into heat or light. Tin is essential for food canning, to facilitate air dropping the military supplies in war front.

Arsenic is used for poisonous and chemical warfare and war uses of antimony are confined to manufacture of anti-friction metals and hardening of lead. Strontium compounds like strontium oxalate and nitrate have war time applications. Strontium oxalate is used in tracer bullets to control the burning rate of the trace composition. Usually, every fifth bullet fired in war is a tracer bullet. Strontium nitrate is required for military flares, rockets and shells. Mercury has innumerable uses both in war and peace times and they are largely confined to pharmaceuticals. Army uses bulk quantities of mercury preparations for antiseptics and the like. Mercury fulminates are used for detonating explosives.

Non-Metals: Piezo-electric quartz crystals play a key role in radio, telecommunication and electronic industry. Quartz plates, used as oscillator plates, prevent wavelengths from wandering and transmit them with correct frequency. They are employed in radio transmitting and receiving sets, for controlling the frequency and detection devices for locating submarines. In radar and in acoustic submarine devices, they amplify a mechanically produced wave, transforming it into electrical energy and projecting it to detect objects. The electric wave bounces back and is transformed into sound by the quartz plate and the sound projected upon a screen indicates the approximate position of submarines.

Sulphur is an indispensable element for war efforts. Manufacture of explosives, refining of petroleum, sugar and preparation of medicines, disinfectants etc. require sulphur. Sulphuric acid is called the king of all chemicals and essential for pickling of steel, galvanising and tinning besides various other applications.

Asbestos, particularly the crysotile variety, is required for heat and electrical insulations. Quick erection of barracks and storage godowns by army is made possible with asbestos cement sheets. Asbestos cloth is used during the fire fighting.

Industrial diamonds, apart from their industrial application, are most needed for cutting hard materials like steel plates used in the manufacture of armour plates, aircrafts and other war equipments.

Recent uses and applications of borax and the various boron compounds have increased the military significance of this mineral. Boron hydride has potential value as rocket fuel developed in recent years. Boron 10 isotope has the unique property of absorbing neutrons produced in nuclear reactions and so it is used to protect personnel from harmful radiations,

in the field of nuclear energy. Ammonium pentaborate is used as a 'poison charge' in atomic submarines.

Fuels: Military dependence on petroleum and its innumerable products is rather unlimited. Petroleum provides the fighting power on land, sea and in air. The so-called napalm bombs, used in Vietnam War were made with petroleum jelly.

13.5.2 Resource position of strategic minerals

Metals: Tungsten: Total recoverable reserves of tungsten ore in the country (as on 1995) are estimated at 38 million tonnes. Andhra Pradesh constitutes 37.86%, Rajasthan constitutes 35.44% and Maharashtra constitutes 21% of the reserves.

There was a significant development in recovery of scheelite (tungsten ore) from the gold field dumps of Kolar and Hutti in Karnataka. Pilot plants, erected at these places, are expected to produce around 70 tons per year in due course.

Molybdenum: We have no molybdenum deposits in the country. Molybdenum is generally associated with copper, lead and zinc ores. Molybdenum concentrates are intermittently produced as a by-product from Jaduguda Uranium mine in Bihar. Reported occurrences of molybdenum include Jaduguda Uranium ores (0.1%), Rakha Copper deposits (0.11%) of Bihar and also Dariba-Rajpura lead-zinc deposits of Rajasthan.

Total recoverable reserves of molybdenum ore in the country (as on 1995) are estimated at 8036900 tonnes. The imports of molybdenum decreased by 21% to 45 tonnes during 1999-2000 compared to 57 tonnes in 1998-1999.

Nickel: There is no indigenous production of nickel or its alloys and the entire requirements are met by imports. Imports of nickel and alloys during 1999-2000 amounted to 367 tonnes as against 1131 tonnes during 1998-1999. The production of nickel sulphate during 1999-2000 was 155 tonnes. Total conditional reserves of nickel ore in the country (as on 1995) are estimated at 183.5 million tonnes.

Tin: Total recoverable reserves of tin ore in the country (as on 1995) are estimated at 29 million tonnes with a metal content of 3272 tonnes located mainly in Bastar district of Chattisgarh. The production of concentrates during 2000-2001 was at 12979 kg as against 22812 kg during 1999-2000.

Antimony: There is no production of either antimony ore or metal. Imports of antimony ores and concentrate in 1999-2000 decreased to 25 tonnes as compared to 40 tonnes in 1998-99. Antimony ore occurrence is reported in Lahul-Spiti, area of Himachal Pradesh, Karimnagar of A.P., Chitradurga of Karnataka, Udaipur of Rajasthan and Chamoli of U.P. The total conditional ore reserve estimated in Himachal Pradesh comprise of 10,588 tonnes (as on 1995).

Arsenic, Strontium and Mercury: There is no production of either arsenic ore or metal in the country. Similar is the case with strontium ore minerals and the liquid metal mercury.

Non-Metals: Piezo-Electric Quartz Crystals: Although the country produces quartz and other silica minerals, suitable for other industrial requirements, in respect of piezo-electric quartz crystals, the country is totally dependent on imports.

Sulphur and pyrite: There is no native sulphur deposit in the country. However, recovery of elemental sulphur is limited to the by product, obtained from petroleum refineries and fuel oil used as feed stock for manufacturing fertiliser. Total recoverable reserves of pyrites in the country as on 1995 are placed at 98.79 million tonnes. Total conditional resources of native sulphur in Leh, Jammu and Kashmir as on 1995 are 0.21 million tonnes. The production of sulphur was at 62047 tonnes in 2000-2001 as against 24883 tonnes in the preceding year. The total sulphur imports of the country during 1999-2000 amount to 2024637 tonnes.

Asbestos: Recoverable reserves of all varieties of asbestos are placed at 9.4 million tonnes. The production of asbestos at 14516 tonnes in 2000-2001 registered a fall of 22% as compared to that of 1999-2000. Barring a small quantity of about 6% of total output of asbestos as chrysotile grade, the entire output was reported in amphibole grade. Imports of asbestos in 1999-2000 totalled 60583 tonnes as against 76094 tonnes in 1998-99.

Industrial Diamond: Production of industrial diamonds is negligible compared to our requirements. The country possesses diamond recoverable reserves of 11,96,154 carats (1991-92) and production of diamonds was at 18,213 carats in 1991-92. The total recoverable reserves of diamond in the country (as on 1995) are placed at 9,81,515 carats. Imports of diamonds during 1999-2000 were valued at Rs. 23,108 crore against 15,556 crores in 1998-99.

Borax: There is no domestic production of borax and the entire requirement is met by imports. India imported 36,311 tonnes of borax during 1999-2000. Conditional resources of 74,204 tonnes of borax are estimated in the only known deposit of little economic significance is in Puga Valley, J & K. The occurrences are also reported in Surendranagar district of Gujarat and Nagaur district of Rajasthan.

Fuels: Petroleum: Exploration and production of crude oil and natural gas in the country is looked after mainly by the Oil and Natural Gas Commission (ONGC) excepting the leasehold area in the north-eastern region, which are managed by Oil India Limited (OIL). OIL is operating mainly in Assam, Arunachal Pradesh and has also completed exploration of 2 off shore wells in the Mahanadi basin of Orissa coast. ONGC's new oil discoveries include Ratnagiri and Godavari offshore structures.

Total hydrocarbon resources of the country for on land and including deep waters of east and west coasts is approximately 30 billion tonnes. The in place geological reserves are 6.85 billion tones. The domestic crude production in 1999-2000 was about 32 M.T and gas production was 28.5 billion cubic meters. During 1999-2000 imports of petroleum increased by 47% to 58.38 million tonnes as against 39.69 million tonnes in 1998-99.

The production of crude oil recorded a spectacular increase during the decade particularly from 1977 with the commencement of production from Bombay High, which alone accounted for 67% of total production in 1983. Despite the setback entailed by the suspension of production in Assam in 1980, production recorded an all time high of 25.1M.T in 1983.

But the rapid rise of petroleum prices during the decade effected our economy and 80% of the total value of mineral imports during 1982-83 was only due to crude petroleum, although the quantum of imports of petroleum increased by only 22% during period. (Production 1973-74: 13.9 M.T; 1982-83: 16.9 M.T). As a result of the massive investment in exploration for petroleum by the country the strategic position is bound to improve to critical if not essential in the near future.

Check Your Progress

- Note: a) Space is given to write your answer.
b) Compare your answer with the one given at the end of the unit.

1. Classify war minerals.

2. Name any five strategic minerals.

13.6 CRITICAL MINERALS

Ores of copper, lead, zinc, uranium and lithium apatite and rock phosphate for phosphorus and graphite may be classified as India's critical minerals, reviewing their present status in the country.

13.6.1 Application of Critical Minerals in War

Metals: Copper, lead and zinc are mainly used as alloy metals and actively employed in the manufacture of war ammunition in different forms. About 400 kg of copper is required to build a tank, a tone of the metal for a large bomber and 1000 tonnes for a battle ship. Still larger amounts are required for ammunition. Sizeable amount of copper goes in the making of anti-aircraft guns and aeroplanes. Copper-Zinc alloys are used in the manufacture of jacket of cartridges, air-bullets and shells. The use of copper is not only confined to the making of ammunitions and shells but also extensively required in other active fronts like telecommunications and telephone exchanges. Several miles length of copper wire is required for such uses. All armatures of electric motors require copper wire. Both lead and zinc are used for the protective coating of steel sheets. Lead is essential to the preparation of 100-octave aviation gasoline and ammunition foil in war times. Lead prevents the gamma radiations and so painting of lead on doors and windows protects people from radiation hazards of atomic bombs. To save tin, use of silver-lead soldering in ships, tanks, rockets etc. was reported during the Second World War.

Uranium is a metal. It can also be treated as a nuclear fuel. Nobody could ever imagine before the first bomb was dropped in Nagasaki and Hiroshima, Japan in 1946, that tiny isotopes of uranium contain such a vast amount of energy stored in them. Atoms of radioactive elements

when made to split up generate tremendous amount of heat, which can ruin anything in a fraction of a second. The energy released by the fission of a single uranium atom is 200 million electron volts. One kg of U^{235} releases heat equivalent to 3700 tonnes of coal. Its heating value will therefore be 30,00 times greater than coal in terms of British Thermal Units (BTU).

Lithium and its compounds acquired great military significance after the Second World War, besides its peacetime applications. Lithium isotopes Li^6 and Li^7 are required for warfare. Li^6 is used for the production of tritium, extra heavy hydrogen, and an intermediate explosive in the preparation of hydrogen bombs. Li^7 metaphosphate and pyrophosphate are valuable constituents in fused salt nuclear breeder blankets. Lithium perchlorate is used as rocket propellant and in nuclear reactors. Lithium hydroxide and lithium borohydride are used for war purposes. Lithium is also used for signal flares in tracer bullets.

Non-Metals: Phosphorus is used in the manufacture of incendiary bombs, tracer bullets and smoke screens. Pure natural graphite is used as a moderator in slowing down the action of neutrons of uranium. It was a primary material used for research during the production of atom bomb in 1940.

13.6.2 Current Status of Critical Minerals in India

Metals: Copper: According to the National Mineral Inventory (as on 1997) there are about 461 million tonnes recoverable reserves of copper ore in the country containing about 4.7 million tonnes of copper metal (1.02%). Production of copper ore are at 3.48 million tonnes during 2000-2001 was higher by 13% as compared to that in the previous year. Imports of copper ores and concentrates at 400,550 tonnes in 1999-2000 were 35% more than 296,110 tonnes in 1998-99. During 1999-2000, meagre quantity of copper ores and concentrates were exported.

Lead and Zinc: India has about 176 million tonnes of recoverable reserves of lead and zinc ore containing about 2.2 million tonnes of zinc metal (as on 1997). The production of primary lead during 2000-2001 decreased to 34,480 tonnes from 35,120 tonnes in 1999-2000. The production of zinc metal at 1,78,015 tonnes in 2000-2001 increased marginally by about 2% as compared to that in 1999-2000.

Uranium: The only uranium mine in the country is at Jaduguda, in Singhbhum dist, Bihar. Singhbhum Copper belt of Bihar constitutes an important source of uranium containing about 0.5 to 1Kg per tonne of rock. The principal mineral is uraninite associated with secondary minerals and the grade is 0.03 to 0.1%, which is economically extractable. Besides, this uranium is also worked out near Umra and Udaisagar in Rajasthan. Uranium also occurs in the mica Pegmatites of Bihar, A.P. and Rajasthan. Singar mica mines of Gaya (Bihar) and Sankara and Kodandarma Mica mines of Nellore dist. A.P., reported occurrence of uranium minerals like samarskite. The barren measures of Gondwana coals are also found to be a source of uranium. Apart from these, the monazite sands of Kerala and Tamilnadu coasts yield 0.2 to 0.5% of U_3O_8 , when processed. The total reserves of uranium in beach sands, estimated by department of Atomic energy, government of India are about 30,000 tonnes.

Exploration, exploitation and production of all radioactive minerals including uranium ores are under the direct control of the central government. Atomic energy Commission (AEC) is the main organisation looking after the developmental programmes. Research and applications of the atomic energy are executed at the Bhabha Atomic Research Centre

Non-Metals: Mica is indispensable for the manufacture of all electronic equipment, because of its unique dielectric strength and insulating property.

Limestone is essential for flux in the manufacture of steel and other materials. It is the primary raw material for cement. Gypsum is also required for cement making and plaster of Paris. China clay is used for insulation purposes. Since the exhaustion of natural cryolite in the world, fluorite rescued aluminium metallurgy. Fluorite is used in the manufacture of artificial cryolite, which is most important for aluminium production. Fluorite is also used as a flux in the cryolite but to balance the fluorine content and in steel metallurgy to reduce the viscosity. Besides these indirect applications, production of atom bombs requires many fluorine chemicals.

Fuels: Military dependence on coal and coke is unlimited. The coal and coke are the inner strength of all metallurgical, chemical and fabrication industries. They are a source of thermal heat and electricity and locomotion.

13.7.2 Present Position of Essential Minerals in India

Metals: Iron and Steel: India is self sufficient in the production of iron, pig iron and steel as already given.

Manganese: According to the National Mineral Inventory (Indian Minerals Year Book, 2001), the total recoverable reserves of manganese ore (as on 1995) are placed at 167 million tonnes. The production of manganese ore at 1.56 million tonnes during 2000-2001 marginally decreased by about 2% as compared to that of 1999-2000. Exports of manganese ore during 1999-2000 were 75,685 tonnes showing a sharp decrease of 55%. Imports of ore during 1999-2000 were 5,102 tonnes showing an increase of 17%.

The two major consuming industries of manganese ore are iron and steel and ferromanganese. Low grade ore of 30 -35% Mn may be used for pig iron, but ferromanganese requires better grade (38% Mn) and preferably of 46% Mn content.

Vanadium: India has large resources of vanadium ore in the form of vanadiferous-titaniferous magnetites occurring in Karnataka, Orissa and Maharashtra. The total recoverable reserves are placed at 11.53 MT as on 1995. India exported 82 tonnes of vanadium in 1999-2000 and imported 6,765 tonnes in 1999-2000. Important applications of vanadium are as ferrovandium for steel and as V_2O_5 catalyst for H_2SO_4 manufacture by contact process.

The Regional Research Laboratory, Bhubaneswar, Orissa was engaged in developing a process for extraction of vanadium from the vanadiferous titaniferous magnetites, and this roasting process made it possible for a 90 to 100% recovery.

Chromium: The total recoverable reserves of chromite in the country (as on 1995) are placed at 86.23 million tonnes. Production of chromite at 1952 thousand tonnes during 2000-2001 registered an increase of 12% compared to that of the previous year.

Exports of chromite during 1999-2000 increased by 45% to 714,448 tonnes. And imports registered a substantial increase to 6,886 tonnes in 1999-2000.

Titanium: The most prolific beach sand deposits containing ilmenite and rutile and other valuable minerals like monazite lie in three prominent coastal regions of India. (1) Between

Neenadakara and Kayamkulam 22km stretch in Kerala (2) From the mouth of Valliyar River to Colachel Newly discovered single sand dune deposit in Chattarpur coast 18 km over an area of 26 sq km in Orissa coast.

Beach sands of Neendakara-Kayamkulam area contain the highest concentrations of heavy minerals in the world with 60 to 70% ilmenite and 4-7% rutile in addition to others. According to AMD of the DAE, the reserves of ilmenite and rutile in the beach sands of India are at 138MT and 7MT respectively. Additional reserves in the Chattarpur sand dune deposits amount to 230 MT, containing 9.4% ilmenite and 0.4% rutile. The Department of Mines and Geology, Government of Maharashtra in the Ratnagiri Coastal region estimated additional reserves of about 4 MT of ilmenite with TiO_2 content of 20 to 40%.

It was reported, the Misra Dhatu Nigam Ltd. has set up a metallurgical plant at Hyderabad to produce commercially pure titanium metal and titanium alloys from does with a capacity of 200 to 250 tpa. The production technology was obtained from France and West Germany. It was also reported that IRE was contemplating to set up an electro-smelting plant for metallurgical processing of ilmenite with a capacity of 50,000 tpa. The titanium slag is an important feed for the production of titanium dioxide pigment.

Magnesium: Magnesite is the primary source for magnesium metal. Total recoverable reserves of magnesite as on 1995 are placed at 245 MT.

Magnesite is used mostly in the manufacture of basic refractories; sorrel cement (magnesium oxychloride) and magnesium salts. A small portion of it is used for metal production on pilot plant scale by the CECRI, Karaikudi. Magnesite (heated upto 800° - 1000° C) is called caustic and is used for sorrel cement. Highly calcined one (heated to 1800° C) is called dead burnt magnesite, and is used for basic refractory bricks. Raw magnesite is used for magnesium chemicals like magnesium chloride and sulphate. India produced 317,000 tonnes of magnesite in 2000-2001. We export magnesite to other countries. Due to non-availability of low silica (to 1.5%) dead burnt magnesite for roof lining in steel industry, we are importing small quantities of such quality for this specific end used.

Aluminium: Details of bauxite reserves, production and also the position of aluminium industry are furnished in power-based industries.

Zirconium: Zircon is the primary source for zirconium metal. Zircon occurs in the beach sand deposits along with ilmenite and rutile. The reserves of zircon are placed at 21.14 MT as on 2000. The total output of zircon in 2000-2001 was 27,119 tonnes.

Beryllium: Beryl is the main source for beryllium metal. Pegmatites of Rajasthan, Bihar and AP contain considerable quantities of beryl. Because of its sporadic mode of occurrence in Pegmatites, its reserves are difficult to estimate. Since the mineral is governed by the Atomic Minerals Act, details are usually not available. During the Second World War, India exported large quantities of beryl. Indian quality of beryl is prized because of its 10 to 14% content of BeO , a percentage considerably higher than in beryls from other sources. In 1967, India contributed 57% of the world production, but in 1968 it came down to 20%.

Non-Metals: Mica: The recoverable resources of mica in India are 1,09,022 tons (1990) and the production of crude mica was considerably declined to 3,592 tons (1991-92) from 7,934 tons (1980). The recoverable reserves of mica (as on 1995) are; Andhra Pradesh 44,837 tonnes, Bihar 12,161 tonnes, Jharkhand 1393 tonnes and Rajasthan 1,589 tonnes. Total

exports of mica during 1999-2000 was 46,558 tonnes showing a decrease of 7% and imports during 1999-2000 was 477 tonnes registering an increase of about 18%.

Limestone: The total recoverable reserves of limestone of all grades as on 1995 are placed at 75,679 MT. The country produced 126 MT of limestone in 2000-2001. Exports of limestone decreased from 2,19,319 tonnes in 1998-1999 to 209,186 tonnes in 1999-2000. Imports during 1999-2000 decreased by 11% to 1.2 MT.

Gypsum: Gypsum is available in three forms. (1) Natural (mineral) (2) marine and (3) by-product (phospho, boro, fluoro or chemical) gypsum. The varieties of gypsum mineral are selenite (finely crystalline), alabaster (compact and massive) and satinspar (fibrous and silky variety). Indian mineral gypsum is mostly gypsite type, which is an earthy porous type of inferior quality admixed with clay and sand.

The total recoverable reserves of natural gypsum is placed at 237.6 MT. The production in 2000-2001 was 2707 thousand tonnes. Exports of gypsum in 1999-2000 were 31,765 tonnes and imports were 10,128 tonnes in 1999-2000.

China clay (kaolin): The country possesses vast resources of kaolin and others clays. The inventory of Kaolin resources including white clay and ball clay is placed at 1,402 MT. Production of Kaolin was recorded at 791,000 tonnes in 2000-2001.

Kaolin is one of the essential constituents in ceramic industry. Products manufactured include high tension and low-tension insulators, white wares, sanitary wares, glazed tiles, stoneware pipes and jars.

Fluorite: Total recoverable reserves of fluorite in the country as on 1995 are placed at 2.95 million tonnes. Bulk of the reserves about 50% are located in Rajasthan, 29% in Gujarat, 13% in Maharashtra and 8% in Chhattisgarh. By-product fluorine gases in the form of fluoro-silicic acid, emanating from phosphatic fertiliser and phosphoric acid plants have been recognised as a powerful source of fluorine for producing synthetic products, for which fluorite was used.

The total production of fluorite in 2000-2001 was 47,055 tonnes from the states Gujarat (93%), Maharashtra (5%) and Rajasthan (2%). The entire output reported was metallurgical grade. Chemical, Iron and steel and ferroalloy and alloy steel industries account for the bulk consumption of fluorite in the country. In the chemical industry, fluorite is required for production of fluorine-based inorganic chemicals, like aluminium-fluoride, cryolite and several other organic chemicals. Its other applications in aluminium metallurgy and steel production etc. were already given.

Imports of fluorspar during 1999-2000 were 76,295 tonnes in comparison to 72,352 tonnes in 1998-99. Exports in 1999-2000 decreased by 91% to 24 tonnes as compared to 279 tonnes in 1998-99.

Fuels: Coal and Lignite: The total geological reserves of coal in India upto a depth of 1200 m stands at 211.59 billion tonnes as on 1-1-2000. The total known geological reserves of lignite stand at about 29.36 billion tonnes. The country produced 304.1 MT of coal during 1999-2000 which was a rise of 2.6% in comparison to previous year. Madhya Pradesh (including Chhattisgarh) continued to be the leading producer accounting for 28.9% of the production, followed by Jharkhand (25.2%), Orissa (14.3%), A.P. (9.7%), Maharashtra

(9.1%), West Bengal (5.9%) and U.P. (5.3%).

The entire coal mining was reorganised with effect from 1.11.1975. As a result, Coal India Limited (CIL), a holding company was set up with 5 subsidiary companies namely Bharat Coking Coal Ltd (BCCL), Eastern Coal Fields Ltd (ECL), Central Coal Fields Ltd (CCL), Western Coal Fields Ltd (WCL) and Central Mine Planning and Design Institute (CMPDI) for mining and planning of coal resources. In addition to the above, two other companies namely Singareni Collieries Co. Ltd (SCCL) and Nyveli lignite Corporation (NLC) were also engaged in mining of coal and lignite respectively. Of these, SCCL is a joint undertaking of Government of India and Government of A.P.

Coal exports at 1157 thousand tonnes in 1999-2000 were about 40% more than 823 thousand tonnes in 1998-99. Imports of coal in 1999-2000 increased to 19,702 thousand tonnes against 16,537 thousand tonnes in 1998-99.

Check Your Progress

- Note: a) Space is given below to write your answer
b) Compare your answer with the answer given at the end of the unit.

5. Name any five essential minerals.

13.8 SUMMARY

The use of minerals in wars for fighting on land, sea and air has created new awareness in notions perspective for mineral planning. Materials provide the fighting power and it comes from minerals alone. It is therefore the policy of all governments now to maintain upto date inventories of domestic resources and also take such measures of procurement and stock piling. War minerals are essential for warfare, communication and transport, taking the relative adequacy of mineral position in a country as basis; war minerals are divided into strategic, critical and essential minerals. A strategic mineral is one in which, a country has more or less negligible resources available and for which it depends upon out side source. A critical mineral is one, in which is a country deficient in supply position, but known occurrences are such that they can be exploited irrespective of cost, as a war time measure. An essential mineral is one in which known resources are quite large and produced in sufficient quantities. It is fact that all the three types are relevant only with reference to an individual country and at a given period.

Ores of tungsten, molybdenum, nickel, tin, antimony, arsenic, strontium, mercury peizo electric quartz crystals, sulphur, asbestos, industrial demand, borax and crucial are classified as strategic minerals. Ores of copper, lead, zinc, uranium, lithium, apatite, rock phosphate, are classified as critical minerals.

Iron ore, steel, coal; ores of manganese, aluminium, cadmium, zirconium, germanium, beryllium, mica, limestone, gypsum, china clay and fluorspar are classified as essential minerals.

13.8 CHECK YOUR PROGRESS - MODEL ANSWER

1. War minerals are classified as strategic, critical, and essential minerals.
2. Ores of Nickel, Tin, Antimony, Sulphur, Arsenic.
3. Critical mineral is one, in which a country is deficient in supply but known occurrences are available as wartime use.
4. Ores of copper, lead, zinc, uranium, lithium, etc.
5. Ores of Iron, coal, mica, limestone, manganese etc.

13.9 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Write about the classification of war minerals.
2. What are strategic minerals? Explain its current status in India?
3. What are critical minerals? Describe the current position in India?
4. What are essential minerals? Explain its status in India?

II. Answer the following questions in about 10 lines each.

1. Application of critical mineral in war.
2. Application of strategic minerals in war.
3. Application of essential minerals in war.

UNIT:14 NATIONAL MINERAL POLICY - IMPORTANCE

Contents

- 14.0 Objectives
- 14.1 Introduction
- 14.2 Concepts of National Minerals Policy and Axioms
- 14.3 Objectives of New Mineral Policies.
- 14.4 New exploration Licensing policy
- 14.5 International implications of Mineral Resources
- 14.6 Close door, open door, and restricted policies
- 14.7 Requisites to frame the policies
- 14.8 Summary
- 14.9 Check Your Progress - Model Answers
- 14.10 Model Examination Questions

14.0 OBJECTIVES

In this unit, national mineral policy and its importance are described.

After studying this unit, you will be able to

- explain the national mineral policy
- describe the concepts and Axioms of mineral policy
- define the requisites to frame the policies.

14.1 INTRODUCTION

Mineral policies are important for the exploration and exploitation of mineral resources available in the country. For the mineral trading with other nations policies act as guidelines.

National Mineral Policy has broad perceptive and has more weightage than any government policy which is formulated for short tenure and it will be changed whenever required. But National policy is long-term policy and more over it takes into consideration past experiences, present status and future perspectives. National policy of any government will project its image in the international arena.

14.1.1 Evolution of National mineral policy

We do not have much details of mineral policies of ancient kings in India. In the book 'Arthashastra' Kautilya described few minerals such as gold, silver, copper, lead, tin, iron and mercury and the royalty collection of kings from private mine owners after selling of mineral products. By permanent settlement (Regulation one of 1793), the mineral rights were vested to the Zamindars or landlords throughout the provinces of Bengal, Bihar, Orissa and presidency of Madras, except the scheduled districts. In the scheduled districts of these four provinces and other provinces of India mineral rights were vested either in the government or in the rules as the case might be. During the British period the mineral rights were vested in the government in the British ruled areas and with the states in the princely states.

In 1894, Government of India framed rules for the grant of exploration and mining. In 1901 "Indian Mines Act" was promulgated for regulation and inspection of mines. Up to 1947,

category viz. measured, indicated, inferred, such information is useful for planning the future projects and also find out the gaps in the knowledge and the quantum of further work needed for getting the present and immediate requirements.

The National mineral policy' 1990 is revised and in March 1993, government of India was announced new National Mineral Policy with a view to encourage private investments both in domestic and foreign sector. The main aim of revised policy is to encourage the flow of foreign investments and technology and securing access to foreign markets. The main objectives of the revised National mineral policy are started in 1993 are discussed here.

- a) To explore the identification of mineral wealth in the land and in off- shore areas.
- b) To develop mineral resources take in to account the national and strategic considerations and to ensure their adequate supply and best use keeping in view the present needs and future requirements.
- c) To promote necessary linkages for smooth and uninterrupted development of the mineral industry to meet the needs of the country
- d) To promote research and development in minerals
- e) To ensure establishment of appropriate educational and training facilities for human resources development to meet the man power requirements of the mineral industry
- f) To minimise adverse effects of mineral development on the forests, environment and ecology through appropriate protective measures and
- g) To ensure conduct of mining operations with due regard to safety and health of all concerned.

The inventory should include not only the reserves position but also it give all the details often deposits such as quality, extraction potential, economic viability and their suitability to different industries. It is in continuous process and should be time to time modified. This invention should be helpful not only for industries but also it avoid duplication of exploration work, it promotes research and development activities.

14.4 A NEW EXPLORATION LICENSING POLICY (NEZP)

A New Exploration Licensing Policy (NEZP) has also been formulated by the government of India to encourage private participation in exploration and exploitation of oil fields. The committed expenditure of private/joint venture for exploration of oil and natural gas is \$286 million for three years (2001-04). Under NELP several blocks were allotted for oil exploration and exploitation. Recently (2002) NELP-III out of 23 blocks 13 were allotted for ONGC, 9 for Reliance Industries and one for Gujarat state petroleum corporation and Geo global resources.

14.5 INTERNATIONAL IMPLICATIONS OF MINERAL RESOURCES

Mineral resources are of international character. To have an overhaul global view of their international implications, an insight into Prof A.M. Bateman's observations on this topic before Indian Science Congress, 1954, will be quite useful. Discussing the relative distribution and sufficiency of the USA, the other NATO countries, USSR (with allied countries) and India, he comes to the conclusion that the USA and the British Commonwealth countries complement each other, and they together have nearly all the minerals needed for industrial development and defence. The other West European countries by

themselves are woefully deficient in most of the essential minerals of industry, but the overseas areas of some of these countries contain important supplies of many of the needed industrial minerals. The Russia has the largest actual and potential mineral resources of any individual country of the world and contains practically all the minerals essential to modern industry. With her rapidly growing industrialisation and wide areas congenial to future ore discoveries, Russia is bound to remain as one of the greatest industrial nations of the world.

14.6 CLOSED DOOR, OPEN DOOR AND RESTRICTED POLICIES

National Mineral Policy has to be viewed from two angles, one domestic and the other foreign i.e., the attitude of a government towards foreign investment. Each country has its own problems and each tries to develop its domestic resources, make search for new ones and reduce external dependence as far as possible. To achieve this objective, countries follow either a 'closed door' policy or an 'open door' policy or a 'restricted' policy. In the closed-door policy no foreign investor is allowed to participate except those of allies. Where as the open door policy is one where foreign investment and participation is freely allowed. In the restricted policy investment and participation is allowed on minority share basis. Mainly communist countries follow closed-door policy.

The policy decision again varies from 'have' countries to 'have not' ones and industrially developed or less-developed to under-developed countries. A number of countries including UK, Japan and most of the European countries have advanced industrially, but without having sufficient mineral resources. Obviously these countries look upon for foreign supplies from different and diversified sources to maintain regular inflow of raw material. The attitude of their government is to encourage their people acquiring mining rights wherever possible and to extend technical know how in mining and get back mineral resources in return. It is only in this context, that Japanese, have financed for development of our Bailadila hill ranges, to ensure supplies of iron ore for their own country. Japan has also extended considerable technical know-how, capital equipment and finance in the iron ore mines of Goa. Such collaboration on mutual benefit has become a common feature of modern thinking. At the same time, collaboration in fabrication and metallurgy is viewed with suspicion and political motives. Such collaboration does not come forth easily, unless a larger interest of the lending country is involved. It is therefore difficult to pin point precise scope of foreign investment policy and the attitude has to be necessarily flexible.

The mineral policy on the whole, is based on realistic knowledge of a country's mineral resources and its industrial status in relation to competing powers. A country's mineral resources are susceptible to progressive measurements upon new resources added or discoveries made. The policy should therefore be subjected to revision promptly upon new mineral evidences.

14.7 REQUISITES TO FRAME THE POLICIES

Keeping the four axioms, universally recognised, and elaborated earlier as a basis and guideline, further framework of policies is worked out in relation to:

(1) appraisal of mineral resources (2) leasing system of mineral rights (3) mines safely (4) mineral taxation policy (5) conservation and substitution of minerals (6) mineral dressing and metallurgical innovations (7) Stockpiling programmes.

but with a difference that it does not accrue any interest; as we go on drawing, the reserves continue to diminish. So any effort that we can make to increase the life of a deposit, without sacrificing our own needs, is an attempt towards conservation. Take for instance our iron ore. We have seen earlier that 45% of our iron ore production constituted fines, while 55% was lumps in 1980. The use of pellets and sinters prepared from these fines, which were thrown out as waste for a long-time, has increased many folds the reserve position of iron ore. Same is the case with manganese ore, limestone and many other minerals. The utilisation of mica powder and waste mica into a number of useful products like micanite is one other example that can be cited in this context. Similarly the refuse of scrap has prolonged the life of metallic mineral deposits considerably. The efforts for conservation should be made at all stages.

The following measures should be adopted to achieve conservation of mineral resources.

1. Efficient method of mining to take out every possible tonnage locked under ground.
2. Utilisation of leaner and unmarketable ores by innovations in ore dressing and metallurgical practices.
3. Use and reuse of scraps.
4. Recovery of all associated elements as co-products or by-products.
5. Economy in use of minerals.
6. Synthesis and substitution.

Let us discuss the scope of these measures for conservation.

15.2.1 Efficient Method of Mining

When we mine a particular mineral, depending on the nature of deposit, attitude of the deposit and the nature of country rocks, there may be more than one method of mining applicable for exploiting the mineral deposit. The main consideration for the choice of a mining method in such cases is the economy and maximum recovery from the deposit without intermittent losses.

15.2.2 Beneficiation of Low-Grade Minerals

By beneficiation of minerals, we improve the grade of a mineral and bring it to the level of specification needed to suit a particular industrial need. Beneficiation of low-grade iron and copper ores has already been mentioned in the earlier unit. I will now appraise you with some of the recent achievements of the research and development wing of our country in 1980. In order to conserve our limited coking coal reserves, the non-coking coal is being blended for production of coke to suit steel metallurgy. The limitation of non-coking coal based sponge iron plants in the country have already been mentioned. (Refer Steel Industry).

The latest reports show that the country is able to produce cold-bonded pellets for use in blast furnace, which requires less energy and avoids heavy capital investment compared to the conventional heat hardening process of pelletization. Similarly instead of using limestone in lumps, lime dust is being injected in one of the blast furnaces at Durgapur Steel Plant. These reported achievements will certainly go a long way in the conservation of minerals in steel industry. To quote another instance of beneficiation, this time in respect of molybdenum, which is a scarce strategic metal, the report reveals the following. Molybdenum content in the copper ore of Rakha mines, Bihar is successfully enriched from 0.014% to 47.58% in the concentrate, with an overall recovery of 80.65% by the mineral dressing wing of the Bhabha Atomic Research Centre at Hyderabad.

15.2.3 Use and Reuse of Scraps

For purposes of utilisation, minerals are divided into 2 classes; namely expendable and non-expendable. Expendable minerals are those, which have practically no salvage value and once consumed are lost forever. Coal, petroleum, natural gas and in fact most of the non-metallic minerals with the exclusion of precious stones come under this class. Metallic minerals have a good salvage value as scrap and are recycled into normal run of consumption in Course of time.

The percentage recovery of scrap of the individual metals, as also the period of recovery for reuse may vary depending upon the type of Use it is put to. Metals used for chemicals, just like the many non-metals do not have salvage value. Non-expendable value of metallic minerals has greatly aided conservation.

Common metals like iron and steel, aluminium, copper, lead, zinc, tin and antimony have good recoverable value as scrap. Scrap utilisation of metals like nickel, cobalt, magnesium and mercury is reported from countries like USA. Precious metals like gold, silver and platinum are seldom lost. Metallurgical and fabrication industries produce large quantities of mill scrap or factory scrap during cutting, trimming and finishing the various products. In steel industry alone, considerable amount of scrap in the form of spillages, trimmings, and cutting comes out, while producing finished steel from ingot. These are recovered, re-melted and put into use again, and form a useful source of secondary metal.

Recovery of metals form a secondary source is true to every metallurgical and fabrication industry, with variations in quantities recoverable. In addition, scraps result from outlined machinery, plants, wagons, rails, automobiles and several other things including household articles. These form huge sources of secondary metals. To cite one memorable instance in this context, even the horse-shoe nails, ordinary nails and other broken steel structures were collected in India during the second world war to meet the shortages of steel.

15.2.3 Recovery of all Associated elements

Recovery of all possible associated elements, which occur as co-products or by-products, is very essential for working of individual deposits. In addition, when we do not have a certain mineral deposit in the country, the co-products and by-products provide potential sources for such metals or non-metals. For instance, we do not have silver or native sulphur or molybdenum deposits in the country. We therefore rely on these co-products and by-products, produced by the various processing plants in the country.

India produced 11,3,777 Kg of co-product and by product silver during 1980, while the gold production during the same year was only 2452 Kg including the by-product gold (56 Kg) by the copper smelter at Ghatsila, Bihar. Out of 11,377 Kg of silver produced, gold refining at Kolar and Hutti gave 117 Kg and 60 Kg respectively, while Tundoo lead smelter, Bihar gave 10,579 Kg and copper smelter at Ghatsila contributed 331 Kg and Visakhapatnam Refinery gave 290 Kg.

Besides gold and silver a number of allied products are produced during refining of copper ores both at Khetri Copper Complex (KCC), Khetri, Rajasthan and Indian Copper Complex (ICC), Ghatsila, Bihar. The sulphide content of these ores is recovered in the form of sulphuric acid. These refining plants are so designed, that they have the necessary installed capacity for production of allied products, depending on the annual yield expected from these. (Table-15.1)

Table 15.1 Production of allied by-products from KCC & ICC during 1980

Name of Refinery	Allied By-products	Installed capacity (Tonnes)	Production (Tonnes)
K.C.C	Sulphuric Acid	182,000	17,960
	Triple super phosphate	90,000	563
	Gypsum	300,000	6,983
	Gold	8,491 (Troy Ounces)	
	Silver	(Licensed capacity) -Do-	
I.C.C	Sulphuric Acid	54,000	4,330
	Selenium	10	4.15
	Nickel Sulphate	26	176
	Crude gold	100 kg	56 kg
	Silver	1,000 kg	331 kg

In addition to these, scarce metals like molybdenum, whose percentage is very low, are being upgraded by research wings as elaborated earlier.

20.2.5 Economy in use of minerals

Economy in use of minerals particularly when we have limited resources of that mineral in the country is a measure of conservation. It only means putting the mineral of limited resource to specific and indispensable uses only. In other words, for other uses a substitute for this mineral has to be used. Take for instance the case of sulphur. It for sulphuric acid in a particular case, hydrochloric acid could be used it amounts to conservation of sulphur. Recent experiments have shown that in pickling of steel for galvanising and tinning purposes, sulphuric acid can be substituted by hydrochloric acid. It has been made possible also to partly, if not completely, substitute sulphuric acid by hydrochloric acid in the manufacture of triple-super phosphate. These measures can greatly help in country's economy in the use of this scarce and strategic commodity for India, and divert the quantity thus saved for other indispensable uses. Our attempt to use non-coking coal instead of our limited cooking coal in steel metallurgy also comes under these measures of conservation.

Check Your Progress

- Note: a) Space is given below to write your answer
b) Compare your answer with the one given at the end of the unit.

1. What is conservation?

2. Name any two measures of conservation.

15.3 SUBSTITUTION OF MINERALS

Both synthesis and substitution are efforts to conserve a scarce mineral commodity. But there is a substantial distinction between the two. Substitution is an effort to find out alternatives to materials in short supply. Efforts of substitution and conservation in most cases are supplementary to each other. A substitute can have only nearly similar properties to that which is substituted, and its availability being cheaper and easier. On the other hand, if a new product is invented or a new mineral or metal having better performance is found out, than the mineral or metal in use, it cannot be categorised under substitution. It can rightly be placed under a new invention. It is a new source of raw material created by synthesis.

15.3.1 Synthetic minerals

To illustrate the role of synthesis, the example of natural cryolite and natural nitre may be cited. These two are replaced today by synthetic cryolite and synthetic nitre. Germans invented these synthetic products during the World War periods. The reserves of natural cryolite from its singular occurrence in Greenland being exhausted even by 1962; synthetic cryolite is universally used now in the place of natural cryolite. Synthetic nitre has become a strong competitor of Chile nitre (sodium nitrate), which is regarded as the largest single source in the world. With the advent of 'nitrogen' fixation from atmosphere, nitrogen and several compounds of nitrogen have become inexhaustible resources. A number of synthetic abrasives and refractories are now manufactured, which have a better performance than some of the common abrasive and refractory minerals. Synthetic diamonds are produced in several countries. These are simple crystals and their abrasiveness is more uniform and higher than the natural sort. Synthesis of corundum, ruby and sapphire for industrial uses has been in vogue for a long time. More recently, about 20 years back, quartz crystals have been synthesised on a commercial basis. Fluor-phlogopite has been synthesized for industrial purposes.

15.3.2 Substitution in Metals

Substitution and replacement of materials has become very common. The replacement of metals by plastics and glasses is a matter of routine, where strength is not a major factor. Let us consider the usage of copper. We were using copper, brass or bronze vessels and tumblers in household. We do not use this scarce metal today. Steel or aluminium and even plastic or glass tumblers and vessels have replaced copper ones depending upon one's own financial soundness and the purpose. The same is the case in industry too. Worldwide shortage of copper and relative abundance of aluminium has made aluminium substitute copper wires in high transmission lines, although aluminium has only 70% capacity to allow flow of electricity, compared to the same volume of copper. All underground cables are manufactured of aluminium instead of copper since 1962 in India. This resulted in saving about 3600 tonnes of copper metal every year. Substitution of copper by aluminium in high-

tension electric lines resulted in another significant advantage because of the low weight of aluminium. The saving in weight permitted a wider spacing of towers on high-tension lines, which in turn economised the use of steel. The possibility of substituting zinc and tin in galvanising and tinning of steel by aluminium has also become a reality. This will save considerable quantities of zinc and tin metals in the country. Similarly replacement of lead pigments by titanium pigments in white-paints and aluminium instead of zinc in certain components in the die-casting industry and use of plastic or glass bottles instead of tin cans have contributed to conservation of lead, zinc and tin metals.

Tungsten carbide is a good substitute for industrial diamond in cutting tools, especially in drilling. Bauxite has substituted fluorspar in steel metallurgy. Fluorite is used as a flux and also to reduce viscosity in steel manufacture. By substituting bauxite, for fluorite has been brought down from the previous rate of 8 Kg per tonne to 2 Kg per tonne of steel. So 6 Kg of fluorite is saved for every tonne of steel produced in the country, with this substitution. One other important substitute to mention is use of vanadium pentoxide in the place of the scarce and costly metal, platinum. Manufacture of sulphuric acid by contact process requires the use of platinum as catalyst. Vanadium pent oxide has substituted platinum. The catalyst industries in the country manufacture V_2O_5 for such purposes. We do not have any known platinum deposits in the country so far.

15.3.3 Substitution in Non-metals

For mica a number of substitutes have been developed and sold in the market under different trade names like Samica, Filmica etc. These products have substituted natural mica in capacitors and become more popular among the design engineers for electric and electronic equipments. Advancement of this technology and substitution outside, has affected our mica exports seriously. Our country is unique in the production of sheet mica in the world.

15.3.4 Substitution in Fuels

Let us turn to substitution in energy resources. Electricity has substituted, where its supply is cheap and abundant, much needed coke in blast furnace to the extent it is required to generate heat. Diesellisation and electrification of many rail routes have helped in the conservation of good quality coal. Hydro-electricity has saved consumption of coal in thermal stations.

Nuclear energy has also become as good competitor of thermal energy in an area, where the supply of coal is to be obtained from long distances. Hydro-electricity is the cheapest of all, but its power cannot be transmitted to every nook and corner, unless sufficient hydel potential is available. Between thermal and nuclear, in certain areas, the latter has an advantage. Cost of generating nuclear power per unit at Tarapur in Gujarat and Ranaparatap Sagar in Rajasthan is estimated at 2.8 paise as compared to 3.25 and 5.25 paise respectively of thermal power.

15.4 MINERAL AND ENERGY RESOURCES – FUTURE OUTLOOK

Substitution of hydro-electricity and nuclear energy for coal and the relative feasibility of these as also their cost are discussed. However much we do conserve these by substituting one for another, the ultimate question that remains is, about the life of these various sources of energy. We have discussed the relative adequacy of mineral resources earlier. We have realised now, that substitution of one mineral by another mineral has become a necessity. In

the long run with the possible exhaustion of minerals, may be at a distant future, development of non-mineralic substitutes like plastics and glass in addition to innovation of synthetic products, is but a vital necessity in the long range planning of mineral resources.

Turning our attention to energy resources, the life of fossil fuels both coal and petroleum over the world may not last long, at the rate of present consumption, with the increasing needs ahead of us. However, with respect to the hydro-electricity, there is a vast scope for development in a country like India with rich river water resources, remaining untapped. But again the main draw back in supplying it to nook and corners, limits our choice to the only possibility of development of nuclear power for the future energy needs of the world.

The supply of Uranium-235 from high-grade ores for the development of nuclear power is also limited. Our only hope is the development of a fast breeder reactor capable of consuming all of natural uranium and thorium, instead of only 1% as in the present light-water reactors. When the technology for the breeder system is fully developed, power production from low-concentration deposits of uranium and thorium becomes economically viable. It would also be possible to realise the potential of nuclear power based on fission to meet the energy needs of the world for several hundreds of years.

The possibility of recycling of nuclear fuel, without loss, in nuclear power generation, which has been engaging all nuclear scientists, including Indian, today when realised, will be a major break through in the conservation of energy resources. However, to be on the safe side one should attempt for a much bigger source-energy from fusion, which has not yet been achieved. The thermo-nuclear power based on fusion of atoms as occurring when a Hydrogen Bomb explodes, is an inexhaustible source of energy derived from heavy water. This is water in which deuterium replaces the hydrogen. If deuterium could be made to fuse in a controlled way into helium, this process would provide a source of unlimited energy. Scientists are working for the production of power from controlled fusion and the feasibility of building a fusion reactor is greater today than it was a decade back.

Check Your Progress

- Note a) Space is given below to write your answer.
 b) Compare your answer with the one given at the end of the unit.

3. What is substitution?

4. What are synthetic minerals?

15.5 NECESSARY STEPS TO IMPROVE MINERAL RESOURCES

There is no point in getting either frightened by the pessimistic view point or feeling over confident, about the optimistic view point. These viewpoints on the other hand, should create the much-needed awareness for improving the position of mineral resources. The following steps are of utmost importance for any nation to improve its own mineral resources.

1. Discovery of new deposits similar to those that are being worked.
2. Development of deposits containing lower concentration of elements than was hitherto exploited.
3. Development of new types of deposits not hitherto exploited these might be termed as un-conventional deposits.
4. Increase of scrap and waste recovery.
5. Synthetic manufacture and substitution of scarce minerals by those that are more readily available or by other materials such as glass plastics etc.

15.5.1 Discovery of new deposits

Discovery of new deposits, similar to those that are now being worked, is one important measure to improve our mineral resources. The latest advances in the geological, geophysical and geochemical methods of exploration in recent times put the modern prospector on altogether a different plane compared to the older prospecting methods. Advancement of photo-geology with modern techniques of aerial photography to decipher geological structures in complicated and inaccessible areas, as also the remote sensing techniques, with satellite data have aided to geological prospecting in a big way. Similarly the application of various geophysical methods on land and seas contributed to enrichment of vital mineral reserves like petroleum; we have now more sophisticated and portable radiation survey meters compared to old Geiger Muller counters. Scintillometers are now used in aeroplanes to cover more area quickly for locating uranium. Fluorescent lamps help to identify tungsten minerals. Mercury sniffed is used to detect traces of mercury in rocks. Employment of the principle of neutron Activation Analysis (NAA) made it possible today, to locate beryllium minerals with Berylometer and silver with silver snooper in the field. Even in the laboratories, latest techniques like NAA and Atomic Absorption Spectrometry have become powerful tools for rapid elemental analysis, thereby contributing to geochemical prospecting in a significant way. Thus with the advent of new geophysical instruments and an array of new tools for locating hidden deposits, the increasing importance of geochemistry and the use of computers to make a quick assessment of the data, the chances of locating new mineral deposits have considerably increased.

15.5.2 Development of low grade deposits

As regards the development of deposits containing lower concentrations of elements than were hitherto exploited, iron ore and copper ore may be cited as two spectacular examples. We in India as on today, have enough iron ore resources. But look at the US in this respect.

The high grade iron ore deposits of the Mesabi Range, which for over a century served the US steel industry got depleted a few years ago, but the joining low-grade taconites have come to the rescue of their steel industry. These taconites were beneficiated to give the iron-rich pellets. Although the change over was more expensive, the extra cost was more than compensated by the fact they were finally higher in grade, cheaper to handle and required less fuel to smelt.

Let us see the example of copper in general. At one time only ores containing at least 0.6% Cu (i.e. containing 120 lbs per tonne of rock mined) constituted copper ore for metal extraction. Advancement in the copper beneficiation techniques, namely flotation has changed the requirement and as a result copper mines are operating with grades of 0.6% (or 120 lbs per tonne of rock) and even 0.4% Cu are processed. One can envisage the fantastic increase in reserves of copper by being able to use such low-grade ores. What was not an ore previously is an ore today, with the advancement of science and technology. This advancement, unlike in the case of iron ore, is of greater relevance to India, in view of our copper position.

15.5.3 Development of new types of deposits

These deposits may be called unconventional deposits. We have earlier in the steps confined our attention to the improvement of conventional types only. Regarding the development of unconventional deposits, the possibilities are

(1) Gypsum and anhydrite for sulphur (2) Clay and high alumina rocks for alumina (3) Oil shale and bituminous sands for petroleum. (4) Sea-floor nodules for manganese, nickel, copper and cobalt. (5) Phosphate for fluorine and (6) Non-pegmatite mineral deposits of bertrandite, phenacite and berylite for beryllium.

The minerals that are included here are of paramount importance in industry and defence. Of these, anhydrite is already being used in the production of sulphuric acid in West Germany. For us sulphur is a strategic mineral and we have no native sulphur deposits. In contrast, we have adequate gypsum deposits. High alumina rocks are used for predestine of alumina in Russia. This only means, that in respect of such a crustally abundant element like aluminium, one has to necessarily look for other aluminous rocks also, not confining to the conventional bauxite.

Regarding petroleum, the first large-scale mining and extraction plant for the recovery of the petroleum from the tar or heavy sands of Athabasca, Canada has already gone into successful operation. Recent advances in oceanography have contributed to location of extensive manganese nodules also containing small amounts of other associated metals like cobalt, nickel and copper. According to Mero, the exploitation of this wealth is feasible. Tapping of these and other resources in seas, will certainly ease demand position to a great extent. Resources of fluorine and beryllium are fast depleting in the world and hence the need for development of unconventional resources for these two is greater.

The remaining two steps namely the utilisation of scrap and application of substitutes constitute methods of conservation and hence are elaborated in the next units.

Check Your Progress

- Note: a) Space is given below to write your answer.
b) Compare your answer with the one given at the end of this unit

5. Name any two steps to improve mineral resources.

15.6 SUMMARY

Conservation and substitution are very important things in the mineral industry because minerals are non-renewable sources. Conservation is an effort that to utilise mineral resources available in the best possible way, depending upon the industrial needs and changing technological requirements conservation does not mean accumulation of mineral wealth without putting it to use, when required.

The following measures should be adopted to achieve conservation of mineral of mineral resources

- 1) Efficient methods of mining to take out every possible tonnage locked underground.
- 2) Utilisation of leaner and unmarketable ores by invention in ore dressing and metallurgical practices.
- 3) Use and reuse of scraps
- 4) Recovery of all associate elements as co-products or by products.
- 5) Economy in use of minerals
- 6) Synthesis and substitution of minerals.

Substitution is an effort to find out alternatives to materials in short supply. A substitute can have only nearly similar properties to that, which is substituted and it's availability being cheaper and easier. The invention of new sources for mineral is synthesis. The natural cryolite and natural nitre and replaced by synthetic cryolite and synthetic nitre. Substitution and replacements of metal with plastic and glass is a matter of routine.

The necessary steps to improve mineral resources are

- 1) Discovery of new deposits similar to those that are being worked.
- 2) Development of deposits containing lower concentration of elements than were hitherto exploited
- 3) Development of new type of deposits
- 4) Increase of scrap and waste recovery
- 5) Synthetic manufacture and substitution of scarce minerals.

15.7 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Conservation is an effort to utilise mineral resources available in the best possible way.
2. Beneficiation of low-grade minerals and use and re use of scrap.
3. Substitution is an effort to find out alternatives to materials in short supply.
4. Synthesis is the invention of new source or alternatives to minerals.
5. Discovery of new deposits and development of low-grade deposits.

15.8 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in about 30 lines each.

1. Explain the conservation measures of minerals.
2. Describe the substitution and synthesis of minerals.
3. Explain the necessary steps to improve mineral resources.

II. Answer the following questions in about 10 lines each.

1. Use and reuse of scrapes.
2. Substitution in metals.
3. Synthetic minerals.
4. Mineral resources-future out looks.

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BRAOU

UNIT:16 GROWTH OF MINERAL INDUSTRY - MINERAL LEGISLATION

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- 16.1 Introduction
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 - 16.3.1 Meaning of terms
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- 16.4 Summary
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16.0 OBJECTIVES

In this unit, growth of mineral industry and mineral legislation are described.

After studying this unit, you will be able to

- explain the growth of minerals based industries
- describes the mineral legislation in India
- define maritime laws

16.1 INTRODUCTION

Minerals are essential for running any industry. A mere knowledge of mineral occurrences in the country will not be of much help to the students of mineral economics. An intelligent study of various mineral deposits in relation to their economic evaluation and industrial applicability is required to be made. In mineral industry usually a number of minerals go to form a single product. The economics of selecting the site for a particular industry in proximity to mines, besides other considerations require great scrutiny. All industries require minerals as basic raw materials. But some of them require power also. So for locating the industry, it is fort to be decided whether is essentially a power based or raw-material based industry

Judicious use of minerals is very essential, because the minerals are non-renewable resources. For this government of India formulated mineral legislation. These laws are useful to solve

technical, economical, political and legal problems involved in the process of exploration and exploitation.

16.2 GROWTH OF MINERAL INDUSTRY

Based on earlier records, Indian mineral industry traced back to 300B.C. There are several evidences on the land by means of slag of ferrous and non-ferrous materials at smelters. There was a big hiatus of records until middle of nineteenth century. In the early 20th century also very few minerals such as, coal, petroleum, gold, manganese, mica, salt peter, salt, agates, rock crystal, beryl, chromite, magnesite, iron ore, diamond, monazite etc were mined. In pre-independence period only 24 mines were worked. During and after world war periods, the mineral industry gains momentum for growth and exploration. After independence mineral exploration, mining and settings of mineral industries were in large-scale. New organizations were set up to increase activities in mineral industry. Central government established the Bureau of Mines in 1948. After that several organizations were set up for exploration, mining and for beneficiation works (Department of Atomic Energy 1954, ONGC 1956, National Mineral Development Corporation 1958, Oil India Ltd. 1958, Pyrites and Chemical Development Corporation 1960, Minerals and Metals Trading Corporation (MMTC) 1963. The Neyveli Lignite Corporation was formed in 1956 for mining and utilization of Lignite deposits, of Tamilnadu. The New Industrial policy, 1991 had made a remarkable impact on the mineral industry. So many regulations and control acts on mineral industries were liberalized and scope was increased tremendously for the growth of mineral industry.

16.2.1 Iron and Steel industry

The most important industry is iron and steel industry. Steel is synonymous with industrialization and per capita steel production of any country is an index of the degree of its industrial development.

The basic requirements for making steel are iron ore and coking coal. Iron has not enough strength and hardness to be used in industry and has to be treated with other elements to change its character. A small amount of Carbon is to be added to get strength. The third major raw material in the manufacture of steel is Limestone, which combines with impurities in the iron ore to form slag. Raw material requirement per ton of steel production is given below (Table 16.1).

Table 16.1 Raw material requirement per ton of steel production

Raw Material	Quantity
Iron Ore (60% Fe)	1.7 Tons
Coking Coal	1.7 Tons
Flux Grade limestone	0.5 Tons
Dolomite	0.25 Tons
Manganese ore	40 Kg
Ferro Manganese	10 Kg
Refractories	
Fire clay	40 Kg
Basic	20 Kg
Silica Bricks	5 Kg

Iron ore in the form of oxide (Hematite) is reduced to metallic iron in the form of pig Iron and subsequently purified to convert it into other forms namely Cast Iron, Wrought iron and Crude Steel. Manganese is essential as it imparts certain desirable characters like tensile strength. For this purpose it is added in the steel making in the form of Ferro Manganese alloy.

Steel is virtually a versatile commodity used everywhere by modern man in one or other forms. Right from ordinary pins to heavy machinery, rails, trains, ships, constructional purposes, shafts, stainless steel, pressure chambers, and Armature plates requires steel. Steel has become an essential requirement in our daily life. This resulted in the making of different types of steel to suit the specific uses by adding ferroalloy metals like manganese, chromium, nickel, vanadium, tungsten and also other metals like copper and non-metals like carbon and silicon. These metals or non-metals cannot be directly added to steel but only in the form of ferroalloys and this promoted manufacturing of ferroalloys in the country.

Steel plants: The Steel Authority of India (SAIL) in 1973 to manage all the public sector Steel plants and associated input industries. Prior to the SAIL, the public sector steel plants were under the control of Hindustan Steel Ltd (HSL). SAIL contributes more than 40% of domestic crude steel production. The important plants are:

1. Bhilai (with USSR collaboration), Madhya Pradesh
2. Durgapur (British collaboration), West Bengal
3. Rourkela (West Germany collaboration), Orissa
4. Bokaro (USSR collaboration), Bihar
5. IISCO, Burmpur (Indian Iron & Steel Company), West Bengal
6. Visweswarayya Iron & Steel Ltd. (VISL); Bhadravati, Karnataka.
7. Tata Iron & Steel Company (TISCO), Jamshedpur, Bihar.
8. Salem Steel plant in Tamilnadu
9. Visakhapatnam Steel plant in Andhra Pradesh.
10. Vijaynagar Steel plant in Karnataka.

In addition to the above integrated steel plants, there are two pig iron producing plants at 1) The Sandur Manganese & Iron Ore Limited, Karnataka and 2) Kalinga Iron Works, Orissa.

Invention of pelletization technology leads to utilization of iron ore fines, which are previously dumped as mine wastes. The important pelletization plants are 1) KIOCL (Mangalore, Karnataka), 2) Noamundi plant (TISCO, Bihar) 3) Mandovi pellets Ltd. (Owned by SAIL and Chowgule & Co.) Shiroda, Goa and 4) Chowgule & Co Pale, Goa.

Sponge iron plants: Sponge iron is metallic product produced by direct reduction of high grade Iron or Iron ore pellets into solid states. Sponge Iron industry was delicensed in 1985. The Sponge Iron units were established with 14lakh tons capacity at 1) Andhra Pradesh Sponge Iron Ltd. (Paloncha, Andhra Pradesh) 2) Orissa Sponge Iron Ltd. (Palapanga, Orissa), 3) IPITATA Sponge Iron Ltd. (Joda, Orissa) 4) Bihar Sponge Iron Ltd. (Chandil, Bihar) 5) Sun flg Iron & Steel Ltd (Warthe, Maharastra) 6) Essar Gujarat Ltd. (Hazora, Gujarat). Three new plants 1) IPITATA Sponge iron Ltd. (Orissa) 2) Vikram Ispat (M.P) and 3) Hindustan Electro-Graphite Ltd., (Gujarat) are recently commissioned. All the integrated steel plants have sintering plants.

Review of Iron and Steel Industry: The iron ore production in general shows upward trend from early 1970 and reached peak level of 43.7 MT in 1979 and now, the production is 70.7

MT (1998-99). Coming to production of metals and alloys, there was a significant growth. In production of pig iron is 8.5 MT in 1980 and reached to 18.2 MT (1999) and steel ingot production reached to the level of 23.1 MT (1999) from 10.8 MT in 1982.

Indian steel making technology has shifting from open hearth technology to BOF and EAF and now on integrating of various processes like steel casting with rolling, direct endless casting and rolling etc.

To attract private investments under the New Mineral Policy, 1991, the Government of India delicensed and deserviced steel sector. Electric Arc Furnace Industry is properly known as mini steel plants are contributing 30% of the India's-crude steel production. Steel melting scrap or sponge iron steel, re-rolling industry, steel wire drawing industry, cold-rolled steel sheets, hot-rolled steel sheets, various steel sheet industries are also established in addition to the integrated steel plants. Pig iron is one of the basic iron raw materials for engineering industry. Seca-Goa unit at Goa, USA plant at Maharashtra and Jindal Ltd. unit in M.P are important pig iron plants.

16.2.2 Aluminium industry

Aluminum is one of the light metal, which has wide applicability in various sectors. India has one of the richest gibbsite bauxite deposits, which consumes low electricity for aluminum concentration process.

In India, the aluminum industry is growing for the last 8 decades. INDAL started its production in 1943. The growth of aluminum industry was very slow until 1990, because of poor knowledge of aluminum application and policy restrictions. In 1991 Government of India announced new economic policies related to domestic and foreign trades of aluminum.

Today aluminum industry is growing tremendously under private and public sector companies in various fields like primary smelting, aluminum refining and value added products etc.

The major organizations such as

- A) Indian Aluminum Company (INDALCO) has three smelters at (a) Alupuram, Kerala (b) Hirakud, Orissa and (c) Belgaum, Karnataka.
- B) Bharat Aluminum Company (BALCO) has two smelters a) Koyana, Maharashtra and b) Korba, Madhya Pradesh
- C) Hindustan Aluminum Company (HINDALCO) has smelters at Renukoot, U.P.
- D) Aluminum Corporation of India has smelter at Asansol, West Bengal.
- E) Madras Aluminum Company has its smelter at Mettur, Tamilnadu.
- F) National Aluminum Company (NALCO) has its plant at Angul, Orissa.

The total capacity of all these smelters is 610,000 tons per year.

In addition to above the private sector M/s Larsen & Toubro, INDALCO and Karnataka Ferro Cable Ltd. are also going to set up their plants. Already NALCO plans to expand from 2.30lakh to 3.45lakh tons per annum and HINDALCO is implementing an expansion from 2.42lakh to 3.42lakh tons per annum.

Indian bauxite production has increased to 5.01 MT (1990-91) from 1.92 MT (1983).

16.2.3 Coal industry

Coal is occupying an important role in mineral industries. It is essential for our country energy requirements. Indian coalmines are mainly confined to Tertiary and Gondwana formations, which are spread in 11 states of India.

Coal mining activities in India have started in 1774. In 1952 coal board was set up for planned development, conservation and distribution of coal. In 1971, all the coking coalmines except those captive mines, held by steel plants and National Development Corporation were nationalized. Six companies namely 1. Bharat Cooking Coal Ltd., (BCCL) 2. Central Coal Fields Ltd., (CCL) 3. Western Coal Field Ltd., (WCL) 4. Eastern Coal Field Ltd., (ECL) 5. Northern Coal field Ltd., (NCL), 6. South East Coalfields Ltd. (SECL) were subsidiaries of Coal India Ltd., a Government of India undertaking. Singareni Collieries Company Limited is a joint undertaking of Government of India and Government of Andhra Pradesh.

TISCO is the only private company mining coal, at its captive mines. Nyveli Lignite Corporation (NCL) is exclusively for Lignite exploration and mining activities at Nyveli in Tamilnadu.

In India, 20 coal washeries are operating by the different companies mainly to reduce the ash content. Coal Concentration and Development Advisory Committee was set up under the Coal Mine Conservation & Development Acts, 1974. In 1977 a working group on coal, was appointed by planning commission for the formation of policies and programmes.

Present Status: Indian coal deposits are in deep, discontinuous are difficult and dangerous to mine. Even though the coal and lignite production increased from 244.8MT (1991-1992) to 322.1MT (1999-2000), the production cost of a ton of coal is high (Rs 426 in 1999-2000) because of its high ash content, high volatility and low fixed carbon. Coal India Limited is practicing age old manual pick and shovel mining, Board and Pillar under ground mines and also having large number of employees.

The low manpower productivity and low capital equipment utilization rate are main causes for reducing the profit of CIL. The Indian washeries are also working under low capacity utilization. The Indian Coal Industry, especially CIL is facing double pronged threat from slower top line growth as well as lower margin on sales.

16.2.4 Cement industry

Cement is the main binding material in the construction. There are varieties of cements like a) Ordinary Portland cement (OPC) b) Portland Pozzolana Cement (PPC) c) White cement d) Portland Blast Furnace Slag Cement (PBFSC) e) Oil well cement and f) Hydrophobic cement, etc. The main raw materials for the cement industry are limestone, magnesite, clay, gypsum and silica, etc.

Even though the usage of cement in India started from Indus valley civilization. The first cement factory was setup in Tamilnadu in 1904 by South India Industries Ltd. During 1913, Indian Cement Company Ltd. established a plant at Porbandar in Gujarat. In 1936, all the old units except Sony Valley Portland Cement Company Ltd. were united and formed Associated Cement Companies Ltd. After the partition of India in 1947 it was left with only 18 cement plants. In 1991, New Industrial Policy was announced and in it, cement industry was delicensed. Cement Corporation of India is the only public sector organization producing cement by its 10 units spread over in 6 states. The country has self-sufficiency in cement

production and also promoting export, to foreign countries.

The production of cement was increased to 100.2 MT (1999-2000) from 54 MT (1991-1992). The cement industry is now using different raw materials such as slag, fly ash and calcium sludge produced from fertilizer factories, other than the traditional raw materials.

16.2.5 Ferroalloy industry

Ferro alloys such as Ferro-chrome, Ferro-molybdenum, Ferro-tin, Ferro-manganese, Ferro-silicon, Ferro-tungsten are main inputs to produce ordinary steel alloy steel and special steels. Since July 1991, Ferro-Alloy industry has been delicensed and expands tremendously both in private and public sectors. With liberalization of government policy, the Ferro-Alloy industry is not only producing for our domestic needs but also producing and exporting to the foreign countries. Ferro-alloy industries are located in 11 states in India.

In the Ferro-alloy sector, production of Ferro-chrome went up from 15,300 tones in 1974 to 22,000 tons in 1979. The production reached the highest level of 41,600 tons in 1982. The output of ferromanganese was 205,600 tons in 1981. The production of Ferro silicon registered a rising trend till 1981 and reached the highest level of 60,400 tones in 1981.

16.2.6 Copper, Lead and Zinc Industry

Copper: In India copper exploration has started in 1857 at Dhalbham area of Singhbhum district. Hindustan Copper Company worked in 1862 for copper in Rajdah and Badia. Rajdoha Mines Company in 1891 also worked in the same area. Geological Survey of India (GSI) exploration work during 1906-1908 was very encouraging and based on that Cape Copper Company took over the mining prospects of Rajdoha Mining Company. During 1920, exploration has been started in Mosaboni area and other areas in India. Indian Copper Corporation (ICC) has been founded in 1924 and a smelter was set up at Mosaboni in 1928. Several copper mines were closed because of greater depth. In early, 1956-57 the exploration has been intensified in Bihar, Andhra Pradesh, Gujarat, Rajasthan, Jammu & Kashmir, and Karnataka and latter in Madhya Pradesh.

Major Copper deposits are Khetri Copper belt in Rajasthan, Malahjkhand in Madhya Pradesh, and Agnigundala in Andhra Pradesh, Rakha of Bihar. Small deposits also are identified at Chitradurga in Karnataka, Ambamatha in Gujarat, Dariba and Chandamati in Rajasthan. The intensive exploration of GSI and MECL lead to discovery of the new deposits in Rangamati Pahar in Bihar, at Ingaldahalli in Karnataka, Ladera-Sakhun, Tikhi and Hesathun-Bebatham in Rajasthan, Tamakhun (West Bengal), Amilha-Kalingr (Madhya Pradesh), Betla (Maharastra).

In India, 14 copper mines are under operation in public sector. Khetri Copper Complex (KCC), Rajasthan, Indian Copper Complex (ICC), Bihar are two main projects under Hindustan Copper Ltd (HCL), which is main organization involving mining and metallurgical activities of copper. Till, 1996 primary copper metal was produced by HCL with annual capacity of 47,500 tons through its integrated mining and metallurgical projects

Lead: India has smelting capacity of 65,000 tones of primary lead through Chanderiya smelter, Rajasthan, Visakhapatnam smelter, Andhra Pradesh. Tundoo smelter, Bihar. Indian lead limited company has a production capacity of 24,000 tons per year from secondary scrap through their plants at Thane at Maharastra and at Kalipark in West Bengal and Comino Benani Zinc Ltd. The beneficiation plants are located at Muchia Dariba, Balria and Bhoting.

Zinc: The zinc production in India is through its public sector smelters at Debari, Udiapur district, Chandriya smelter (Rajasthan), Visakhapatnam smelter, Visakhapatnam, Andhra Pradesh, and Binani Zinc (Pvt) Ltd. Alwaya district (Kerala). The Zinc smelters are also producing gold, cadmium and sulphuric acid etc as byproducts. In order to utilize zinc waste, government is now encouraging secondary zinc production through private organizations such as Ambuja Zinc Ltd., Patna (Bihar), MEWAT Zinc Ltd. Gurgaon district of Haryana, Bharat Zinc Ltd., (Mandideep), Indo Zinc Ltd. at Indore (M.P), M/S Scrub Alloys and Metal Industries at Lote of Parshuram (Maharashtra).

Lead and Zinc deposits of Zawar and Ajmeer district of Rajasthan have been discovered during Rana Lakhasingh (1382-97) and for more than 400 years worked on the above deposits. Eastern Smelting and Refining Ltd in 1942 acquired lead ore deposits of Banjari, Jaipur district of Rajasthan. Same company set up a plant at Tundoo in Dhanbad of Bihar in 1924.

Latter MEWAT Mineral Company and Geological Survey of India came and explored in Zawar area. The Metal Corporation of India set up an ore dressing plant in 1950 for preparing Zinc-Lead concentrations, another plant at Debari in 1962. Later in 1965 Hindustan Zinc LTD has taken over the above the plants. Cominco Binani Zinc Private Ltd. set up the first zinc smelter based on imported concentrations, in 1967.

Total zinc smelting capacity in India is 169,000 tones per year. Hindustan Zinc Ltd. the public sector undertaking has three smelters, 1) Chandriya (Rajasthan) 2) Debari (Udaipur) 3) Visakhapatnam (A.P.). HZL has set up a plant at Visakhapatnam in 1977. The existing smelting capacities have been increased in private sector. Binani Zinc Ltd. was established in Binanipuram (Kerala) based on imported concentrates.

16.2.7 Oil industry

The first oil occurrence was reported by Lt.R.Wilcox in Assam forest on the recommendation of H.B.Medlicott, the GSI had drilled six bore wells at Margherita and Neharkatiya. Assam Oil Company was formed in 1899 to work on Digboi oil fields.

The Assam Oil Company carried out intensive geophysical exploration in Assam. Till 1953 Digboi field was the only oil field and also only refinery in India. Government of India established HPCL in 1958 with the partnership of Assam Oil Company. Two refineries are set up at Noonmati near Guwhati, Assam and other Barauni, Bihar with the help of Rumanian and Russian Government. Now these refineries are in Indian Oil Corporation Ltd. Another refinery was set up at Bongaigaon with the aim of intensifying oil exploration.

The ONGC directorate set up in 1956; latter it was converted into ONGC in 1957. ONGC identified several petroleum and natural gas reservoirs in Cambay area (Ankaleswar, Kalol, Navagon, and Vadsar). ONGC started refinery at Koyali in 1965 with collaboration of USSR. ONGC and OIL are the main organizations in oil exploration. India is now trying to augment its petroleum and natural gas production. Directorate General of Hydrocarbons (DOH) a regulating body was set up by the Government of India under the Ministry of Petroleum and Natural Gas with the aim of promotion and management of Indian oil reserves.

Check Your Progress

- Note: a) Space is given below to write your answers.
b) Compare your answer with the model answer given at the end this unit.

1. What are the raw materials of Steel Industry?

2. Give the names of any two petroleum refineries In India?

16.3 MINERAL LEGISLATION

Laws governing the mines and minerals are called mining laws. These laws are enacted to solve the technical, economical, political and legal problems involved in exploration and exploitation of various mineral deposits. Legislation is essential for planned economic development, strategic consideration and conservation of minerals for future use. Indian mining laws are placed under two categories. First one is for the regulation and development and another is for the safety and welfare of miners.

16.3.1 Meaning of terms

The following terms are used in legislation with special connotations.

Minerals: According to the Mines Act any substance extracted from the earth by mining, digging, drilling, quarrying or any other operation is called as mineral. By the guidelines of Mines and Minerals (Regulation and Development) Act, minerals are all said about except natural gas and petroleum. These two are called as mineral oils. Minerals are further divided into a) minor minerals and b) major minerals

a) **Minor minerals:** These are locally important minerals and these can be developed by small scale industry. The list of minor minerals can be changed time to time and it will vary from state to state. The state Govt. has power to add or delete some minerals from the list of minor minerals ex. Building stones, building materials like lime, shale, limestone (used for the manufacture of lime only), slate, gravel, kankar etc.

b) **Major minerals:** Minerals other than those declared as minor minerals are called as major minerals. The minerals required for the production of atomic energy and some other minerals are declared as "prescribed substance" under Atomic Energy Act, ex: minerals of uranium, thorium, beryllium, deuterium, plutonium, neptunium and other as columbine, tantalite, pitchblende, samarskite, monazite etc. These minerals have been notified as

"specified minerals" under the first schedule.

Prospecting license: It is a license granted for the purpose of exploring, locating or producing mineral deposits.

Mining lease: It is license granted to any mining operation.

Mineral concession: A mineral concession confirms right to prospect or mine with in acquired properties. The concession can be granted in the form of a prospecting license, mining lease, quarry lease/permit.

Claim System: This prevailed in the early days, whoever discovered mineral deposit had a claim to work on it.

Royalty and Dead rent: Royalty is the payment to the (Government/private) owner of the privilege granted by him for mining and producing mineral. Dead rent is the minimum royalty to be paid. This is charged on the basis of area of mining lease granted irrespective of mineral.

Rates of royalty

Mineral	Royalty
Coal (depending upon the group)	Rs. 7 per tone to Rs.2.5 per ton
Mica (based on grading and quality)	Rs.3.5 per 100 Kg. to Rs.16 per 100Kg
Iron (based on iron content and size)	Rs. 4 per tone to Rs. 0.5 per tone
All precious and semi precious stones	20 % of sale price at the pits mouth
Manganese ore (based on Mn %)	Rs. 2 to 30 per ton
Barites (based on color)	Rs. 8 to 15 per ton
Copper	Rs. 4 per ton
Lead	Rs. 3 per ton
Zinc	Rs. 4 per ton
Silver	Rs. 100 per one Kg metal
Gold	Rs. 2 per 1 gram per ton
Cadmium	Rs. 16 per ton
Nickel	Rs. 2 per ton

As per Mines and Minerals (Regulation and Development) Amendment Act, 1986, the period of prospecting license for major minerals is three years (except mica for one year). The maximum total area covering not more than 25 sq km and mining lease is minimum for 20 years and maximum for 30 years, which may be renewed for two periods each not exceeding 10 years. As far as minor minerals are concerned, it varies from state to state. For petroleum and natural gas the tenure for prospecting, license is 4 years, which may be extended further two periods of one year each and the maximum area allowed for the prospecting of petroleum and natural gas is 3000 sq miles.

Mining lease granted to any mining operations, the maximum period is 30 years in the case of coal, iron ore and bauxite and 20 years for other minerals. The maximum for petroleum and natural gas is 100 sq miles and as for other minerals only 10 sq km. For the sanction of prospecting or mining lease, the minerals have been classified in to three categories a) specified minerals b) major minerals and c) minor minerals.

Table 16.1 Specified Minerals

1. Asbestos
2. Bauxite
3. Beryl and other Beryllium bearing minerals
4. Chrome ore
5. Coal and Lignite
6. Copper
7. Iron
8. Lead
9. Lime stone except when it is used in kilns for the manufacture of lime
10. Lithium bearing minerals
11. Manganese ore
12. Minerals of Rare Earth group containing Uranium and Thorium
13. Niobium-bearing minerals
14. Phosphorite and other phosphatic ores containing uranium
15. Pitchblende and other uranium ores
16. Precious stones
17. Silver
18. Titanium bearing minerals
19. Uraniferous, alienate monazite and other thorium minerals
20. Uranium bearing tailings left over from ores after extraction of copper and gold, ilmenite and other titanium ores
21. Zinc
22. Zircon
23. Rutile

Table 16.2 Major Minerals

1. Coal	22. Corundum
2. Mica	23. Bauxite
3. Gold	24. Ochre
4. Iron	25. Talc
5. All precious and semi precious stones	26. Apatite and Phosphate
6. Manganese ores	27. Asbestos
7. Chromite	28. Cadmium
8. Limestone	29. Calcite
8. Dolomite	30. Feldspar
9. Graphite	31. Diaspore
10. China clay	32. Fluorspar
11. Kyanite	33. Nickel
12. Gypsum	34. Magnesite Pyrites
13. China shell	35. Porphyllite
14. Fire clay	36. Rutile
15. Lead	37. Vermiculite
16. Copper	38. Tungsten
17. Zinc	39. Wollastonite
18. Ilmenite	40. Quartz and silica sand
19. Garnet	41. Lime shell
20. Sillimanite	42. Quartzite
21. Barites	43. Quartz and silica

Table 16.3 Minor minerals

1. Marble
2. Saltpeter
3. Lime shell, Kankar, limestone used in limekilns
4. Brick earth
5. Bentonite
6. Fullers earth
7. Murrum
8. Sand
9. Shingle
10. Rahamatti
11. Chalcedony pebbles
12. Slate and Shale
13. Stone
14. Boulders
15. Quartzite and sandstone

16.3.2 Current status

The Mining Lease Rules Act, 1956, (Modification of terms): The main purpose of these rules are to bring all the leases granted prior to act 1949, in conformity with the mineral construction rules.

M.M.R.D. Act, 1957 (Mines and Minerals Regulation and Development Act): This act covers all minerals except coal, petroleum, natural gas and atomic minerals and this act deals the maximum limits of area for prospecting and mining lease and their periods and procedure for obtaining license, royalties and retrans of mining lease and powers of the Central and State Govt. etc.

- a) **Mineral Concession Rules, (1960):** These rules define procedures of obtaining mineral concessions for prospecting license and mining laws.
- b) **Mineral Conservation and Development Rules, 1958:** These rules and regulations has been framed for the conservation and systematic development of the minerals other than atomic and minor minerals, coal, petroleum and natural gas.

Mines Act, 1952:

- a) Mines Rules, 1955
- b) Mines (posting up of abstracts) Rules, 1954.
- c) Indian Coal Mines Regulations, 1957.
- d) Indian Metalliferous Regulation Rules, 1961.
- e) Oil Mines Regulation, 1963.

Coal Mines Act Rules, 1952:

- a) Coal mines (conservation and safety) Rules, 1954.
- b) Coal bearing areas (Acquisition and Development) Act, 1957.
- c) Coal Mines (Conservation and Development) Act, 1974.

Atomic Energy Act, 1962

This act provides wide powers to the central government for regulating the prospecting and

mining minerals used for the production of atomic energy.

Oil Fields (Regulation and Development) Act, 1948: This deals with procedure and rules regarding the grant of exploration license and mining lease for petroleum and natural gas.

Territorial water, Continental shelf, EEZ and Neritic zones etc. act rule 1976: This covers rules and regulations for prospecting license and mining lease of marine mineral resources and other rights of on seawater. In addition to the above acts, there are several acts to come in to the force in relation to safety, welfare, and conservation etc.

16.3.3 Maritime Laws

The traditional Laws of sea should be revised after evolution technological developments. Coastal countries as well as the land locked countries are claiming that, the marine mineral wealth is common heritage for all the nations. It is necessary to revise the old traditional laws of sea, redefine the term High Sea, Territorial sea, National water and continental shelf and to revise existing laws. In 1970, The UN general assembly constituted the UN seabed committee. Three sub committees were formed under this committee.

- a) International seabed area and its resources
- b) Law of the sea overtimes i.e. Territorial sea, Continental shelf, Exclusive Economic Zone (EEZ)
- c) Marine Scientific research, Marine pollution and transfer of technology

Several sessions were held after formation of UN seabed committee, 1970 and its sub committees. In the 7th session (UNCLOS) at New York, 1978 was discussed Informal composite regulatory text (ICRT). In this session it was resolved ocean wealth out side national jurisdiction should be considered common heritage and should be shared equitably through International Seabed Authority (ISA). This authority should encourage Exploration/Exploitation through its area enterprise or other agencies.

The Territorial waters, Continental shelf and Exclusive Economic Zone and other Maritime Zones Act, 1976 (Govt. of India act.).

India has enacted the above act, which lays down the limits and the jurisdiction of India over Territorial waters, Continental shelf and Exclusive Economic Zone and Contiguous zone.

16.3.4 Territorial waters

The limit of territorial waters is 12 nautical miles from the shoreline. India has sovereignty over the territorial waters, seabed, sub soil and air space over the waters.

16.3.5 Contiguous Zone

The limit of Contiguous Zone extends upto 24 nautical miles from the base line.

16.3.6 Continental shelf

It comprises seabed and sub soil of the sub marine areas that extends up to edge of the continental margin to a distance of 200 nautical miles from the base line.

16.3.7 Exclusive Economic Zone (EEZ)

It is an area beyond and adjacent to the territorial waters and extends up to 200 nautical miles

from the base line.

The central government has expressed to alter the limit of Territorial waters. The Government of India has sovereignty rights for exploration, exploitation, conservation and navigation of all resources in territorial waters, Contiguous zone, Continental shelf and EEZ. The government has exclusive rights and jurisdiction for any construction in the above zones for exploration and exploitation, exclusive jurisdiction is through, regulations and country scientific research.

Nobody will allow to do any work without prior permission / license from the Government of India.

Check Your Progress

- Note: a) Space is given below to write the answers
b) Compare your answer with the model answer given at the end this unit

3. What is Royalty?

4. Name any five major minerals.

16.4 SUMMARY

Minerals are essential raw materials for running the industries. A systematic study is required for various minerals in relation to their industrial applications. The economics of selecting industrial sites nearer to mines are also planned perfectly. The judicious use of minerals is essential because minerals are non-renewable resources.

Indian mineral industry is as old 300 B.C. Before independence also very few mining centers were located in India. After independence new organizations were set up to increase activities in mineral industries. The new industrial policy 1991 liberalized many regulations and controls; with this the growth of mineral based industries took momentum.

The most important industry is steel and iron industry. The basic raw materials are iron ore

and coking coal. The iron ore production is around 70.7 MT in the year 1998-99. In India aluminum production grew tremendously under private and public sector companies. The chief raw material is bauxite. The present annual production is 6.25 lakh tons.

Coal mining activities started in India since 1774. In the year 1974 government of India nationalized all coalfields and created Coal India Limited. The annual production in the year 1999-2000 was about 322MT.

Cement is another important industry. The basic raw materials are limestone and gypsum. The annual production in the year 1999-2000 was 100MT.

Ferroalloy industry is producing ferrochrome. Our country exports some of ferroalloys. Copper, lead and zinc industry is also expanded. Hindustan copper limited and Hindustan zinc limited are supervising the production. The first oil occurrence was reported from Assam. Later after Independence oil deposits were explored from Gujarat and Bombay high. Recently rich deposits of natural gas were reported from Krishna-Godavari basin.

Laws governing the mines and minerals are called mining laws. These are useful to solve the technical, economical, political and legal problems involved in exploration and exploitation of minerals. As per the mines and minerals amended act 1986 all the minerals are grouped into major and minor minerals and allowed private companies also in the process of exploration and exploitation. There are maritime laws to supervise exploration and exploitation of minerals on seas.

16.5 CHECK YOUR PROGRESS – MODEL ANSWERS

1. The raw materials required in steel industry are iron ore, coking coal, limestone, dolomite, manganese ore, ferromanganese, fire clay, basic and silica bricks.
2. Digboi oil refinery, Bongaigaon refinery in Assam
3. Royalty is the payment to government by private mine owners.
4. Coal, mica, gold, iron, manganese, etc.

16.6 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines each.

1. Explain the growth of mineral industry?
2. What are maritime laws? Explain
3. Describe the growth of iron and steel industry in India.

II. Answer the following in about 10 lines each.

1. Aluminum industry
2. Major minerals
3. Oil industry
4. Coal industry

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13.7 ESSENTIAL MINERALS

Iron ore and steel, ores of manganese, vanadium, chromium, titanium magnesium, aluminium, cadmium, zirconium, germanium and beryllium (beryl) amongst metallic minerals, mica, limestone, gypsum, china clay and fluorspar amongst non-metallic minerals and coal in fuels, constitute India's essential minerals as per their present position in the country.

13.7.1 Application of Essential Minerals in War

Metal and Alloys: Steel is the industrial vehicle, which keeps all industries, including its own, going. We have already seen that steel could only be produced from iron ore with some other important raw materials. Steel is the basic raw material for ammunition and provides a galaxy of supplementary war material. It is always required in bulk quantities in terms of millions to tonnes for war efforts. Manganese ore is required to produce ferromanganese, which is one of the essential constituents for steel making. Vanadium is required in minute quantities for making different vanadium steels; 0.5 to 5% in high-speed tool steel 0.15 to 1.3% in low alloy tools and special steels and in minute proportion in carbon and alloy steels for structural uses. It has high melting point (1989°C) and low density (mid way between titanium and steel). Vanadium alloys beat best titanium alloys and stainless steel in strength. They are ductile and can be welded. Their thermal conductivity is double that of both titanium and stainless steel, which is regarded as an important criterion in aircraft and nuclear reactor application.

Vanadium, alloyed with metals like chromium, manganese and tungsten are necessary for making high-speed steels, where strength, hardness and fatigue are primary requisites. Chromium is another ferroalloy metal and it is required for ferrochrome production. Ferrochrome is essential for armour plates and for a variety of structural steels. Utility of chrome-nickel alloys has been already mentioned during nickel applications in war (refer strategic minerals). Titanium metal finds increasing use in aircraft and missiles. On strength-density basis, it is superior to light structural metals like magnesium aluminium. Low density, magnificent corrosion resistance to marine and saline atmosphere and also to oxidation damage upto 649°C , make titanium suitable for various war applications. Magnesium metal is used for making light metal alloys for planes, automobiles and trains. It is used in incendiary bombs for flares. Commercial quantities of aluminium metal were available only from 1939. Since then, it was applied for military uses, as a light structural metal. Because of availability in great abundance, aluminium has fast replaced copper, lead, zinc and tin and steel in certain uses both in peace and war times. Cadmium is used in the processing of uranium and in the manufacture of special steel. It gives excellent resistance to corrosive actions. Pure zirconium is resistant to heat and corrosion. Its particular property of total inability to capture thermal neutrons, in addition to the above, made it prominent as a structural and cladding material in atomic reactors. Zirconium is alloyed with iron, silicon and tungsten. During the Second World War, zirconium steel was used in the manufacture of war equipment. Germanium metal is responsible for the invention of transistorised radio communication. The metal has made it possible to make smallest sets, carriable in pockets, for communicating between different lines of the army. Beryllium metal is used as a moderator in atomic piles and nuclear reactions. It has the property of slowing down neutrons, without absorbing them. Beryllium-copper alloys have high tensile strength and can withstand repeated stress. They are non-sparking and non-magnetic. So these alloys are used in many special forms, in parts of aeroplanes, engine, motors, switches and watches. Beryllium oxide is a high temperature refractory (257°C). It is used in aircraft spark plugs and high temperature electric furnaces.

Non-Metals: Mica is indispensable for the manufacture of all electronic equipment, because of its unique dielectric strength and insulating property.

Limestone is essential for flux in the manufacture of steel and other materials. It is the primary raw material for cement. Gypsum is also required for cement making and plaster of Paris. China clay is used for insulation purposes. Since the exhaustion of natural cryolite in the world, fluorite rescued aluminium metallurgy. Fluorite is used in the manufacture of artificial cryolite, which is most important for aluminium production. Fluorite is also used as a flux in the cryolite but to balance the fluorine content and in steel metallurgy to reduce the viscosity. Besides these indirect applications, production of atom bombs requires many fluorine chemicals.

Fuels: Military dependence on coal and coke is unlimited. The coal and coke are the inner strength of all metallurgical, chemical and fabrication industries. They are a source of thermal heat and electricity and locomotion.

13.7.2 Present Position of Essential Minerals in India

Metals: Iron and Steel: India is self sufficient in the production of iron, pig iron and steel as already given.

Manganese: According to the National Mineral Inventory (Indian Minerals Year Book, 2001), the total recoverable reserves of manganese ore (as on 1995) are placed at 167 million tonnes. The production of manganese ore at 1.56 million tonnes during 2000-2001 marginally decreased by about 2% as compared to that of 1999-2000. Exports of manganese ore during 1999-2000 were 75,685 tonnes showing a sharp decrease of 55%. Imports of ore during 1999-2000 were 5,102 tonnes showing an increase of 17%.

The two major consuming industries of manganese ore are iron and steel and ferromanganese. Low grade ore of 30 -35% Mn may be used for pig iron, but ferromanganese requires better grade (38% Mn) and preferably of 46% Mn content.

Vanadium: India has large resources of vanadium ore in the form of vanadiferous-titaniferous magnetites occurring in Karnataka, Orissa and Maharashtra. The total recoverable reserves are placed at 11.53 MT as on 1995. India exported 82 tonnes of vanadium in 1999-2000 and imported 6,765 tonnes in 1999-2000. Important applications of vanadium are as ferrovanadium for steel and as V_2O_5 catalyst for H_2SO_4 manufacture by contact process.

The Regional Research Laboratory, Bhubaneswar, Orissa was engaged in developing a process for extraction of vanadium from the vanadiferous titaniferous magnetites, and this roasting process made it possible for a 90 to 100% recovery.

Chromium: The total recoverable reserves of chromite in the country (as on 1995) are placed at 86.23 million tonnes. Production of chromite at 1952 thousand tonnes during 2000-2001 registered an increase of 12% compared to that of the previous year.

Exports of chromite during 1999-2000 increased by 45% to 714,448 tonnes. And imports registered a substantial increase to 6,886 tonnes in 1999-2000.

Titanium: The most prolific beach sand deposits containing ilmenite and rutile and other valuable minerals like monazite lie in three prominent coastal regions of India. (1) Between

BLOCK – V ADVANCED ASPECTS OF GEOLOGY – I

BRAOU

UNIT :17 PLATE TECTONICS

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17.0 OBJECTIVES

This Unit gives a brief introduction to the concept of plate tectonics and different types of plate boundaries.

At the end of this unit you will be able to

- define the term plate tectonics
- describe various types of plate boundaries
- explain the mechanism of plate motion

17.1 INTRODUCTION

In the early 1960s, the emergence of the theory of plate tectonics started a revolution in the earth sciences. Plate tectonics influences nearly all geologic processes, past and present. In geologic terms, a plate is a large, rigid slab of solid rock. The word tectonics comes from the Greek root "to build." Putting these two words together, we get the term plate tectonics, which refers to how the Earth's surface is built of plates.

The theory of plate tectonics states that the Earth's outermost layer is fragmented into a dozen or more large and small plates that are moving relative to one another. Before the advent of plate tectonics, however, some people already believed that the present-day continents were the fragmented pieces of pre-existing larger landmasses ("super-continents"). The break-up of the super-continent Pangaea (meaning "all lands" in Greek), which figured prominently in the theory of continental drift -- the forerunner to the theory of plate tectonics. According to the continental drift theory, the super-continent Pangaea began to break up about 225-200 million years ago, eventually fragmenting into the continents as we know them today.

Plate tectonics has provided explanations to questions such as why earthquakes and volcanic eruptions occur in very specific areas around the world, and how and why great mountain ranges like the Alps and Himalayas formed. Even though the theory of plate tectonics is now widely accepted by the scientific community, aspects of the theory are still being debated today. Scientists debate how plate tectonics may have operated earlier in the Earth's history

and whether similar processes operate, or have ever operated, on other planets in our solar system. It is now very well known that, directly or indirectly, plate tectonics influences nearly all geologic processes, past and present.

17.2 PLATE TECTONICS

The surface of the earth is composed of rigid plates 50-150 km thick, known as the lithosphere, consisting of both oceanic and continental crust as well as the upper mantle. These plates rest on a hotter, denser layer that deforms plastically and is known as the asthenosphere. The asthenosphere, or low-velocity zone, extends from the base of the lithosphere to a depth of about 700 km. The upper most part of the lithosphere (6-40 km thick) composed of the crust. The lithosphere is being continuously created at oceanic ridges by injection of magma derived from the mantle. This lithosphere spreads laterally away from ridges and is finally consumed by the asthenosphere in subduction zones.

The rigid plates move in a conveyer-belt fashion in both directions across the ocean floor at rates of 1-20 centimeters per year. Only a small number of major lithospheric plates exist, which grind and scrape against each other as they move independently like rafts of ice on water. Most dynamic activity such as seismicity, deformation, and the generation of magma occur only along plate boundaries, and it is on the basis of the global distribution of such tectonic phenomena that plates are delineated.

The plate tectonics model for the Earth is consistent with the occurrence of sea-floor spreading and continental drift. Convincing evidence exists that both these processes have been occurring for at least the last 600 million years. This evidence includes the magnetic anomaly patterns of the sea floor, the paucity and youthful age of marine sediments in the ocean basins, the topographic features of the sea floor, and the indications of shifts in the position of continental blocks which can be inferred from paleomagnetic data on paleopole positions, paleontological and paleoclimatological observations, the match-up of continental margins and geological provinces across present-day oceans, and the structural styles and rock types found in ancient mountain belts.

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 Plate Tectonics.

17.3 PLATE CHARACTERISTICS

Geological observations, geophysical data, and theoretical considerations support the existence of three fundamentally distinct types of plate boundaries, named and classified on the basis of whether immediately adjacent plates move apart from one another (divergent

plate margins), toward one another (convergent plate margins), or slip past one another in a direction parallel to their common boundary (transform plate margins). Figure 1 shows the major plates of the lithosphere, and the major plate margins. Plate margins are easily recognised because they coincide with zones of seismic and volcanic activity; little or no tectonic activity occurs away from plate margins. The boundaries of plates can, but need not, coincide with the contact between continental and oceanic crust. The nature of the crustal material capping a plate at its boundary may control the specific processes occurring there, particularly along convergent plate margins, but in general plate tectonics theory considers the continental crustal blocks as passive passengers riding on the upper surface of fragmenting, diverging, and colliding plates.

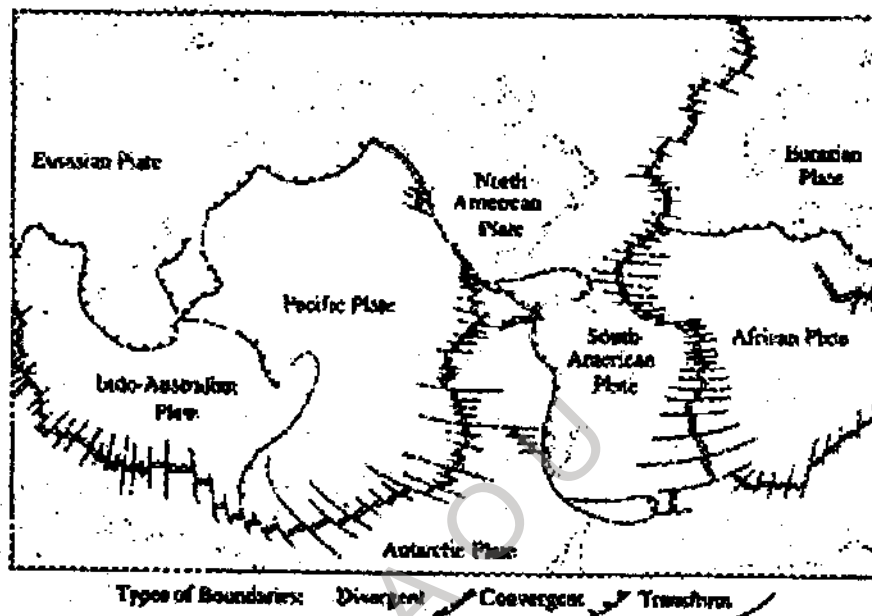


Fig. 17.1 Major tectonic plates of the Earth.

There are three types of plate boundaries:

- Divergent boundaries — where new crust is generated as the plates pull away from each other.
- Convergent boundaries -- where crust is destroyed as one plate dives under another.
- Transform boundaries -- where crust is neither produced nor destroyed as the plates slide horizontally past each other.

17.3.1 Divergent boundaries

Divergent boundaries occur along spreading centers where plates are moving apart and new crust is created by magma pushing up from the mantle. Like two giant conveyer belts, facing each other but slowly moving in opposite directions as they transport newly formed oceanic crust away from the ridge crest. New ocean floor is produced along the spreading ridges as magma from the Earth's mantle rises into their crests (axes) to form new oceanic crust. This adds about 15–20 cubic kilometres of new oceanic crust each year. About an equal volume of old crust is lost each year along convergent plate boundaries so that the overall size of the

Earth stays the same. Almost all of the world's divergent plate boundaries, and the abundant volcanism along them, lie beneath the oceans. An estimated three-quarters of all the lava erupted on Earth each year pours out along the oceanic spreading ridges. Earthquake activity along the oceanic spreading ridges is neither as strong, nor as deep, as at convergent plate boundary zones. The reason is that the younger, hotter lithosphere is very thin and weak, and stresses cannot build up enough to cause large earthquakes. The best-known divergent boundary is the Mid-Atlantic Ridge. This submerged mountain range, which extends from the Arctic Ocean to beyond the southern tip of Africa, is but one segment of the global mid-ocean ridge system that encircles the Earth. The rate of spreading along the Mid-Atlantic Ridge averages about 2.5 centimeters per year (cm/yr), or 25 km in a million years. This rate may seem slow by human standards, but because this process has been going on for millions of years, it has resulted in plate movement of thousands of kilometers. Seafloor spreading over the past 100 to 200 million years has caused the Atlantic Ocean to grow from a tiny inlet of water between the continents of Europe, Africa, and the Americas into the vast ocean that exists today.

Mid-Atlantic Ridge : The volcanic country of Iceland, which straddles the Mid-Atlantic Ridge, offers scientists a natural laboratory for studying on land the processes also occurring along the submerged parts of a spreading ridge. Iceland is splitting along the spreading centre between the North American and Eurasian Plates, as North America moves westward relative to Eurasia.

The consequences of plate movement are easy to see around Krafla Volcano, in the northeastern part of Iceland. Here, existing ground cracks have widened and new ones appear every few months. From 1975 to 1984, numerous episodes of *rifting* (surface cracking) took place along the Krafla fissure zone. Some of these rifting events were accompanied by volcanic activity; the ground would gradually rise 1-2 m before abruptly dropping, signaling an impending eruption. Between 1975 and 1984, the displacements caused by rifting totaled about 7 m. Pulling apart of the lithosphere may also occur on a smaller scale within a plate, creating zones of localized divergence, as shown, for example, by the rift valleys of East Africa. Here, faulting has dropped down narrow blocks of crust, and the rift is widened by magma injected from below the valley floor. Volcanoes such as Kilimanjaro are the visible result of this process, and shallow earthquakes occur along the edges of the rift valleys. The East African rift valleys may eventually develop into a young ocean basin, such as the Red Sea to the north.

In East Africa, spreading processes have already torn Saudi Arabia away from the rest of the African continent, forming the Red Sea. The actively splitting African Plate and the Arabian Plate meet in what geologists call a triple junction, where the Red Sea meets the Gulf of Aden. A new spreading center may be developing under Africa along the East African Rift Zone. When the continental crust stretches beyond its limits, tension cracks begin to appear on the Earth's surface. Magma rises and squeezes through the widening cracks, sometimes to erupt and form volcanoes. The rising magma, whether or not it erupts, puts more pressure on the crust to produce additional fractures and, ultimately, the rift zone.

East Africa may be the site of the Earth's next major ocean. Plate interactions in the region provide scientists an opportunity to study first hand how the Atlantic may have begun to form about 200 million years ago. Geologists believe that, if spreading continues, the three plates that meet at the edge of the present-day African continent will separate completely, allowing the Indian Ocean to flood the area and making the easternmost corner of Africa (the Horn of Africa) a large island.

Seafloor Spreading: Seafloor spreading is the process by which the oceanic lithosphere splits at oceanic ridges and moves away from ridge axes with a motion like that of a conveyor belt as new lithosphere is created and fills the resulting crack. Oceanic lithosphere is consumed in the asthenosphere at subduction zones to accommodate the newly created lithosphere such that the surface area of the Earth remains constant. This hypothesis was supported by several lines of evidence: (1) at or near the crest of the ridge, the rocks are very young, and they become progressively older away from the ridge crest; and (2) the youngest rocks at the ridge crest always have present-day (normal) polarity.

Additional evidence of seafloor spreading came from an unexpected source: petroleum exploration. In the years following World War II, continental oil reserves were being depleted rapidly and the search for offshore oil was on. To conduct offshore exploration, oil companies built ships equipped with a special drilling rig and the capacity to carry many kilometers of drill pipe. This basic idea later was adapted in constructing a research vessel, named the Glomar Challenger, designed specifically for marine geology studies, including the collection of drill-core samples from the deep ocean floor. In 1968, the vessel embarked on a yearlong scientific expedition, criss-crossing the Mid-Atlantic Ridge between South America and Africa and drilling core samples at specific locations. When the ages of the samples were determined by paleontologic and isotopic dating studies, they provided the clinching evidence that proved the seafloor-spreading hypothesis.

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. Explain the importance of divergent plate boundary.

3. Define the term sea floor spreading.

17.3.2 Convergent Boundaries

The size of the Earth has not changed significantly during the past 600 million years, and very likely not since shortly after its formation 4.6 billion years ago. The Earth's unchanging size implies that the crust must be destroyed at about the same rate as it is being created. Such destruction (recycling) of crust takes place along convergent boundaries where plates are

moving toward each other, and sometimes one plate sinks (is subducted) under another. Most convergent plate boundaries are called subduction zones because one of the plates moves down, or is subducted, beneath the other. Often a deep trench forms on the ocean floor where the subducting plate begins its descent. Earthquakes are common in the subduction zone, particularly within the sinking lithospheric slab, thereby producing an inclined zone of earthquakes that dips into the Earth's upper mantle typically at angles of 40–60° from the horizontal. Earthquakes can occur at any depth within the sinking slab, from shallow (0–60 km) to as great as 700 km.

Over three-quarters of the world's earthquakes take place at convergent plate boundaries. As the subducted lithosphere moves deeper into the hot mantle, its fluids are "sweated out" and rise, triggering partial melting within the overlying mantle. The new magma is less dense than the surrounding rock and ascends buoyantly; some of it erupts on the Earth's surface to form a line of volcanoes. Such volcanoes typically are steep-sided cones called stratovolcanoes that erupt explosively. Nearly four-fifths of the Earth's historically active volcanoes are found near convergent plate boundaries. An excellent example of a convergent boundary is that between the Nazca plate and the South American plate. At other convergent plate boundaries, such as the Aleutian trench in Alaska, subduction results in a curved chain of submarine volcanoes or volcanic islands (called an island arc) behind the oceanic trench. Extensive island arc-trench systems also exist in much of the western Pacific. Several of these subduction zones also show localized divergence behind the arc, known as back arc spreading (for example, the Marianas-Bonin arc). Convergence may also force two continents together, as illustrated by the boundary between the Indian and Eurasian plates. Continental lithosphere is not as dense as oceanic lithosphere and resists subduction into the Earth's interior. The collision of India with Asia has doubled the thickness of continental crust in that region and produced the highest elevations on Earth in the Himalayas and Tibetan Plateau. Continent to continent convergence produces shallow and intermediate depth earthquakes but little volcanic activity. The map shows a broad belt of abundant earthquake activity in the Himalayas, extending across central Asia to the Caucasus Mountains and on to the Mediterranean Sea. In this geologically complex region, much of the activity occurs between smaller plate fragments called microplates.

Convergent and divergent plate margins are natural complements. New crust is formed at the spreading ridges and is then rafted away to either side of the ridges. Old parts of the lithosphere, generally far away from the spreading ridges, are eventually consumed by subduction in a natural "recycling" process; consequently no oceanic crust is older than about 200 million years. As the subducting plate sinks deeper into the hot mantle, it softens to a state incapable of producing earthquakes by brittle fracture. It ultimately loses its identity altogether and merges into the deeper mobile mantle that convectively flows back toward the spreading floor. The type of convergence -- called by some a very slow "collision" -- that takes place between plates depends on the kind of lithosphere involved. Convergence can occur between an oceanic and a largely continental plate, or between two largely oceanic plates, or between two largely continental plates.

Oceanic-continental convergence: Off the coast of South America along the Peru-Chile trench, the oceanic Nazca Plate is pushing into and being subducted under the continental part of the South American Plate. In turn, the overriding South American Plate is being lifted up, creating the towering Andes Mountains, the backbone of the continent. Strong, destructive earthquakes and the rapid uplift of mountain ranges are common in this region. Oceanic-continental convergence also sustains many of the Earth's active volcanoes, such as those in the Andes and the Cascade Range in the Pacific Northwest.

Oceanic-oceanic convergence: As with oceanic-continental convergence, when two oceanic plates converge, one is usually subducted under the other, and in the process a trench is formed. The Marianas Trench (paralleling the Mariana Islands), for example, marks where the fast-moving Pacific Plate converges against the slower moving Philippine Plate. The Challenger Deep, at the southern end of the Marianas Trench, plunges deeper into the Earth's interior (nearly 11,000 m) than Mount Everest, the world's tallest mountain, rises above sea level (about 8,854 m). Subduction processes in oceanic-oceanic plate convergence also result in the formation of volcanoes. Over millions of years, the erupted lava and volcanic debris pile up on the ocean floor until a submarine volcano rises above sea level to form an island volcano. Such volcanoes are typically strung out in chains called island arcs. As the name implies, volcanic island arcs, which closely parallel the trenches, are generally curved. The trenches are the key to understanding how island arcs such as the Marianas and the Aleutian Islands have formed and why they experience numerous strong earthquakes. Magmas that form island arcs are produced by the partial melting of the descending plate and/or the overlying oceanic lithosphere. The descending plate also provides a source of stress as the two plates interact, leading to frequent moderate to strong earthquakes.

Continental-continental convergence: The Himalayan mountain range dramatically demonstrates one of the most visible and spectacular consequences of plate tectonics. When two continents meet head-on, neither is subducted because the continental rocks are relatively light and, like two colliding icebergs, resist downward motion. Instead, the crust tends to buckle and be pushed upward or sideways. The collision of India into Asia 50 million years ago caused the Eurasian Plate to crumple up and override the Indian Plate. After the collision, the slow continuous convergence of the two plates over millions of years pushed up the Himalayas and the Tibetan Plateau to their present heights. Most of this growth occurred during the past 10 million years. The Himalayas, towering as high as 8,854 m above sea level, form the highest continental mountains in the world.

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. Explain various types of plate convergence.

17.3.3. Transform Boundaries

The zone between two plates sliding horizontally past one another is called a transform-fault boundary, or simply a transform boundary. A well-known example is the San Andreas Fault, California. These large faults or fracture zones connect two spreading centers (divergent plate boundaries) or, less commonly, trenches (convergent plate boundaries). Most transform faults are found on the ocean floor. They commonly offset the active spreading ridges, producing zigzag plate margins, and are generally defined by shallow earthquakes. However, a few occur on land, for example the San Andreas Fault zone in California. This transform

fault connects the East Pacific Rise, a divergent boundary to the south, with the South Gorda - Juan de Fuca -- Explorer Ridge, another divergent boundary to the north. The San Andreas Fault zone, which is about 1,300 km long and in places tens of kilometers wide, slices through two thirds of the length of California. Along it, the Pacific Plate has been grinding horizontally past the North American Plate for 10 million years, at an average rate of about 5 cm/yr. Land on the west side of the fault zone (on the Pacific Plate) is moving in a northwesterly direction relative to the land on the east side of the fault zone (on the North American Plate).

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 transform boundary?

17.3.4 Rates of Motion

It can be measured that how fast the tectonic plates are moving today, but how do scientists know what the rates of plate movement have been over geologic time? The oceans hold one of the key pieces to the puzzle. The rate of ocean-floor movement can be calculated for a given time span. These average rates of plate separations can range widely. The Arctic Ridge has the slowest rate (less than 2.5 cm/yr), and the East Pacific Rise near Easter Island, in the South Pacific about 3,400 km west of Chile, has the fastest rate (more than 15 cm/yr).

Evidence of past rates of plate movement also can be obtained from geologic mapping studies. If a rock formation of known age -- with distinctive composition, structure, or fossils -- mapped on one side of a plate boundary can be matched with the same formation on the other side of the boundary, then measuring the distance that the formation has been offset can give an estimate of the average rate of plate motion. This simple but effective technique has been used to determine the rates of plate motion at divergent boundaries, for example the Mid-Atlantic Ridge, and transform boundaries, such as the San Andreas Fault. Current plate movement can be tracked directly by means of ground-based or space-based geodetic measurements; geodesy is the science of the size and shape of the Earth. Ground-based measurements are taken with conventional but very precise ground-surveying techniques, using laser-electronic instruments. However, because plate motions are global in scale, they are best measured by satellite-based methods. The late 1970s witnessed the rapid growth of space geodesy, a term applied to space-based techniques for taking precise, repeated measurements of carefully chosen points on the Earth's surface separated by hundreds to thousands of kilometers. The three most commonly used space-geodetic techniques -- very long baseline interferometry (VLBI), satellite laser ranging (SLR), and the Global Positioning System (GPS) -- are based on technologies developed for military and aerospace research, notably radio astronomy and satellite tracking.

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.
6. Explain the rate of plate motion.

17.4 VOLCANOES IN PLATE INTERIORS

Some active volcanoes, such as those making up the Island of Hawaii, are located nearly 3,000 km from the nearest plate boundary. These Hawaiian volcanoes are above-sea-level summits at the southeastern end of a vast submarine volcanic mountain chain. This chain formed during the last 70 million years by the continuous northerly (and the north westerly) movement of the Pacific plate over a mantle magma source that is relatively fixed in one spot, called a hotspot. These features are thought by many geologists to be caused by long, thin convection plumes rising through the mantle. In the overlying plate, partial melting produces new magma that collects into blobs that rise and ultimately erupt to form a new volcano on the sea floor. During perhaps a million years and countless eruptions, the submarine volcano may grow large enough to emerge above sea level as an island volcano. Such midplate oceanic lavas are more fluids than those building stratovolcanoes along convergent plate boundaries are which usually erupt non-explosively and form gently sloping shield volcanoes such as Hawaii's Mauna Loa. Continued northwestward movement of the Pacific plate eventually carries each volcano away from the underlying hotspot. Then, severed from its feeding magma source, the volcano ultimately dies.

Even as a new volcano grows over the hotspot, the forces of erosion slowly wear a volcanic island down; it then gradually sinks below sea level and form a flat-topped seamount. Active volcanoes in Hawaii, like Kilauea and Mauna Loa and the nearby offshore (submarine) new volcano called Loihi, currently lie above the Hawaiian hotspot. In many thousands of years, Loihi may grow above sea level to become the next island in the Hawaiian chain. Intraplate volcanism also occurs in continental interiors. For example, the spectacular geothermal system at Yellowstone National Park, Wyoming, is the product of volcanic activity over a hotspot in the mantle below.

17.5 EARTHQUAKES IN PLATE INTERIORS

Earthquakes in plate interiors are far less common than those near plate margins, but they can be devastating. Most lithosphere in midplate regions is geologically old and stiff, allowing very high stress levels to build up before rupturing in a large earthquake. Intraplate earthquakes greater than magnitude 7.5 have occurred in the central and eastern United States (Missouri in 1811-12 and South Carolina in 1886) and in Asia.

17.6 TRIPLE JUNCTIONS

Triple junctions are points where three plates meet. Because the Earth's lithosphere shell is segmented into a mosaic, the boundary between any two plates must end in a triple junction. The orientation of the boundary between these plates will determine the type of interaction at the boundary. There are a number of possible triple junctions. The Cocos, Pacific, and Nazca plates join at a ridge-ridge-ridge triple junction. This is an example of a stable triple junction. Other triple junctions are unstable. The most important triple junctions are those that migrate along the boundary. This type of plate interaction occurred at the western boundary of the North American plate.

17.7 HOT SPOTS AND MANTLE PLUMES

The existence of convective plumes originating in the deep mantle from below the level of the asthenosphere and rising to the bottom of the lithosphere has been proposed. These plumes are believed to be nearly stationary with respect to each other, and hence they may be used as reference points, with respect to which all the plates are moving. Mantle plumes are regarded as driving mechanism for plate motion. Some of the mantle plumes may not act as a driving mechanism for plate motion. Such type of plume is called as a hot spot. As a plate passes over a hot spot, the hot spot burns its way through the plate. This releases volatile and eruptive magma on the plate surface. A classic example of the volcanic consequences of passage of a plate over a hot spot is the Emperor Seamount along Hawaiian Island chain.

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.

7. Explain the role of mantle plumes in Plate Tectonic Theory.

17.8 SUMMARY

The Earth's surface is composed of several distinct lithospheric plates which continuously being interacting each other and this process leading to creation, migration and destruction of plates. The plate tectonic theory is very significant in understanding many varieties of problems. The formation of volcanoes, earthquakes, mountain belts and many types of ore deposits can be explained by this theory. This theory also provides convincing explanation for the growth, drift and fracturing of continents. The lithosphere of the earth is composed of several major and minor plates with four types of boundaries. The boundaries are recognised as divergent plate margins, convergent plate margins, transform plate margins and plate boundary zones. The mantle plumes are regarded as main driving force for the movement of plates. The intra plate mantle plumes are called hot spots.

Plate tectonics is important economically because of the theory's usefulness in predicting and explaining the occurrence of ore deposits. The hot waters which rise to the surface along the plate boundaries are enriched in copper, iron, zinc, and sulphur. The minerals such as pyrite (iron sulphide), chalcopyrite (copper and iron sulphide), and sphalerite (zinc sulphide) are formed along the oceanic rises. One such type in Cyprus is formed by this process. This kind of mineral deposits are also found along the tensional zones formed in the basins behind many subduction zones. Many ferromanganese nodules are thought to be formed on the ocean floor by chemical precipitation of sea water. In addition to iron and manganese these nodules are also enriched in cobalt and nickel.

Many chromium deposits are associated with folded and faulted rocks along the subduction zones. These deposits along with host rocks are thought to be brought out from upper mantle and thrust on to the nonsubducted plate. Many intrusions of silica-rich magma above the subduction zones contain hydrothermal fluids. These fluids deposit elements such as copper, gold, silver, tin, mercury, molybdenum, tungsten, and bismuth in the granites. These kinds of deposits are found along the subduction zones around Pacific Ocean.

17.9 CHECK YOUR PROGRESS – MODEL ANSWERS

1. Plate Tectonics is the theory that explains how plates are formed and explains their movement and destruction.
2. Divergent plate boundary is a tensional plate boundary at which oceanic lithosphere is being created.
3. Sea floor spreading is the process by which the oceanic lithosphere splits at oceanic ridges and moves away from ridge axes.
4. Various types of plate convergence include oceanic-continental, oceanic-oceanic and continental-continental convergence.
5. The interacting plane of two plates at transform/strike-slip faults is known as transform plate boundary.
6. The velocity of plate motion varies from plate to plate ranging from 2 to 20 cm per year.
7. The presence of mantle plumes in the interior of the earth can be considered as a driving force for the creation of lithospheric plates.

17.10 MODEL EXAMINATION QUESTIONS

I Explain the following in 30 lines each.

1. Explain the theory of plate tectonics.
2. Enumerate various types of plate boundaries.

II Explain the following in 10 lines each.

1. Explain the following:
 - a) Mid-oceanic ridges, b) Sea floor spreading, c) Triple junctions
2. Explain the rate of lithospheric plate motion.
3. What are mantle plumes? What is their role in the plate tectonics?

UNIT : 18 ENGINEERING ASPECTS OF GEOLOGY

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- 18.2 Geological aspects of dam sites
 - 18.2.1 Geological investigation at dam sites
- 18.3 Geological aspects of reservoirs
 - 18.3.1 Geological investigations
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- 18.5 Geological aspects building and road material
 - 18.5.1 Building stones
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- 18.6 Geological aspects of bridge site
 - 18.6.1 The depth to the bedrock
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- 18.8 Check Your Progress - Model Answers
- 18.9 Model Examination Questions

18.0 OBJECTIVES

In this unit, geological aspects of dam's sites, reservoirs, tunnels, building and road materials, bridge sites are described.

After studying this unit, you will be able to

- explain the geological concepts of dam sites
- explain geological aspects of reservoirs
- describe geological aspects of tunnels
- explain geological aspects of building and road material

18.1 INTRODUCTION

The important engineering projects like dams, reservoirs, tunnels, bridges and buildings etc., are constructed on rocks or soils. It is, therefore, essential to have the fullest knowledge possible of the strata or soil through which works of construction are to be carried or on which these have to rest. When the geological characters of the site or alignment are not properly investigated or properly interpreted, the structures might involve considerably higher costs. Not only that, their stability might be in question. Many dam disasters, foundation failures in buildings, collapse of bridges and tunnels were, on subsequent study, found to be closely related to ignorance of geological conditions that existed in and around these structures. The main object of geological investigations for engineering projects is to determine the geological structure of the area, lithology of the area and the ground water conditions of the region. The geological structure of the area is determined by conducting extensive and intensive geological surveys. These surveys would reveal the entire

topographic details, occurrence of folds, faults, major unconformities, joint systems and geomorphic details of water bodies like rivers, lakes, springs, drainage systems etc.

The lithological details, as revealed by these investigations, would include the type of rocks that make up different parts of the area, on the surface as also upto and even beyond a desired depth, their textures, major structures and physical and engineering properties. Groundwater table conditions are significant in the success of the engineering structures and hence, detailed investigations are essential.

18.2 GEOLOGICAL ASPECTS OF DAM SITES

A Dam is defined as a solid barrier constructed at a suitable location across a river valley with a view of impounding water flowing through that river. Dams are constructed with various objectives: (1) power generation, (2) irrigation, (3) domestic water supply, (4) flood control, (5) silt prevention, (6) navigation etc. Additional benefits coming from dams are development of fisheries and recreation facilities in the reservoirs.

The dams are classified as concrete dams and earth dams.

Concrete dams: Concrete dams are of three basic types : (a) Mass gravity dam, in which load of the dam is spread over a large area, hence foundation pressures are comparatively low, b) Buttress dam, in which the load is carried up to the strong foundation through a series of narrow buttresses. Hence foundation pressures are high, c) Arch dam: A relatively thin structure. Hence foundation pressures are high.

Earth dams: These are constructed on thick soil foundations. If the soil structure is less they may be founded on solid rocks. If a dam serves more than one objective, it is called a multi-purpose dam.

In our country important multipurpose dams are constructed mainly for irrigation and hydropower generation. For instance, Nagarjunasagar dam in Nalgonda district,; Sriramasagar dam in Nizamabad district, Andhra Pradesh and Konar dam at Hazaribagh, Bihar and Bhakra dam, Bilaspur district, Himachal Pradesh etc.

18.2.1 Geological Investigation at Dam Site

The suitable geological conditions, which lead to the success of dams are (a) a narrow river channel, which can be blocked with a relatively small dam, (b) safe foundation (c) suitable spillways etc. To achieve these objectives, the following investigations are to be carried out.

General Geology of the Area: Preliminary geological surveys of the entire catchment area followed by detailed geological mapping of the reservoir area have to be conducted. These should reveal (i) main topographic features, (ii) natural drainage patterns, (iii) general characters and structures of rock formations such as their stratification, folding and faulting and igneous intrusions and (iv) the trend and rate of weathering and erosion in the area.

Lithology: The single most important feature that must be known thoroughly at the site and all around and below the valley upto a reasonable depth is the lithology, i.e. types of the rocks that make the area. Surface and subsurface studies using the conventional and latest techniques of geological and geophysical investigations are carried out. Such studies would reveal the type, the composition and textures of the rocks exposed along the valley floor, in

the walls and upto the required depth.

Structures: The structural features of rocks of the site are also thoroughly investigated. This involves detailed mapping bedding planes, schistosity, foliation, cleavage, joints, shear zones, faults and fault zones, folding and the associated features. Each one of these features modifies the engineering properties of the rocks to a great extent. While mapping these features, special attention is given to recording their attitude, spacing and nature.

Dip and Strike: The strength of sound, unfractured stratified rock is always greater when the stresses are acting normal to the bedding planes than if applied in other directions. This being so, horizontal beds should offer best support for the weight of the dam. (Fig. 18.1) But the resultant force (due to weight of the dam and thrust of the impounded water) is always inclined downstream. As such, gently upstream dipping layers offer best resistance to the resultant forces in a dam. (Fig 18.2-A) They also serve as a natural obstruction for leakage.

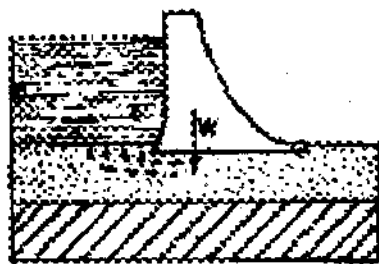


Fig. 18. 1 Dam on horizontal strata

It is also easy to understand that the easiest direction for displacement or slippage in stratified rocks is along the bedding planes. Consequently, the most unfavourable strike direction is the one in which the beds strike parallel to the axis of the dam and the dip is downstream (Fig 18.2-C). Therefore, other conditions being same, beds with upstream dips are quite favourable sites for dam foundations (Fig. 18.2-A).

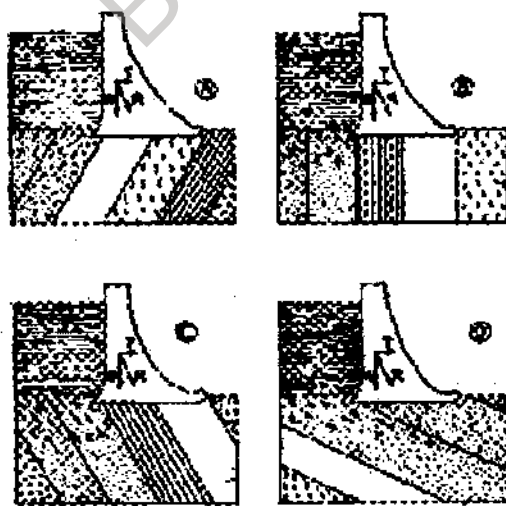


Fig. 18. 2 Dams on sedimentary beds of different orientation. A-Upstream inclined strata; B-Vertical strata; C-Downstream inclined strata

Fault: These structures can be source of danger to the dam in a number of ways. a) The faulted rocks are generally shattered and weak along the rupture surfaces; b) Unexpected and totally different types of rocks may be present on either side of a fault plane. Hence, sites with fault planes require great caution. c) Dams founded on beds traversed by fault zones and on major fault planes are more liable to shocks during an earthquake compared to dams on non-faulted rocks.

Folds: Dams aligned along axial regions would be resting on most unsound rocks in terms of strength. Similarly, in synclinal bends dams placed on the upstream limbs would run the risk of leakage from beneath the dam. The balance of forces in the stressed limbs would be disturbed if these were opened up during construction of diversion tunnels and galleries.

Joints: No sites are totally free from jointing. Hence, sites cannot be abandoned, even if profusely jointed. However, the detailed mapping of all the aspects and character of jointing as developed in the rocks of proposed site has to be taken up with great caution. The geometry of joints, their intensity, nature and continuity with depth all must be thoroughly established, and their effects on the site rocks evaluated and remedial measures taken in advance.

18.3 GEOLOGICAL ASPECTS OF RESERVOIRS

Reservoirs may broadly be defined as artificially created water storage basins with storage capacity that may range from a few thousand cubic meters to hundreds of thousands of million cubic meters. Depending on the purpose of storage, reservoirs are classified into three main categories: They are Storage and conservation reservoirs, (ii) Flood control reservoirs, and (iii) Distribution reservoirs.

18.3.1 Geological Investigations

Since reservoirs are essentially water storage basins, the area should possess such geological characteristics that favour holding of water in the basin so created. Such characters are: topographic suitability, ground water conditions, permeability and structural stability.

Topography: Topographically the area should be a broad natural valley preferably ending in a narrow gorge where a barrier could be placed. The valley could be a U-shaped glacial valley, V- shaped river valley or a broad synclinal valley. Flatlands and plains cannot make convenient places for reservoirs.

Groundwater conditions: Groundwater conditions in the proposed reservoir area must be thoroughly established for an approximately accurate evaluation of storage capacity of the reservoir. Anyone of the three possibilities could be there:

- i.) The general water table is much above the top water level in the proposed reservoir. This is a very favourable situation, as there is no risk of water loss from the reservoir to the surrounding area (18.3-A)
- ii.) The general water table is much below the minimum water level in the reservoir, obviously, depending upon the permeability of rocks along the base and the flanks of the reservoir; water would be lost from the reservoir to the surroundings thereby effecting the total storage inventory considerably (18.3-B)
- iii.) The general water table of the area and the top water level of the proposed reservoir are almost the same (18.3-C), This is an ideal situation ensuring a no loss no gain

condition but generally not available on a large scale.

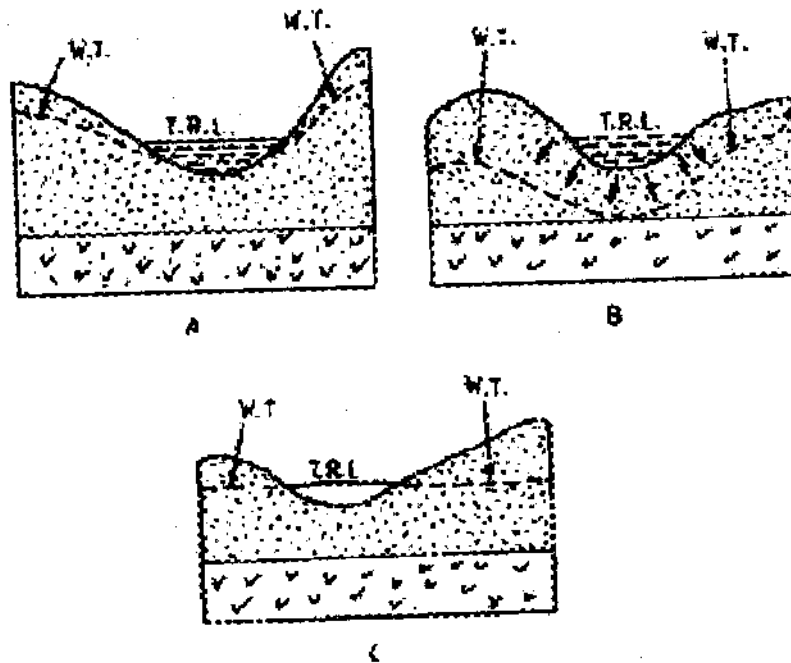


Fig. 18. 3 Groundwater conditions with respect to top reservoir level (TRL).

In view of such a close relationship between water table and storage capacity of the proposed reservoir, it is absolutely essential that water table position all along must be thoroughly established.

Permeability: Permeability is a critical property in reservoir area studies, especially in those areas where ground water table is below the minimum water level of the reservoir. Permeability values, whether primary or secondary, must be thoroughly established.

Structures: Structural constitution of the area of the reservoir is important to identify those zones along the flanks, which are liable to failure by sliding, creep or subsidence.

Rate of weathering: Rate of weathering in catchment area is of considerable importance in determining the age of the reservoir. If the catchment happens to be made up predominantly of weathered, barren slopes which are broken, falling, shattered and jointed profusely, the run off and slope wash would contribute heavy load of sediments to the reservoir after every rain.

This would obviously decrease the effective storage capacity of the reservoir on the one hand and its total life on the other hand. However, stable rock slopes covered with thick forests and vegetation would make ideal catchment areas for reservoirs.

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 are the geological factors considered in the selection of dam site?

2. What is a reservoir?

18.4 GEOLOGICAL ASPECTS IN TUNNELS

Tunnels are under ground routes or passages driven through the ground without disturbing the overlying soil or rock cover. Tunnels are driven for a variety of purposes e.g. traffic tunnels, which are used for traffic flow, hydropower tunnels used for conveying water under gravity from one point to another etc. Rocks may be broadly divided into two categories in relation to tunnelling: consolidated, unconsolidated and soft ground. Tunnel design, method of its excavation and stability is greatly influenced by the following geological conditions.

18.4.1 Lithology

The mineralogical composition, textures and structures of the various igneous, metamorphic, and sedimentary rocks, through which the proposed tunnel is to pass, is of great importance in deciding (i) the method of tunnelling, (ii) the strength and extent of lining and, thus (iii) the cost of the project.

Hard and crystalline rocks: Rocks falling in this group include granites, diorites, syenites, gabbros, basalts and all the related igneous rocks, sandstones, limestones, dolomites, quartzites, arkose, greywackes, etc. of sedimentary group and marbles, gneisses, quartzites, phyllites and slates from the metamorphic groups. When anyone of these rocks is stressed, such as during folding or fractured as during faulting, tunnelling in these rocks proves greatly hazardous due to rock bursts.

Soft rocks: This group includes shales, friable and poorly compacted sandstones, chalk and porous varieties of limestones and dolomites, slates and phyllites with high degree of cleavage and also decomposed varieties of igneous rocks. Their excavation cost, volume for volume, might be lower than those in hard rocks. However, in most cases, these rocks are not self-supporting. Hence, temporary and permanent lining becomes necessary that would involve extra cost and additional time.

Fissured rocks: Fissured rocks form a category in themselves and include any type of hard and soft rock that has been deformed extensively due to secondary fracturing as a result of

folding, faulting and metamorphic changes of shearing type. Tunnelling in such rocks is always hazardous. The extent of deformation has to be thoroughly established. The fissured rocks are very often the zones where ground water would be encountered.

18.4.2 Geological Structures

The design, stability and cost of tunnel depend not only on the type of rock but also on the structures developed in these rocks. Following main structural features of rocks have to be fully determined along the proposed tunnel route:

Dip and Strike: These two properties determine the attitude of the rocks and hence influence the design of tunnel to a great extent. Three general cases may be considered.

i. **Horizontal Strata:** Such a situation is rare in occurrence for longer tunnels. When encountered for small tunnels or for short lengths of long tunnels, horizontally layered rocks might be considered quite favourable (Fig. 18.4).

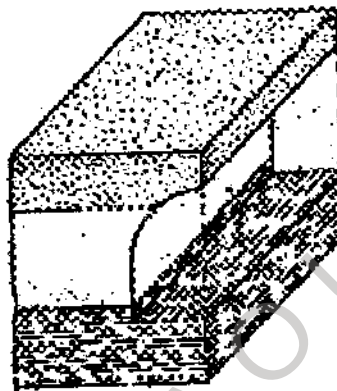


Fig. 18. 4 Horizontal tunnel through horizontal beds

ii. **Moderately Inclined Strata:** Layers that are dipping at angle upto 45° may be said as moderately inclined. The tunnel axis may be running parallel to the dip direction, at right angles to the dip direction or inclined to both dip and strike directions. Each condition would offer a different set of problems.

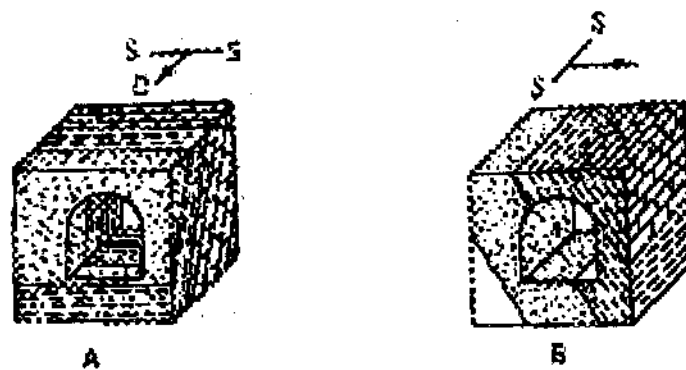


Fig. 18. 5 Tunnelling parallel to: A - Dip of layers; B - Strike of the layers

In the first situation (Fig. 18.5A), the layers offer a uniformly distributed load on the excavation. It is a favourable condition from this aspect. In the second case (Fig. 18.5B), the pressure distributed to the exposed layers is unsymmetrical along the periphery of the tunnel opening. Such a situation obviously requires assessment of forces liable to act on both the sides and along the roof and might necessitate remedial measures. In the third case, when the tunnel axis is inclined to both the dip direction and the strike direction, weak points of both the above situations would be encountered and have to be taken care of.

iii. Steeply Inclined Strata: In rock formations dipping at angles above 45° , quite complicated situations would arise when the tunnel axis is parallel to dip or parallel to strike or inclined to both dip and strike directions.

Folding: Folding of rocks introduces considerable variation and uncertainty in a sequence of rocks so that entirely unexpected rocks might be encountered along any given direction. This situation becomes especially serious when folding is not recognized properly in preliminary or detailed surveys. Folding creates unequal energies in anticlines, synclines and their limbs. The alignment of a tunnel passing through a folded region has to take these aspects in full consideration. When excavations are made in folded rocks, the strain energy is likely to be released immediately. Folded rocks are often best storehouses for artesian water and also ideal places of aquifers. When encountered during tunnelling unexpectedly, these could create uncontrollable situations.

Faulting: Intersection of fault planes, fault zones and shear zones with the tunnel axis play important role in tunnelling. Wherever fault planes or shear zones intersect tunnel, it is to be considered as passing through most unsafe situations and hence designed accordingly by providing maximum support and drainage facilities.

18.4.3 Ground Water Conditions

There are three general possibilities of relationship between tunnel axis and groundwater level.

(a) The tunnel axis may be passing entirely through impervious formations in which there is no possibility of water seepage or leakage or movement. It is an ideal condition for tunnelling of course, but is very rare in nature. Good lengths in short tunnels or small lengths of long tunnels might show such a relationship.

(b) The tunnel axis might be located mostly above the water table, intercepting the aquifer only in some sections. This is one of the most common situations and would involve provision for special drainage facilities to be located in water-bearing zones of the section.

(c) The tunnel axis might be located below the water table. Such a situation should be avoided as far as possible. In some specific cases, however, this might be the only possibility, such as in soft ground tunnelling, under water or in the karst regions. Wherever tunnels enter the saturated zones, effective drainage systems and also support systems have to be planned much in advance.

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 geological parameters influence the tunnel design?

18.5 BUILDING STONES AND ROAD MATERIAL

Building stones include all kinds of rocks, which are used as dressed blocks or slabs, in the construction of dams, bridges, docks, retaining walls, buildings, ornamentation and other masonry structures. Stone-chips used as aggregate in concrete, rocks utilised in the manufacture of lime: cement, earth, clay etc.

Amongst the raw materials required for the construction of roads, clay, sand, gravel and crushed stone are the four major items, the selection of which can be made properly with the assistance of appropriate geological knowledge.

18.5.1 Building Stones

Amongst the different types of rocks occurring in nature, the well-cemented, hard and durable varieties of sedimentary rocks are used most conveniently as building stones since they are available readily. In view of the higher cost and greater difficulty involved in their quarrying and dressing, the massive and compact igneous and metamorphic rocks are less frequently used as building stones than the sedimentary rocks of similar strength and durability.

A building stone of good quality must be durable and should preferably be of light colour. Durable as well as beautiful rocks are, however, rather costly and are generally used as ornamental stones. It is, therefore, apparent that the selection of a building stone should depend primarily on the following parameters.

(a) The strength and durability of building stones depend mainly on their mineralogical composition, texture and structure, if the constituent minerals are hard, free from cleavage and resistant to weathering it is apparent that the stone is likely to be strong and durable. The rock granite composed mainly of quartz, feldspar and mica is, thus, very strong and durable while the carbonate rocks like marble and limestone are relatively weak and are worn out more rapidly. The rock quartzite, composed mainly of quartz alone is obviously strong and durable while the mica-schists are rather weak since they contain much of mica, which is an easily cleavable mineral. In crystalline rocks of igneous and metamorphic origin, the mineral grains are mutually interlocked and no open space is usually left in between the constituent grains. The interlocking texture of the mineral grains contributes substantially towards the strength of the crystalline rocks and the impervious nature of these enables them to resist weathering.

In most of the sedimentary rocks, on the other hand, the discrete mineral grains are held together by cementing materials of variable strength such rocks are generally porous due to the presence of void spaces in them. The nature of the cement determines the strength and

durability of these rocks. From the point of view of their textural characteristics, therefore, it is apparent that the igneous and metamorphic rocks; should be, more strong and durable than the sedimentary rocks.

The volcanic rocks often contain vesicles while the sedimentary rocks are characterised by the presence of bedding planes. Some varieties of metamorphic rocks, again, are conspicuously foliated. The aforesaid structural features serve as planes or zones of weakness and reduce the strength of the rocks affected by them. The structure of a rock is, therefore, of great significance in ascertaining its strength and durability.

b) Colour of a building stone is governed mainly by its mineralogical composition while its beauty is dependent on its texture as well. The acid igneous rocks, composed principally of quartz and feldspar, are light-coloured while the intermediate and basic rocks exhibit a darker shade due to the presence of much of Ferro-magnesia minerals in them. Granite and rhyolite are, thus, light-coloured while diorite, gabbro, dolerite, basalt, peridotite, etc., are dark-coloured. The light-colour of most of the sandstones, limestones, marbles and gneisses is, in a similar manner, an expression of their characteristic mineralogical composition. The colour of a sedimentary rock is, however, influenced considerably by the nature of the cementing materials and impurities present in them. Thus, sandstones with siliceous cement are light-coloured while those with ferruginous cement are dark-coloured. In a similar manner, pure limestones are white while those with clayey impurities are greyish or black. Ferruginous impurities and cements are generally responsible for the development of yellow, red and brown colour in sedimentary rocks.

In some of the metamorphic rocks again, the nature and amount of the accessory minerals and impurities present in them determine the colour. Thus, pure marbles are white while those with argillaceous impurities may be dark. Marbles, containing serpentine as one of the minor constituents is generally of a greenish shade. The beauty of an ornamental stone depends not only on its colour but also on its texture. Thus, the interlocking grains of quartz, feldspar and ferromagnesian minerals, in granite, impart the texture of a mosaic to the polished surface of the rock and, as a consequence, the rock becomes more beautiful than a slab of sandstone of similar colour. Porphyritic granite with well-developed phenocrysts of feldspar is more beautiful than ordinary granite. Assemblage of different bands or shades of colour in a rock often increase its beauty. Thus, the presence of alternate bands of dark and light-coloured minerals adds to the beauty of a gneissic rock. Pure marbles of milk-white colour and serpentine marbles with greenish tinge are obviously very beautiful building and decorative stones.

c) From the economic point of view, the selection of a building stone should naturally depend on its cost, which, in its turn, is governed by its availability, workability and location. Easily available rocks of good quality are obviously cheaper than those, which can be procured with difficulty. The easily available rock sandstone is, thus, cheaper than the less abundant rock marble. Easily workable rocks like sandstone and limestone are, thus, cheaper than granites and gneisses. Moreover, readily accessible deposits of building stone naturally involve less cost than those which are located at a great distance or, are accessible with difficulty.

Before selecting a building stone, its mineralogical composition and texture should be studied carefully under the microscope and at the same time, its structural features should be closely observed in the field. In addition to these studies, it is necessary to determine, its porosity and absorption, crushing and transverse strength, resistance to frost, fire and abrasion,

modulus of elasticity and other physical properties.

Deposits of various types of building and ornamental stones occur in abundance in different parts of the Indian sub-continent. The granites, charnockites, gneisses, marbles, quartzites and slates of Archaean age constitute an inexhaustible source for the supply of excellent building and decorative stones.

18.5.2 Road Materials

The construction of a road involves use of large quantities of road materials. In the interest of the economy of the project, therefore, it is always desirable to find out suitable deposits of the required raw materials in the vicinity of the proposed roadways and, to achieve this end; it is essential to have a thorough knowledge of the geology of the region.

Clay and other argillaceous rocks are occasionally used in the construction of roads; but these materials are worn out readily when dry and become muddy when wet. A mixture of sand and clay however constitutes a more suitable road material than sand or clay alone. By virtue of the hardness, toughness and durability of their constituent grains, gravels are used widely in the construction of road. Gravels in which the constituent grains are composed of weak and highly foliated rocks are, however, not suitable for road construction. In the construction of stabilized roads a mixture of gravel, sand and clay is generally used. A road of this type is sufficiently durable.

Amongst the different types of road materials, crushed stones are most abundantly used, nowadays, in the construction of highways. Crushed stones of good quality must, therefore, be (a) hard (b) tough, (c) resistant to abrasion and, at the same time, should possess a (d) high cementing value. The hardness, toughness, abrasive resistance and cementing value of crushed stones are, however, dependent on mineralogical composition, grain size and texture of the rocks, from which they are derived.

The volcanic rocks, however, possess a high cementing value as well since they contain some secondary minerals like calcite, zeolite, etc. All the volcanic rocks are amply suitable for use as crushed stones. The plutonic and hypabyssal rocks are otherwise quite suitable for the purpose but are rather poor in their cementing properties. Very coarse grained igneous rocks (like pegmatite) possess a very poor cementing value. The sedimentary rocks are generally softer and less tough than the igneous rocks. Amongst metamorphic rocks, the compact gneisses, granulites, amphibolites, quartzites and marbles are suitable for use as crushed stones, although they are generally rather poor in their cementing properties. The common varieties of slates, schists and phyllites, which are soft and strongly foliated are, however, rather unsuitable although they often possess a high cementing value.

18.6 GEOLOGICAL ASPECTS OF BRIDGE SITE

A bridge is defined as a structure built over a river, a dry valley, low land or any depressed part of the land to provide a link between the two opposite sides. It is essentially a communication link on a road or railway track or a highway. Bridges, especially over major rivers and in hilly and mountainous areas are very important civil engineering structures. Within big cities divided by rivers or streams, a bridge has to be placed where it is needed, irrespective of the subsurface geology. However, on highways, there is often some flexibility available in the choice of placement of a bridge. The design, stability and durability depend, to a great extent, on the subsurface geological conditions that must be properly investigated.

In any major bridge construction project, the designer is keen to place the bridge abutments and piers on as sound and strong and stable rock foundation below as possible. This being so, the geological characters that are investigated and thoroughly established are:

- (a) The depth to the bedrock;
- (b) The nature of the bedrock;
- (c) The structural disposition of rocks.

18.6.1 The Depth to the Bedrock

Loose and unconsolidated sediments, or weather country rock material at the site of bridge is unsafe due to lack of stability of material and possibility of erosion by running water. As such, the pier must be placed on a stable foundation, preferably of rock, under a suitable thickness of cover material so that it is safe from scour by river water.

The height of pier from under the span to the foundation level therefore, depends on the 'depth of the bedrock' below the river water. Such sound bedrocks might be available within a depth varying from 5 to 20 meters below a riverbed or they might not at all be available even upto 100 meters or more. All that depends on the local geology, which has to be investigated and understood.

18.6.2 The Nature of the Bedrock

The bedrock at bridge site has to bare compressive force due to vertical load of the bridge, the horizontal load from running water and complex load of due to heavy traffic consequently, the bedrock selected as foundation for the pier must be strong enough to bear the sum total of all these loads, not temporarily, but throughout the proposed life of the bridge.

The nature of the bedrock is commonly determined through study of petrological characters and engineering properties, especially the strength values, using the core samples obtained during drilling of test bore holes. Most igneous and massive type of sedimentary and metamorphic rocks are quite strong, stable and durable as foundations for bridge piers and abutments. The group of weak rocks, which might behave badly in the presence of water, includes such types as cavernous limestones, chalk, friable sandstones especially with clayey cements, shales, clays, slates, schists and the layers of peat and compressible organic material. Many of them are amenable to treatment by artificial methods.

18.6.3 The Structural Disposition of Rocks

Ideally, the horizontal attitude and uniformly massive structure with depth are desirable characters in the foundation rocks as these offer inherent resistance against failure. However, even inclined rocks in a confined situation under the bridge piers are considered quite safe if these possess normal strength values. Folding and faulting might cause some uncertainty in establishing a perfect geological profile but are not otherwise negative factors. Acute fracturing and profuse jointing is, however, undesirable at the foundation levels as these might cause settlement beyond the allowable limits.

In the glaciated areas, special care must be taken to establish the existence of drowned or buried valleys that might be filled by secondary material of most heterogeneous characters. In such cases, the bed rock may be encountered only at great depths and it may be desirable to reach through piles. In fact, occurrence of drowned valleys is considered one of the major complications in bridge foundations that limit the options of a design engineer.

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. What are the criteria for the selection of building stones?

5. What are the geological characters investigated for the selection of Bridge site?

18.7 SUMMARY

The important engineering projects like dams, reservoirs, tunnels, roads and bridges etc., are constructed on rocks or soils. It is, therefore, essential to have the fullest knowledge of subsurface geology of the area for the success of the engineering structures. The suitability of rock as foundation or material to be used as for construction not only depends on the origin (igneous, metamorphic, and sedimentary) but also on the mineral composition, structures, and textures. In the present day engineering construction, it is almost mandatory to decide about the location, design and construction of all major structures only after geological characters of the area have been investigated and recorded to the last possible detail.

Dams are constructed with various objectives: (1) power generation, (2) irrigation, (3) domestic water supply, (4) flood control, (5) silt prevention, (6) navigation etc. The suitable geological conditions, which lead to the success of dams are (a) a narrow river channel, which can be blocked with a relatively small dam, (b) safe foundation (c) suitable spillways etc. To achieve these objectives, a thorough systematic investigation of geological characters of the area is necessary.

Reservoirs are artificially created water storage basins. Depending on the purpose of storage, reservoirs are classified as storage and conservation reservoirs, flood control reservoirs, and distribution reservoirs. Since reservoirs are essentially water storage basins, the area should possess such geological characteristics that favour holding of water in the basin so created. Such characters are: topographic suitability, ground water conditions, permeability and structural stability. Tunnels are under ground routes or passages driven through the ground without disturbing the overlying soil or rock cover. Tunnels are driven for a variety of

purposes. Tunnel design, method of its excavation and stability are greatly influenced by the lithology, geological structures and groundwater conditions.

Building stones include all kinds of rocks, which are used as dressed blocks or slabs, in the construction of dams, bridges, docks, retaining walls, buildings, ornamentation and other masonry structures. Stone-chips used as aggregate in concrete, rocks utilised in the manufacture of lime; cement, earth, clay etc. Amongst the raw materials required for the construction of roads, clay, sand, gravel and crushed stone are the four major items, the selection of which can be made properly with the assistance of appropriate geological knowledge.

A bridge is defined as a structure built over a river, a dry valley, low land or any depressed part of the land to provide a link between the two opposite sides. It is essentially a communication link on a road or railway track or a highway. Bridges, especially over major rivers and in hilly and mountainous areas are very important civil engineering structures. Within big cities divided by rivers or streams, a bridge has to be placed where it is needed, irrespective of the subsurface geology. The design, stability and durability of bridges depend, to a great extent, on the subsurface geological conditions that must be properly investigated.

18.8 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Lithological and structural parameters.
2. Reservoirs may broadly be defined as artificially created water storage basins with storage capacity that may range from a few thousand cubic meters to hundreds of thousands of million cubic meters.
3. Tunnel design is greatly influenced by following geological conditions: lithology, geological structures and ground water conditions.
4. Selection of a building stone depends primarily on its (a) strength and durability ability, (b) colour and beauty particularly when it is used as a decorative stone, and (c) Cost.
5. The geological characters that are investigated thoroughly are (a) The depth to the bedrock, (b) The nature of the bedrock, and (c) The structural disposition of rocks.

18.9 MODEL EXAMINATION QUESTIONS

- I. Answer the following questions in 30 lines each.
 1. What are dams? Why are they constructed? Discuss the role of geological investigations at dam sites?
 2. What are building stones? On what factors does their selection depend?
 3. Give a broad account of geological conditions that influence the tunnel alignment.
 4. Discuss the geological conditions that contribute towards the stability of a bridge.

II. Answer the following questions in 10 lines each.

1. Tunnel in horizontal strata.
2. Types of dams.
3. Rate of weathering in catchment area of Reservoirs.
4. How do you assess the nature of Bedrock at bridge site?

BRAOU

UNIT : 19 NATURAL RESOURCES MANAGEMENT

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19.0 OBJECTIVES

In this unit the idea of natural resource, different types of natural resources like forests, soils, mineral resources and energy resources are discussed. The possibility of usage of alternate sources of a resource is also given.

After completion of this unit, you will be able to

- describe the natural resource
- explain the different types of natural resources
- describe the importance of soil and its conserving methods
- explain the importance of water and its utilisation

19.1 INTRODUCTION

A resource is a naturally occurring substance that is potentially feasible to extract under prevailing conditions. Natural resources are those structures and processes that can be used by humans for their own purposes but cannot be created by them. If the supply of a resource

is very large and the demand for it is low, the resource is often thought of as free. Sunlight, land and air are often not even thought of as natural resource because their supply is so large. A natural resource is anything drawn from Earth to support life or a way of life. The development of technology has allowed for the exploitation of natural resources to a much greater extent than that was capable by our ancestors.

The landscape is also a natural resource as is readily seen in countries with the proper combination of mountainous terrain and high rainfall, which can be used to generate hydroelectric power. Rivers, forests, scenery, climates and wildlife populations are additional examples of natural resources. Resources, especially those like land, air and water become more valuable as we begin to exploit them more intensively.

Natural resources are broadly of two types (i) Renewable (ii) Non-renewable. Renewable resources are those that can be formed or regenerated by natural processes. Soil, vegetation, animal life, air and water are renewable primarily because they naturally repair and cleanse themselves. Renewable resources are materials that can be regenerated with relatively short span of time (crops, timber) or reused (air, water). Non-renewable resources are those that are not replaced by natural processes or whose rate of replacement is so low as to be ineffective. Non-renewable resources (rocks, minerals and fossil fuels) are found in nature in finite quantities. Their formation within earth involves such extraordinarily long periods that there is no reasonable expectation that new supplies could form in hundreds or even thousands of years. Therefore, when non-renewable resources are used up, they are gone and a substitute must be found or we must do without. These can be further divided based on the specific reference to the nature of a resource. Both renewable and non-renewable resources are available in large quantities both on land and in oceans.

Proper planning, better management and optimum utilization of the natural resources leads to the better way of life. Good management of the available resources always helps the mankind to progress with confidence, stability in society.

Natural resources can be classified as (i) Renewable: Solar energy, Soil, Water, Marine energy (tides, waves, currents, etc.). (ii) Non-renewable: Mineral resources, Fossil fuels.

The best natural resources Mother Earth has given to mankind are soil, water, light (solar energy). Without these the very existence of life is under threat. So management of these resources has a vital role in the survival of mankind and ultimately to life on planet earth.

The long strides of civilization, constant struggles for higher standards of living, explosions in population, expansion in urbanization, demands of industrial revolution and shortages in accumulation have depleted the natural resources base around the globe.

19.2 FORESTS

Forests of the world cover about 4400 million hectares of the land surface of the earth occupying 30% of the geographical area. The United States of America has a forest cover of 30% of the geographical area and almost all the developed countries in Europe and elsewhere maintain even higher percentage of forest cover.

The annual rate of deforestation in the world is more than 20 million hectares, around 0.45% of the forest cover. The forests in India cover only 10% of the geographical area, while the

annual rate of deforestation is 1.5 million hectares, 5% of the existing cover. The world average rate of deforestation itself is high. While that of India's is appalling eleven times higher.

On an average globally, 25 billion tones of topsoil from croplands are being washed into the oceans every year and an estimated 2 billion hectares of land have been destroyed by it. The damage is more apparent in developing nations with an exploding population.

The effects of deforestation are Soil erosion, Floods, Silting of reservoirs and agricultural lands, Decrease of recharge to groundwater, Desertification.

There is crisis of economic development, due to misuse of natural resources like soil, water and forests, than industrialization.

19.3 SOIL

Soils may be defined and classified in a number of ways, depending on who defines them and the purpose of classification. An engineer, for example considers the soil to be any unconsolidated material overlaying bedrock at the earth's surface. For an earth scientist, soil is defined as that portion of the loose material at earth's surface capable of supporting plants with root systems.

There is close relationship exists from ancient civilization to the present human life that exists on the earth. Even today most of the world's population are tillers of the soil and live close to the soil because of its importance. Thus soil is integrally and intimately connected with rocks beneath, the vegetation growing above and the water percolating through it. In other words it has its own microclimate wherein the vegetation growing above and the water percolating through it.

Soil consists of products of weathering of rocks, intermixed with living organisms and the products of their decay, the moisture and air filling and interstitial space. In other words the soil has a microclimate of its own, controlled by water, air and organisms. The silt particles constitute the framework and the clays and organic matter (humus) hold together the framework serving as the nutrient base. The colloidal clays and humus will have the capacity for cation exchange and attract the molecules of water that form a sort of atmosphere around the clay particles. It is water attracting and water holding capabilities of the colloidal humus and clays that keep the soil moist even during the dry seasons. Thus the soil is living system and is endowed with an internal micro-atmosphere of air and vapor; and is capable of supporting vegetation and promoting various biological and biochemical process.

Geologists consider soil as the upper part of the weathered material (regolith) resting on the bedrock and contain inorganic and organic nutrients. But the environmentalists say that soil is a dynamic living layer forming the foundation of all ecosystems. The farmers and horticulturists etc. are dependents upon soil and are more concerned with the primary production systems. It not only sustains and nourishes the primary production but also acts as a passage and store for groundwater, which is essential for survival after cessation of rainfall. There are two major categories of soil viz., Insitu or zonal soil and drift or azonal soil. The former category usually occurs in relatively flat or undulating areas which are found as a result of weathering. The second category of soil is formed over the colluvial (emplacement by mass-movement) or alluvial (river borne) deposits also referred to as transported soils.

Five factors seem most important in the formation of any soil: time, parent material, topography (slope and drainage), climate and organisms. Agriculture depends heavily on soil quality, but agriculture can lead to a decline in that quality. A high quality agricultural soil has all the chemical elements required for plant growth and a physical structure that lets both air and water move freely through the soil, yet retains water well.

Such soil has a high organic matter content, which helps retain chemical elements and a mixture of sediment particle sizes. Traditional demands based agriculture has combated the decline in soil fertility through use of organic fertilizers, such as animal manure. Organic fertilizers have an advantage in that they can improve both the chemical and physical characteristics of the soil. But organic fertilizers have drawbacks; they can be low in specific elements required by a particular soil.

One of the factors that have led to great increases in agricultural production is the development of modern, industrially produced, chemical fertilizers. The major focus for the future must be on sustainable agriculture, which means that production per unit area is restricted to the amount that does not damage soils, eliminate water supplies and does not lead to permanent pollution downstream.

19.3.1 Soil Erosion

Soil erosion is one of the management issues in recent years by which soil loses its fertility and converts into deserts. The adverse affects of drastic microclimate change are due to deprivation of vegetation cover. The human activity lead to destroy the green cover as seen in Himalayas and Niligiri hills. The increased degradation lead to soil erosion and clearly visible in the form of sediments transported by the rivers. The national and international volunteer organization together with the ministry of environment are trying to put control soil erosion in order to safeguard the soil fertility in the farm aggravation in the hill regions where in drought resistant (xerophytic) plants tolerant to dryness have taken a hold to the deforested slopes in the mountain regions. These will rapidly be replacing the local flora on the eroded soil region. Example, Kosi Valley of the lesser Himalayan terrain in Kumuan and Garhwar sector of Himalaya. Soil erosion occurs naturally and also by human activity. The natural erosion takes place by sheet erosion and gully erosion.

19.3.2 Sheet Erosion

Uniform skimming of topsoil will take place by the sheet erosion. The soil grains are separated and made free to float away during the initial stages of rainfall and an amount of water flowing downwards exceeds the soil grains are carried downwards. This process starts simultaneously over a large area during the rainy season and huge thin sheet area eroded away in the form of loose soil grains are carried downslopes along with the water.

19.3.3 Gully Erosion

The soil surface is not uniform but slightly depressed and is known as gullying. Thus the slightly depressed area in the field eventually get much eroded in the gullies of varying depth and extent during the rain season and is carried away the loose soil materials.

19.4 PREVENTION AND CONTROL OF SOIL EROSION

Control measures so far available for soil erosion fall under two heads, viz., agronomic methods and engineering methods.

19.4.1 Agronomic practice

The protection of the topsoil by special methods and schemes of crop cultivation. This has been proved successful in many cases and these are (i) Crop rotation: Different crops are grown in the same field according to a definite scheme of rotation i.e. one after another. A sequence commonly followed, for instance, is a cultivated crop, a small grain and then grass (after which again cultivated crop will be grown). (ii) Strip cropping: Cultivated crops and cover crops are grown in alternate strips. These strips are generally made parallel with the contours.

19.4.2 Engineering methods

Engineering methods are most widely used for combating soil erosion, which include the following

- excavation of different types of ditches for the removal of excessive water in the fields
- construction of suitable types of terraces
- Construction of dams for checking the soil erosion.

Check Your Progress

- Note: (a) Space is given below for writing your answer.
(b) Compare your answers with the model answers given at the end of

1. What is a natural resource?

2. By what natural process soil erosion takes place?

19.5 MINERAL RESOURCES

The wealth of a nation is ultimately the amount of mineral resources available and exploited. The usage of minerals is as old as civilization. There has been Stone Age, the Bronze Age, and Iron Age depending upon the minerals and their products used. Today the modern world is largely the result of extreme exploitation and use of minerals. From fertilizers for food, coal, petroleum, natural gas and atomic energy as sources of power, minerals are used. For other necessities of life, like automobiles, ships, modern communications and a host of

chemicals which are derived from the use of minerals. All engineering and structural material, machinery, equipments are manufactured from metals and their varied alloys.

We are facing a global mineral resource crisis. Earth's finite supply of minerals is being used by a population that is growing faster than at any time in history. To make matter worse mineral consumption is growing even faster than the population.

Although we need more minerals to supply civilization we are becoming increasingly aware that their production and use are polluting planet. Effects that were once local in scale have become truly global with mineral consumption implicated strongly in global warming, acid rain, and destruction of ozone in the upper atmosphere. Just when we need to expand mineral production, there is concern that earth is reaching its limit of mineral related pollution.

Fossil fuels are non-renewable. The amounts of these fuels are finite. When fossil fuels are exhausted, they will have to be replaced with other forms of energy, probably renewable forms. Waterpower, which generates 7 percent of the world's electrical energy, is only developed to 17 percent of its potential. Substitutions of alternative energy resources are useful for controlling environmental effects. The selection among alternative non-conventional resources depends on their relative abundance, easy recovery, and convenience in handling and economics. The major alternative energy sources that can supply energy continually to the biosphere over a geological time span include solar energy and its derivatives, wind, waves and hydropower in addition to the energy from geothermal, biomass and nuclear reactions. The use of geothermal and tidal energy is limited by geographic locations. Wind power may be used to generate electricity but may require wide, open areas and a large number of wind generators. Solar energy can be collected and used in either passive or active systems and can also be used to generate electricity. Lack of constant supply of sunlight is solar energy's primary limitation. Fuel wood is a minor source of energy in industrialized countries but is a major source of fuel in many less developed nations. Biomass can be burned to provide heat for cooking or to produce electricity or it can be converted to alcohol or used to generate methane. In some communities solid waste burned to reduce the volume of the waste and also to supply energy.

19.5.1 Marine Mineral Resources

Mining beneath the seafloor includes (a) petroleum (b) Natural gas (c) coal (d) limestone (e) tin (f) copper (g) nickel (h) iron and (i) sulfur.

Mining on the seafloor includes (a) phosphorite (b) sands and gravels (c) iron bearing sands (d) diamonds (e) gold, platinum, osmium, palladium, titanium and other heavy mineral placers (f) copper, lead, zinc, vanadium (g) barium, zirconium, tin, sulfur, barites and (h) manganese nodules (containing cobalt, copper, nickel and magnesite).

The most important part of the mineral endowment consists of reserves, material that has been identified geologically and that can be extracted at a profit at the present time. The reserve base includes reserves as well as already identified material of lower geologic quality that might be extractable in future, depending on economic factors. Resources include the reserve base plus any undiscovered deposits, regardless of economic or engineering factors.

In order to obtain maximum benefits from technological developments, it is imperative that the natural resources, soil, and water be properly protected and judiciously utilized to improve their productivity constantly.

19.5.2 Energy from Tides and Waves

Energy from ocean waves is potentially available almost everywhere at the sea. There are many systems, which propose to harness the energy of waves. The simplest system consists of letting the energy of the waves be released as an uprush of water on a steep ramp that falls into a reservoir. United Kingdom, Japan are the pioneers in the wave energy development. India along with Sweden, Norway and the United States of America has started research and development activities on a large scale. The Rance river estuary power plant in France is the world's largest tidal electrical generating station.

It is estimated that the global wave energy potential is 60 to 80 MW/m. Along Indian coast it may lie anywhere between 5 MW/m and 15MW/m. For a total Indian coast, the wave energy potential is around 60,000 MW. Only 2% of the total tidal resources is suitable for harnessing (2% of 3×10^6 megawatts). This is significant amount since it represents nearly 5% of worldwide power generation from all sources. In India, possible sites are Gulf of Kutch, the Gulf of Cambay and Sunderbans in West Bengal having annual average tidal range of 11m, 6m and 3.5 m respectively and possible installed capacities are 7300MW, 1000MW and 15MW. The first wind generator in India is at Kanai creek (Gujarat) to operate a lighthouse with a power output of 300 watts.

19.5.3 Geothermal Power

In some regimes, the hot material is close enough to the surface to heat underground water and form steam. Geysers and Hot Springs are natural areas where this steam and hot water come to the surface. In areas where the steam is trapped underground, geothermal energy is tapped by drilling wells to obtain the steam.

The United States has over half of the world's geothermal electrical generating capacity. Other countries included here are Philippines, Italy, Mexico, Japan, New Zealand and Iceland. In Iceland, half of the geothermal energy is used to produce electricity and half is used for heating.

19.5.4 Solar Energy

The basic principle in this is to convert the solar radiation into the electricity without polluting the ecosystems. The radiation can be converted directly into electricity during the day by photo voltaic cells and stored in batteries. The indirect method of tapping solar energy involves concentrating the sunrays by use of mirrors or blackened collectors on water to produce steam that runs an electric generator.

Solar energy has been successfully used in various parts of the country to run tube wells, rice mills, lighting the homes etc. In India bright sunshine (solar radiation) is available in almost all parts of the country. The states of Rajasthan, Gujarat, Western Madhya Pradesh and Northern Maharastra receive high quantity of solar radiation.

19.6 WATER

Water is vital to all forms of life on earth. Of all the renewable resources freshwater is most important, unjustified use of freshwater is likely to make it more precious. Conservation of water faces more difficulties than other natural resources. Agriculture is the single largest drain on water, accounting for about 69 percent of all water use, while 23 percent of water is used for industry and energy and just 8 percent to domestic use.

Like every natural resource, groundwater must be wisely managed, which means that the groundwater resources must be carefully protected against over-exploitation, contamination by pollutants or salt water, depletion of the groundwater reservoir.

19.6.1 Deterioration of the Water Quality

Groundwater is a natural resource and reserve. The available groundwater in storage fluctuates due to recharge from precipitation, canal seepage, stream aquifer interaction and pumping. There is a normal recharge pattern from normal rainfall and it gets affected due to recurring failure of monsoons, and indiscriminate pumping.

Groundwater is replenishable unlike other mineral resources that are normally exhaustible in nature. The aquifers are recharged every year from the rainfall. Groundwater recharge of an area depends on the annual rainfall and its distribution, topographic gradient, vegetation and most important of all soil and rock permeability. The intake capacity in an area by infiltration of rainwater or surface water is limited to the permeability factor. It decides the amount of water that can be transmitted per day through the soil and the underlying geological formation. Any excess of water to this component would go as surface run-off. Therefore, rainfall of high intensity for short spell do not have as much influence on the recharge as the same amount of rainfall is distributed uniformly over a long period. Similarly, the higher the slope of the ground, the faster is the run-off and lesser the infiltration. A plain ground on the other hand, allows maximum infiltration as the run-off is slow and the contact between the water and ground surface is long. Vegetation helps to reduce the run off and indirectly helps for more groundwater recharge.

19.6.2 Overexploitation

If the groundwater draft exceeds recharge, it leads to overexploitation. Overdraft of groundwater is undesirable as it causes declining of water levels to greater depths whereby groundwater development becomes uneconomical or the resource may gradually exhaust.

Monitoring of water levels in select dug wells (observation wells) all over the country for the last three decades indicated declining trends in some parts. The water levels have gone deeper by more than 10 to 15 meters in some parts indicate overexploitation. The areas with groundwater extraction at more than 85% of the annual recharge are classified as dark areas (overexploited). In Andhra Pradesh some areas in districts like Chittoor, Nalgonda, Karimnagar, Nizamabad, and urban areas like Hyderabad, Visakhapatnam have reached this state. It is a known fact that many dug wells and bore wells dry up in summer and recoup again in rainy season. Framing legislation that may curb indiscriminate digging wells and over pumping so that groundwater resource remains as a sustainable and dependable source of water, is the one of the solutions for the problem of overexploitation. Watershed management is another method to improve the groundwater levels and balance the ecosystem.

19.6.3 Groundwater Management

Groundwater development in the country has gained momentum during the last three decades because of institutional finance through banks. Some pockets in many states including Andhra Pradesh reached optimum stage tapping more than 85% of the groundwater potential that are classified as dark areas. Therefore, management techniques are needed to restrict the groundwater draft to the safe yield limit or to increase the safe yield itself through artificial recharge methods. The other methods of management involve change of crop-pattern and adoption of modern irrigation practices like sprinkler and drip irrigation that reduce the

quantity of water applied and increase the area of irrigation. Reuse or recycling of wastewater is also practiced for certain purposes that do not require high standards of quality like irrigation, cooling, etc.

19.6.4 Conjunctive Use

The other concept of water management is conjunctive use of surface waters and groundwater for maximum utilization of water resources in an area and to bring as much land as possible under irrigation and to raise more number of crops in a year. In the tank ayacut areas, channel irrigation areas and even in the ayacut of major irrigation projects, surface water is not sufficient to raise second crop in the entire command area. The first crop called kharif is grown with the surface water and with rainfall during monsoon. The second crop called Rabi crop is raised during December-March. For this crop in the absence of rainfall, the complete requirement of water is to be met only from the surface water. Which may be inadequate.

It is therefore suggested to develop groundwater in the command area to supplement surface water at the fag end stage of the Rabi crop. Groundwater is generally substantial in the ayacut areas because of seepage from the surface water bodies in the up slope. Groundwater would also be advantageous in the ayacut areas to raise nurseries well in advance to the monsoon so that it will be ready for transplantation at the onset of monsoon and thus helps to advance the crop by about a month which leaves scope for the third crop during summer.

19.6.5 Water Use Efficiency

To increase the water use efficiency some methods are (i) border strip and check, basin irrigation (ii) furrow irrigation (iii) sprinkler irrigation (iv) drip irrigation

Border strip and check basin irrigation: In border irrigation, soil ridges keep the water flowing down a strip of land. Border irrigation works well if the soil surface is level in direction perpendicular to water flow and the slope in the direction of water flow is gentle. Basin irrigation, creating soil-ridged basins to hold water, can be quite efficient and has been widely used for pastures and for orchards. Where each tree is within its own check or basin. Basin irrigation is not suitable for highly permeable soils (sands, organic soils) for irregularly sloped land, for crops harmed by temporary flooding (tomatoes, beans, corn in early stages, lettuce) or for very slowly permeable soil (clays).

Furrow irrigation: Including small, close furrows termed corrugations, is the oldest form of irrigation. In this method water flows by gravity from a main ditch and down each furrow.

Sprinkler methods: More uniform application of water is usually possible than with surface irrigation (except in high winds) with sprinklers. The amount of water added can be calculated and applied with great precision and usually at the rate desired.

Drip irrigation: Drip irrigation is the frequent slow application of dripping water to soil through small outlets (emitters) located along small plastic delivery lines.

19.6.6 Watershed Management

Watershed management is not merely anti-erosion and anti-runoff approach but also a comprehensive, integrated approach of land and water resources management. The approach is preventive, progressive, corrective as well as curative, wasteland resources could be fruitfully harnessed into a productive face for natural development.

The chief objectives of the watershed management are conserving soil and water, improving the ability of land to hold water, rainwater harvesting and recharging, growing greenery – trees, crops and grasses.

Rainwater harvesting is another technique of increasing the groundwater reserves. It is a technique to collect and store the locally available water through rainfall for specific purposes. This has a high scope of application in places where rainfall is low, as well as in places where the rainfall may be high but the number of rainy days is very limited.

Watershed management arrests soil erosion, reclaims vast tracts of eroded lands, improves soil moisture harvests rainwater, reduces floods, recharge groundwater and revives greenery. In due course, it restores rainfall, revives healthy climate, regenerates soil regimen, rejuvenates green foliage and revivifies environment. Further it renders the rural population self-sustaining in food, fat, fiber, firewood, fodder, fruit, health and hygiene. In consequence, dependence of the rural poor reduces, their farm produce increases per capita income gains and economy improves.

19.7 ENERGY CONSERVATION

Although conservation is not a way of generating energy, it is a way of reducing the need for additional energy consumption. Severe conservation technologies are sophisticated, while others are quite simple. For example, if a small, inexpensive wood-burning stove was developed and put into use to replace open fires in the less developed world, energy consumption in these regions could be reduced by 50 percent.

Several technologies are now available that reduce energy consumption. Highly efficient fluorescent light bulbs that can be used in regular incandescent fixtures give the same amount of light for 25 percent of the energy. Low emissive glass for windows can reduce the amount of heat entering a building while allowing light to enter. The use of this glass is new construction and replacement windows could have a major impact on the energy picture.

19.7.1 Geological Conservation

Geologic conservation mainly emphasis on the totality of human effort to deal with the effective management of the earth's surface and sub-surface resources such as soil, water and minerals and fuel with reclamation and rehabilitation of damaged environments.

Conservation is essential for the sustainable development of mankind. It is not good to enjoy the resources at present; one has to think of future generations. Soil conservation consists of maintaining balance in soil profile and prevents excessive erosion or deterioration.

Natural resources conservation involves planning, extraction, marketing and use for the long-range utilization by man. Reclamation and rehabilitation are two different aspects of conservation that deal with man's deliberate attempts to change or restore environment. Along with conservation man has to develop new strategies and device new materials for survival that are equal or better than those which have been destroyed.

Check Your Progress

- Note: (a) Space is given below for writing your answers.
(b) Compare your answers with the model answers given at the end of this unit.

3. What minerals are mined beneath the seafloor?

4. What are the chief objectives of the watershed management?

19.8 MISMANAGEMENT OF A NATURAL RESOURCES

Although soil is a renewable resource extensive use can permanently damage it. Many of the world's deserts were formed or extended by unwise use of farmland.

When the material is reclaimed and used over for another structure or process, it is recycled. For recycling to be economically practical the obsolete items must be recaptured before they have dispersed into the environment. For example, waste oil is relatively easy to recapture at the servicing center where engine oil is replaced, but difficult to recapture if the oil is dumped on the ground or into a sewer.

19.9 SUMMARY

A resource is a naturally occurring substance that is potentially feasible to extract under prevailing conditions. Natural resources are broadly of two types (i) Renewable (ii) Non-renewable. Renewable resources are those that can be formed or regenerated by natural processes. Non-renewable resources are those that are not replaced by natural processes or whose rate of replacement is so low as to be ineffective. Non-renewable resources (rocks, minerals and fossil fuels) are found in nature in finite quantities. Forests of the world cover about 4400 million hectares of the land surface of the earth occupying 30% of the geographical area. The forests in India cover only 10% of the geographical area, while the annual rate of deforestation is 1.5 million hectares, 5% of the existing cover. The effects of deforestation are Soil erosion, Floods, Silting of reservoirs and agricultural lands, Decrease of recharge to groundwater, Desertification.

For an earth scientist, soil is defined as that portion of the loose material at earth's surface capable of supporting plants with root systems. Soil consists of products of weathering of rocks, intermixed with living organisms and the products of their decay, the moisture and air filling and interstitial space. Five factors seem most important in the formation of any soil: time, parent material, topography (slope and drainage), climate and organisms. Soil erosion

is one of the management issues in recent years by which soil loses its fertility and converts into deserts. The increased degradation leads to soil erosion and is clearly visible in the form of sediments transported by the rivers. Soil erosion occurs naturally and also by human activity. The natural erosion takes place by sheet erosion and gully erosion.

Control measures so far available for soil erosion fall under two heads, viz., agronomic methods and engineering methods. The increased deforestation in recent years has posed an environmental hazard by which soil loses its fertility and converts to desert land. The soil erosion is generally achieved by artificial and by natural processes.

The wealth of a nation is ultimately the amount of mineral resources available and exploited. The usage of minerals is as old as civilization. Fossil fuels are non-renewable. The amounts of these fuels are finite. Substitutions of alternative energy resources are useful for controlling environmental effects. The selection among alternative non-conventional resources depends on their relative abundance, easy recovery, and convenience in handling and economics.

The major alternative energy sources that can supply energy continually to the biosphere over a geological time span include solar energy and its derivatives, wind, waves and hydropower in addition to the energy from geothermal, biomass and nuclear reactions.

Water is vital to all forms of life on earth. Of all the renewable resources, freshwater is most important, and unjustified use of freshwater is likely to make it more precious. Conservation of water faces more difficulties than other natural resources. The chief objectives of the watershed management are conserving soil and water, improving the ability of land to hold water, rainwater harvesting and recharging, growing greenery – trees, crops and grasses. Rainwater harvesting is another technique of increasing the groundwater reserves. It is a technique to collect and store the locally available water through rainfall for specific purposes. This has a high scope of application in places where rainfall is low, as well as in places where the rainfall may be high but the number of rainy days is very limited.

19.10 CHECK YOUR PROGRESS - MODEL ANSWERS

1. A natural resource is anything drawn from Earth to support life or a way of life.
2. The natural erosion takes place by sheet erosion and gully erosion.
3. Mining beneath the seafloor includes (a) petroleum (b) Natural gas (c) coal (d) limestone (e) tin (f) copper (g) nickel (h) iron and (i) sulfur.
4. The chief objectives of the watershed management are conserving soil and water, improving the ability of land to hold water, rainwater harvesting and recharging, growing greenery – trees, crops and grasses.

19.11 MODEL EXAMINATION QUESTIONS

- I. Explain the following in 30 lines each.
 1. Discuss the importance of soil as a natural resource.
 2. Explain the potential of generating energy from (a) waves and tides (b) geothermal energy and (c) solar energy
 3. What are different groundwater management techniques?
 4. Explain the different ways of energy conservation.

II. Explain the following in 10 lines each.

1. Classify the natural resources with examples
2. What the methods for prevention of soil erosion and control
3. What is the importance of watershed management?
4. What are the different water use efficiency methods

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UNIT : 20 ENVIRONMENTAL GEOSCIENCE

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20.0 OBJECTIVES

In this unit, scope of Environmental geoscience, natural hazards, atmospheric pollution, exploitation of resources and its impact on the Environment, surface water pollution, treatment of polluted waters, solid waste disposal – environmental impact, groundwater and human health are described.

After completion of this unit you will be able to

- explain the importance of environmental geoscience
- describe the different kinds of environmental issues
- explain the impact of exploitation of natural resources
- explain the impact of pollution on human health

20.1 INTRODUCTION

Environmental geoscience is a branch of geology. This branch deals with creating an awareness for preserving the natural environment, conserving the earth's resources, coping

with geological hazards and participating in technological and industrial development without disturbing the ecological balance.

Environmental geoscience is study of the interrelationship of various earth processes, their consequences and the activities of man who forms the central figure in the environmental scheme of things. This course embraces coordinated and integrated studies and the application of geosciences for the improvement and preservation of the environment through a more judicious use of natural resources and by ensuring the safe guards against degradation of land and contamination of air and water.

The better quality of life can be achieved through use of land in accordance with its capabilities, better management of water resources and judicious utilization of mineral and energy resources without endangering their bases. The primary objective is to aid in those studies and decisions in order to minimize the human impact on the human environment.

20.2 SCOPE OF ENVIRONMENTAL GEOSCIENCE

The scope of environmental geosciences is very broad. It consists of all the sub-disciplines of geology but also the other physical, biological and social sciences. On the whole the discipline embraces the total gamut of human use of the earth- the prediction, assessment and combating of natural hazards and application of technology and engineering for the development of society without destruction of environment.

The major areas where environmental geosciences plays vital role are:

Earth resources: development of any nation depends on the exploitation and utilization of these resources. Minerals, oils and gas, soil etc are depleting at faster rate, as these are the non-renewable resources, proper conservation and management procedures can only solve the problems. The exploitation, beneficiation, usage all are related to environment. If proper methods are not used environment may be damaged.

Water: water is the most vital source for the sustainable development of living things. This resource of required quality is available in limited extent, so its judicious use without deterioration of its purity, freshness and source are essential elements for environmental management of water.

Natural hazards/geological hazards: a geological hazard is a phenomenon associated with geologic process that can produce a disaster when a critical point is exceeded and can result in significant loss in life and property. The natural hazards of this type are volcanoes, earthquakes, cyclones, etc. which will cause damage within a short duration. By mapping of hazard-prone areas and avoiding occupation in such areas may benefit from the disasters. However, taking necessary precautions can certainly minimize the incidence of human induced changes such as landslides, subsidence, floods, and desertification.

Pollution and waste disposal: the manufacturing and mining and ultimate disposal of the by-products of civilization impose a tremendous alteration of natural systems. The dumping of large volumes of waste threatens not only to deface the landscape but also to pollute the air and water. The environmental geosciences is related to this waste disposal and pollution in a way to locate suitable sites for disposal of waste, to know the exact causes of pollution of air, soil, surface water and ground water and remedial measures for avoiding the pollution.

20.3 NATURAL HAZARDS

Natural hazards cause significant loss of property and life. Some of them discussed here are volcanoes, earthquakes, Landslides, Subsidence and Swelling. These cannot be avoided, but steps can be taken to protect human life, since saving property is difficult.

20.3.1 Volcanoes

Volcano is a vent or fissure in the surface of earth through which magma and associated gases and ash comes out. Lava is a molten form of magma. Magma is a naturally occurring mobile rock material generated within the earth. The volcanic products are classified as gaseous (fumes like H_2O , SO_2 , CO_2 , HCl , H_2S , He etc) solids (dust, ash, cinder, flocks, bombs etc) liquids (lava).

Volcanic products affect environment around the active volcano. Volcanic hazards are due to lava flows, ash, gases, etc. Volcanic eruption also causes earthquakes, floods, landslides, etc. Lava flows can be avoided by landuse planning and also this will be detected by scientific equipment in the active areas, enables to clear the people in the possible lava flow directions. Evacuation based on prediction will reduce human loss but property loss is must. Bombing the volcanic vent before eruption controls volcanic ash hazard. Volcanic gases like H_2O , SO_2 , CO_2 , H_2S etc can be controlled by drilling out these gases from volcanoes. Soil formed with volcanic ash and dust is more productive in nature. Prediction of volcanic eruption is possible by continuous study with help of modern equipment like seismographs, geodetic surveys, tiltmeters, remote sensing, gas analysis, etc.

20.3.2 Earthquakes

Earthquake is a vibration or oscillation of the surface of the earth for a few seconds caused by a transient disturbance of the rocks at or beneath the surface. Seismology is the science of earthquake and related phenomena. Earthquakes are mainly due to release of stress from rock masses by natural process or due to man made structures. The natural phenomena are landslides, avalanches, collapse of caverns, volcanic eruptions, etc. Earthquakes with human activity are explosions, dams and reservoirs, mining etc.

The hazards associated with earthquakes are the ground shaking, surface faulting, earthquake induced ground failures and Tsunami. Ground shaking can be avoided by zoning of such areas and construction of lightweight civil constructions. Surface faulting cannot be avoided totally but zoning of such fault zones and suitable precautionary measures in the design of dams, reservoirs, roads, etc will help to avoid large-scale damage. In case of landslides the land use zoning and prevention of excavation are useful to avoid damage. The best way to avoid tsunami is through warning system with communication network like T.V. Radio, etc.

Earth quake prediction can be done with geodetic work, tide gauge observation, continuous observation of crustal movement, seismic activity and seismological method, seismic wave velocity. Geotechniques, gravity survey, radon and helium surveys, animal and bird behavior, water levels.

20.3.3 Landslides, Subsidence, Swelling

Landslides: landslides, subsidence, avalanching are part of environmental disturbances. Generally these will occur along the mountain regions. These types of events are causing damage to nature and mankind.

Hill slopes are the prime areas of landslides. The downward pull of geological materials along the hill slopes is called mass movement. Landslides are mainly due to rapid mass movement. The mountain regions of Nilgiris and Himalayas are the most active areas for landslides. The six important factors for landslides are the (i) effect of slope (ii) effect of rock types (iii) role of earthquakes (iv) role of water (v) role of climate and vegetation and (vi) human activity. Landslides can be classified as creeps, mudflows, slide falls etc. Identification of landslide prone areas can be made by observing the structural and lithological setting, instability of slopes, seismicity of the area, presence of cracks on the ground, falling of trees, etc. Landslides can be controlled by drainage control, retention structures, slope reduction, afforestation, etc. The choice of these methods depends on the factors responsible for landslides.

Subsidence is the failure of the surface materials of the ground in vertically downward direction. This may be due to natural process or artificial causes. Groundwater and geological materials play a vital role in natural process. Removal of material and overloading are the two prime factors for artificial causes of subsidence. Ground subsidence can be prevented by filling the underground with sand, leaving ore pillars in mines and artificial recharge of groundwater.

Swelling is another problem in clay zones. Clay absorbs water rapidly and expands causing swelling and damage to structures. To control swelling clay may be replaced with other types of soils or chemical treatment of clay. Great masses of snow moves then it is called avalanching. This snow movement will occur due to temperature variance, wind velocity and steeper slopes. Construction of structures normal to the slope direction in the upper parts of slopes can control avalanches.

20.4 ATMOSPHERIC POLLUTION

Among all types of damages done to atmosphere by humans, by far the most widespread and most concerned to the life on the planet earth is the greenhouse effect. The presence of carbon dioxide generated by burning of fuels and by various industries has a great impact on the global climate. The amount of CO_2 has been rising steadily at an exponential rate. It lets the sunlight enter the atmosphere, inhibits or prevents the heat rays (infrared) from returning back to the sky and thus causes a warming up of the atmosphere. This is called the greenhouse effect of CO_2 . There is warming up of the earth's surface.

In Polar Regions the increase would be two or three times as much, which would cause rapid melting of the ice caps. Large-scale deforestation has greatly contributed to the rise of CO_2 content in the air. Plants consume a considerable amount of CO_2 to generate oxygen through the process of photosynthesis or carbon assimilation. With less than a third of land left with forest cover, it is inevitable that the atmosphere is beginning to show a steep rise in CO_2 content. Since the oceanic water is also warming up, its capacity to dissolve and hold CO_2 in captivity is also diminishing.

20.4.1 Pollutants in atmosphere

Quality of lower atmosphere has degraded by various human activities mainly over densely populated areas of the industrial nations. The most common types of pollutants are NO_2 , CO_2 , CH_4 , H_2S , Cl_2 , SO_2 and other volatile hydrocarbons and particles of carbon and tiny drops of water called aerosols. The amount of pollutants discharged into atmosphere will cause formation of acid rains and various sources of air pollution.

20.4.2 Harmful effects of atmospheric pollutants

Breathing problems and respiratory ailments are the more serious consequences. For humans in cities both sulfur dioxide and hydrocarbon compounds altered by photochemical reaction to produce H_2SO_4 and other acidic components, irritants to the eyes and respiratory system. Nitrogen dioxide is also an eye and lung irritant when present in sufficient quantity. Photochemical alteration of nitrogen oxides leads to ozone, which acts as irritant in smog and would be lethal if it occurred in large concentrations.

20.5 EXPLOITATION OF RESOURCES AND ITS IMPACT ON THE ENVIRONMENT

Exploitation of resources (Mining) is second only to agriculture as the world's oldest and most important activity. Maximum exploitation of natural resources was, until recently considered as a desirable objective and the attendant pollution of air, water and land was accepted as unavoidable. The onset of industrial revolution demands for raw materials for ever-increasing standards of living, culminated in extensive mining. Thus the criteria of impact of mining on the environment and environmental protection in resource exploitation have become more prominent.

It is not possible to stop mining activities for the sake of keeping the environment intact. The crux of the problem is how to minimize the impact on the ecosystem and still achieve and advance in the industrial development of the nation.

Accidental or deliberate dumping of oil on to the seawaters is known as oil spills. These are toxic to several marine organisms like mollusk, lobsters and crabs. Water birds may also be affected. The occurrence of blowouts is common in the process of exploitation of oil and gas. Blow out is the burst of gas and burning of gas in the atmosphere causing huge flame. The most important environmental impact with gas blew outs will be the acidification of surface water, soils and groundwater.

Exploitation of coal with mining causes natural toll of both environment and the people engaged in coal mining. The environmental problems with coal mining are (i) deforestation and displacement of tribal people. (ii) Land subsidence and underground burning of coal and (iii) solid waste disposal. Burning of coal to generate energy, is releasing pollutants like oxides of sulfur, carbon, nitrogen into the air as well generating lot of ash.

Environmental problems with petroleum are due to exploitation, production refining and transportation. Land is disturbed with drilling, drilling produce brine waste, transportation with shipping generate oil spills. The important air pollutants namely SO_2 , NO_2 , CO , CO_2 etc. are releasing directly and indirectly through burning of petroleum liquids.

Non-conventional energy resources are useful for controlling environmental effects. Solar energy will be obtained from the sun without polluting the ecosystem. Other sources would be geothermal energy, energy from biogas, nuclear energy. Switching over to non-conventional energy resources wherever possible will minimize the atmospheric pollution.

Check Your Progress

- Note: (a) Space is given below for writing your answers.
(b) Compare your answers with the model answers given at the end of this unit.

1. What are the causes of mass movement?

2. What are the environmental problems of coal mining?

20.6 SURFACE WATER POLLUTION

Man is the biggest polluter. His activities have led to the generation of great amounts of pollutants of varied kinds and the introduction of poison in the food chain leading to impairment of health and deterioration in the aesthetic quality of the landscape. Both sewage from domestic and municipalities and effluents from industries are polluting water bodies such as rivers, lakes and the sea.

20.6.1 Types and sources of surface water pollution

In general the surface water pollution may be classified into three types: (a) river water pollution (b) lake water pollution and (c) marine water pollution.

River water pollution: In India, all the major rivers, which meet 85% of the drinking water needs of the country, are polluted. They are heavily loaded with organic wastes, especially animal manure, human excreta, decaying vegetable matter and microorganisms including pathogens. The wastewater produced by industries is characterized by organic and inorganic toxic matter (Pb, Zn, Cr, Cu, Ad, Hg, etc.).

Generally, the dissolved oxygen (DO) in water degrades the wastes and thus, under normal conditions, brings about purification. However, if the quantity of wastes becomes high, the DO is not sufficient and not able to effect biodegradation and purification. The oxygen in water is consumed by the microorganisms feeding on organic pollutant, that is called "Biochemical oxygen demand (BOD)". The higher the number of microorganisms, the greater is the consumption of DO and greater the extent of eutrophication.

Domestic and municipal sewage contain high quantities of phosphate, nitrogenous compounds, potassium and carbon. They serve as fertilizers and stimulate excessive growth of algae and other aquatic weeds that further overburden the river water with pollutants. The result is a further depletion of oxygen from an already oxygen-deficient ecosystem. The death and decay of these weeds make the waters murky and still more polluted.

Mining and ancillary activities also contribute significantly to river pollution, mainly due to rains, which are washing the mine wastes downstream, joining the riverbed. The Tiri stream, which drains the Pb-mines at Zawar (Rajasthan), is polluted for 15 km downstream. The Domodar flowing through the coal-mining belt (Bihar) is one of the very heavily polluted rivers. Not only the industries (fertilizer plants of Sindri and power plants of Bokaro) the coalmines are also contributing pollutants in a big way.

Exposure of fresh rocks due to coal mines initiates weathering, with inevitable oxidation and hydration of such minerals as pyrite, marcasite, siderite, limonite, etc. which produce sulfuric acid and soluble sulfates and oxides causing pollution of water. Similarly at Singrauli coalfields, Uttar Pradesh, the water accumulated in depressions caused by opencast mining and the streams draining the area shows higher contents of Ca, Mg, Na, K, Fe, and Al derived from coal seams and associated rocks. In addition to this, flora and aquatic life was affected.

20.6.2 Lake water Pollution

The waters of ponds, tanks, reservoirs and lakes are not able to revive or purify themselves when their DO is consumed in oxygen-demanding bio-chemical processes which take place due to the influx of organic wastes. The prolific growth due to the presence of phosphate and nitrate nutrients and overcrowding of algae and weeds and their eventual death and decay creates the same situation. The result is the rapid setting of anaerobic conditions. Lack of oxygen and pungent smell of H_2S , a lake suffers eutrophication, resulting in the destruction of its productivity.

The Naini Tal Lake in the Kumaun Himalaya is a well-nourished lake in terms of phosphatic and nitrogenous compounds derived from organic sewage from the many open drains. The contents of these pollutants have been steadily rising. About 0.239 million m^3 of sediments is deposited in the lake at the rate of 0.022 million meter/year. If erosion is not checked, the lake will be completely filled within the near future.

The Dal Lake of Kashmir valley contains more contents of NH_3-N , NO_2-N and phosphate due to inputs of domestic garbage and sewage carrying 16 tones of phosphorous and 365 tones of nitrogen per year. Thus, the fish population has declined following damage and destruction of their spawning and breeding areas.

20.6.3 Marine Water Pollution

The coastal belts of ocean, which yield 90% of the world's marine food, are being increasingly threatened by pollution through sewage discharges, spilling of petroleum from offshore oil wells, tanker wrecks, offshore drilling and various dock operations.

The coastal areas, which supply 80% of the seafood in India, are becoming increasingly polluted by sewage discharged by cities/towns and effluents from the coastal industries. For example, Mumbai dumps 0.40 Km^2 of sewage and 0.095 Km^2 of industrial effluents, every day so that the total pollutant annually added an amount of 50 Km^2 .

Another major cause of seawater pollution is petroleum oils added 2 to 5 million tones annually. About 0.9 million tones of this quantity is derived from offshore exploration and development of seabed mineral resources. Pipeline breaches, tanker accidents and offshore blowouts contribute more than 1.5 million tones. Disposal from engines and machines account for more than 1.5 million tones. The dock basin of Mumbai is yielded 90,000 liters of recoverable waste oil in a year. Similar situation is prevalent in the docks of Chennai and

Visakhapatnam. In the Indian coasts up to the depth of 20m, the petroleum hydrocarbon content is 0.2 to 0.05 ppm in the southern sector and 0.005 to 0.001 ppm in the eastern coast.

The effects of oil pollution on the ecosystem are profound. The concentration of lead (Pb) in the marine waters has increased by a factor of 3 to 5 due to the introduction of lead based petroleum additive. The primary productivity of diatomaceous communities has declined, while the growth of blue-green algae and flagellate has increased. Highly toxic aromatic hydrocarbons are instrumental in causing the death of a number of aquatic organisms, especially the bottom-dwelling shellfishes. Some of the hydrocarbons like the cancer causing benzopyrene have got into the food chain through the fatty tissue of marine organisms. Oil slicks commonly attract sea birds and cause mass mortality by poisoning.

20.7 TREATMENT OF POLLUTED WATERS

Water that is having the chemical and biological contents more than the desirable is polluted. Polluted water should be treated by different methods for removing the unwanted material. In this section water treatment for different wastes is discussed.

20.7.1 Domestic and Industrial organic waste waters

If there is no disease carrying pathogens and toxic elements, the nutrient-rich sewage can be utilized straight away for irrigation. Removal of pathogens and toxic elements would make the wastewater more useful. The biological methods of treatment involves holding the sewage in a tank, pond or ditch for several days so that coarse particulate matters settle down and finer particles coagulate through use of Fe and Al salts or lime and caustic soda. The liquid is then filtered through a mesh screen and allowed to trick down through filters of sand or diatomaceous earth. The filtered liquid fraction is then aerated by passing oxygen, which also removes H_2O and CO_2 . This process stimulates bacterial activity leading to biodegradation of fine or colloidal organic matter left in the liquid. This type of treated liquid can be utilized for all purposes, except drinking purpose. Resort to chlorination inappropriate dosage kills pathogen bacteria. The muck collected from the settling tanks can be used as manure. A complementary process involves symbiotic activity of algae and bacteria in the presence of sunlight, free oxygen and nutrients present in the wastewater. The prolific algal growth consumes CO_2 and excess pollutants (nutrients - phosphorous and nitrates) and release abundant oxygen. The result is the cleaning of the wastewater.

20.7.2 Toxic wastes

Industrial effluents rich in the toxic elements including pesticides and detergents, are subjected to physico-chemical treatment-adsorption on activated carbon, neutralization, thermal reduction and ion exchange. Intense nuclear radicals in water estimates trace organic and inorganic pollutants including pesticides and pathogens. Water hyacinth, which doubles its biomass every eight days and today covers 25-40% of the water courses in India, is capable of clearing up metals by absorbing Cd, Ni, Cr, Zn, Cu, Fe present within the waste water. The weed can be used for generating biogas and for making cement boards and paper.

20.8 SOLID WASTE DISPOSAL -- ENVIRONMENTAL IMPACT

Rapid urbanization, industrialization, green revolution with fertilizers and pesticides in agriculture brought many problems to environment. Gas and liquid effluents and solid waste are the refuse of industries and domestic waste.

20.8.1 Municipal Waste

Garbage generated in the domestic routine is mostly of organic substances. It is a common observation that this solid waste is heaped up in the backyards of every home in the villages. Sometimes it is dumped in shallow pits. Cattle are another important factor in village. Cattle feed rejects and dung is usually dumped in separate pits. In towns and cities, the garbage is collected systematically from different centers and carried to a far-off place in the outskirts. In urban areas, the solid waste includes not only the garbage from the domestic and market places but also all kinds of refuse from shops and minor industries, which include some inorganic materials and also demolished construction materials. Usually, the solid waste is thrown on the open ground as a dump.

20.8.2 Ground water pollution

Groundwater is said to be pure as it is filtered when percolating through soils and geological formations. But the rainwater when infiltrating through the same formations from the surface dissolves certain chemical compounds including gases modifies its composition from place to place depending on the nature of formation it is traversing. Water is a powerful solvent. It dissolves certain organic and inorganic substances as it comes in contact with them.

Garbage and other solid wastes mentioned above become sources of groundwater contamination. When, the rainwater falls on these dumps of surface water passes through it, dissolves certain organic and inorganic compounds and become a leachate. The leachate infiltrates through the soil zone and the geological formation below and reaches the groundwater body. The leachate contains high range of total dissolved solids (TDS), alkalinity, hardness and nitrates. Iron, manganese and trace elements are also added. Gases such as methane, carbon dioxide ammonia and hydrogen sulfide generated in the landfills are dissolved in the leachates. The composition of leachate, however, depends on the nature of the materials dumped.

The leachate with high concentrations of chemical constituents forms a plume in the groundwater body. It spreads in the direction of flow. It is diluted as it moves away from the source point. This is due to dispersion and absorption of certain chemical constituents in the aquifer materials. The size of the plume depends on the leachate produced from a solid waste. This in turn depends on the area of spread of the dumps, nature of the soils and more important the amount of water passing through it. If the surface or geological formations are porous and permeable, the leachate infiltrates with less resistance. If they are impermeable, the leachate would go only as a surface flow and it may join the nearby surface water bodies or infiltrate from another area where the permeability is favorable. The problem is severe in humid areas of high rainfall. In arid zones with scanty rainfall, the little or no groundwater recharge and very deep water table, there may not be groundwater contamination from solid waste dumps.

20.8.3 Sanitary landfills

The solid waste should be subjected to land burial in shallow excavations either above water table (upper surface of zone of saturation) or extending below, which is called Landfill. It is covered on the surface with compacted clay cap, so that it is not exposed to atmosphere.

Sanitary landfill is constructed according to engineering specifications to minimize damage to the environment. Ideal location for landfill is the area with deep water table condition so that the trench or pit can be made in the vadose zone. The leachate when passes through this zone

undergoes natural attenuation due to ion exchange and adsorption in the soil. Clayey formation is more suitable as it has the maximum attenuation capacity. Formation of leachate can be avoided or minimized if the land fill is covered on the surface with a layer of about one meter thick compact clay cap or a polyethylene sheet. This avoids entry of rainwater. Secondly it protects from air pollution. It also gives an aesthetic look.

Such landfills, however, cannot control leachate and the groundwater contamination below effectively. Providing lining also on the sides and bottom of the trench can minimize groundwater pollution. The liner is a compact clay soil of 1 to 3 m thick. At the bottom, a layer of sand or gravel is provided studded with perforated pipes. The leachate, which accumulates at the bottom, is drained out through these pipes and treated. Still it is possible that 10 to 30 percent of the leachate may seep through the clay layer. A secondary liner is also provided with polythene sheet below the clay layer. At the bottom again another sand layer with drainpipes is arranged to remove such leakage of leachate.

20.8.4 Site selection for landfill

Municipal wastes should be disposed as far as possible in sanitary landfills. The landfills should be located far away from the towns where there is no scope for the expansion of the town. If available, it may be located in and around a place, which has already undergone environmental degradation. Other wise, the site should have ideal hydro geological situation. An elevated place is preferable so that rainfall or running water will have limited contact with the landfill. Water table should be deep. Clays or clayey soils and hard rock terrain, are ideal. Basically, the area should provide little scope to form a leachate from the landfill and secondly there should be restricted infiltration to the deeper layers. A good site is one that satisfies maximum of these conditions.

20.8.5 Radioactive waste

Radioactive waste disposal is very problematic since it is a refuse of highest health hazard not by simple contact with air or ground but by mere presence in an area even covered. The hazard is by radiation that can penetrate any solid substance except certain materials like lead. Therefore it requires special chambers or cells constructed with highest scientific technology that can store the refuse for hundreds of years. Radioactive waste is generated by fission a process adopted in Nuclear Power Plants. About 99% of the uranium used in the fusion come out as radioactive waste, which is a slurry consisting of solid, liquid and gas. It contains dangerous radioactive substances with half-life of a few hundred years or even thousands of years. The refuse therefore should be sealed without having any contact with the environment i.e., air, water and earth for such a long time when the radioactivity completely decays and becomes non-hazardous.

In India, low and intermediate level radioactive wastes are stored in concrete lined containers and kept in shallow land depositories with concrete walls. The high level wastes are vitrified in borosilicate glass or synthetic rock and then stored in concrete encased steel tanks. These containers are stored for 20 years or more in deep underground and finally disposed in salt beds or underground salt mines. Generally, the surroundings of such storage places are monitored continuously in air and groundwater for any leakages either in the form of gases or leachate.

Check Your Progress

Note: (a) Space is given below to write your answers.

(b) Compare your answers with the model answers given at the end of this unit.

3. Oil spillage generally occurs and spreads easily in which environment?

4. What is sanitary landfill?

20.9 GROUNDWATER AND HUMAN HEALTH

Groundwater to be used for drinking and domestic purpose should be free from the undesirable physical parameters such as color, odour and taste; temperature and turbidity. pH has no direct effect on the human health. However, all biochemical reactions are sensitive to the variation of pH. For most reactions as well as for human beings, pH value of 7 is considered to be the best and most ideal. The limit for pH value for drinking use is, however, specified at 6.5 to 8.5.

The total hardness (TH) of water is characterized by content of Ca or Mg or both. The contents of Ca and Mg in potable water ranges from 75-200 mg/l and 30-100 mg/l respectively. The safe limit of TH in water is 300 mg/l. The excess TH in water is therefore undesirable. It causes more consumption of soap, affects the working of drying system, produces scales on boilers, causes corrosion and incrustation of pipes and makes food tasteless.

The content of chlorine imparts salty taste to water. For people, who are not accustomed to high Cl in water are subjected to laxative effect. For drinking water, the highest desirable level of Cl is 250 mg/l.

The Na concentration in drinking water should not be more than 200 mg/l. Otherwise, it causes hypertension. Na and Mg sulphate salts exert a cathartic action on human beings. It is also associated with respiratory diseases. Thus, the recommended content of SO_4 in potable water is limited to 150-400 mg/l.

The concentration of nitrate in groundwater should not exceed 45 mg/l. High levels in drinking water have been reported to responsible for prevalence of methemoglobinemia or blue baby syndrome in infants.

The fluoride content is important in human nutrition for the normal development of bones. Hence, it should not exceed 1.2 mg/l in potable water. The content of F with less than 0.6 mg/l indicate the desirability of fluoridation of the water supplied to prevent the dental decay. If it is in excess of 1.2 mg/l, it will cause serious dental disorder, i.e., bone fluorosis.

Excess fluorine in water is removed by defluoridation methods. There are many methods to remove F in water. They are (i) activated carbon (ii) lime soda (iii) calcium phosphate (iv) bone charcoal (v) synthetic tricalcium phosphate and (iv) filter beds containing F retaining materials.

20.10 SUMMARY

Environmental geoscience is of importance in preserving the natural environment, conserving the earth's resources, coping with geological hazards and participating in technological development with disturbing the ecological balance. Natural hazards are those occurrences brought about by the forces of nature that cause discomfort, injury or death to life, damage or destroy the physical structures and property. The major geological hazards are volcanoes, earthquakes, and landslides.

Natural resources are minerals, fuels and water. The process of extraction of these resources, its usage and dumping of waste from such resources is largely affecting the environment. Water resources are the essential requirement to life. Water occurs on the surface of earth in the form of rivers, lakes etc. and in the subsurface as groundwater. Occurrence of groundwater depends on the nature of geological formations. The withdrawal of groundwater causes depletion of water resources, lowering of water level and seawater intrusion. The discharge must be maintained based on the recharge of the system; otherwise the environmental problems will develop. The overdraft may also cause the subsidence of the loosely consolidated sediments.

Environment gets pollution mainly with the activities of man. Both domestic and industrial wastes are polluting water. The urban and rural communities are generating large quantities of polluted water everyday. Water pollution is classified as river water pollution, lake-water pollution and marine water pollution. The river waters are mainly loaded with animal manure, human excreta, decaying vegetable matter, pathogens, etc. mining and ancillary activities also contributes, significant pollution to river waters. The waters of lakes, ponds, tanks are also polluted by municipal, domestic and industrial waste. Lake water pollution is not possible to purify naturally, whereas river water pollution can be purified to certain extent naturally.

The water required for public supply should be potable. It is however not essential to have physically or chemically pure. The presence of some minerals are essential to get taste and for easy assimilation of food materials. If the dissolved salts are more than the required concentrations, then the water requires treatment process. Treatment process involves sedimentation, coagulation, filtration, disinfecting, chlorinating, water softening, etc.

20.11 CHECK YOUR PROGRESS - MODEL ANSWERS

1. The causes of mass movement are
1) the effect of slopes 2) type of earth material 3) climate and vegetation 4) water 5) earthquakes and 6) human activity.

2. The environmental problems with coal mining are (i) deforestation and displacement of tribal people. (ii) Land subsidence and underground burning of coal and (iii) solid waste disposal.
3. Marine environment.
4. The solid waste should be subjected to land burial in shallow excavations either above water table or extending below are called sanitary landfills.

20.12 MODEL EXAMINATION QUESTIONS

I. Explain the following in 30 lines each.

1. Describe the impact of groundwater quality on human health.
2. Explain the sources of marine water pollution.
3. What different types of solid wastes, what is their impact on environment.
4. Discuss the impact of atleast two natural hazards on the environment.

II. Explain the following in 10 lines each.

1. How natural hazards are parts of environmental geosciences?
2. Describe the impact of CO₂ on global climate with reference to greenhouse effect.
3. What is the effect of atmospheric pollutants on human health?
4. What is a sanitary landfill, how they affect the groundwater?

BLOCK – VI ADVANCED ASPECTS OF GEOLOGY – II

BRAOU

UNIT: 21 REMOTE SENSING AND GIS PRINCIPLES

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21.0 OBJECTIVES

In this chapter, the principles of Remote Sensing and Geographical Information System (GIS) are described.

After studying this chapter, you will be able to

- explain how remote sensing data is acquired by satellite sensing systems and the physics behind the data acquisition
- describe the orbital characteristics of satellites and sensor characteristics of sensors.
- define and describe the conceptual design of GIS

21.1 INTRODUCTION

The application of spatial information products, derived from remote sensing satellite, to various areas of management, planning and development has been highly rewarding. These areas include environmental impact assessment, water resources assessment and management, watershed management and planning, infrastructure development, land use planning and land cover management, ocean resources management, urban and regional planning, and

transportation planning. The use of Remote Sensing and Geographical Information System (GIS) technology has opened the door for immense opportunity in large-scale mapping, updating of existing maps, project planning and decision-making. This phenomenal growth in the field of Remote Sensing and GIS is due to the successful launching of a series of state-of-art satellites.

21.2. REMOTE SENSING PHYSICS

Remote sensing is defined as an art, science and technology of obtaining reliable information about an object, environment and any phenomenon by recording and measuring electromagnetic energy through a device which is not in touch with the object, environment and any phenomenon. Broadly, there are two types of remote sensing, namely, passive and active remote sensing.

In passive remote sensing the source of radiation is sun, i.e. solar radiation. The camera without flash is a form of passive remote sensor. Landsat of USA and IRS are examples of passive remotes. In active remote sensing, the sensor sends its own energy to illuminate the object and the reflected energy will be recorded by itself. A camera with flash can be considered as active sensor. The classical example of this type is Radar (radio detection and ranging). Since the source of energy in passive remote sensing is sun's radiation or electromagnetic energy, this remote sensing is called as electromagnetic remote sensing. In this unit, the basic components of electromagnetic remote sensing are discussed and these components can be seen in fig.21.1.

Broadly, remote sensing can be explained by means of three processes: (i) Data acquisition (ii) Data Analysis and (iii) Reference data / ground truth data analysis.

Fundamentally, the data acquisition process of electromagnetic remote sensing consists, of fine components, namely,

- (i) Source of electromagnetic radiation
- (ii) Transmission of energy through atmosphere and energy interactions with atmosphere
- (iii) Energy interaction with earth surface features
- (iv) Retransmission of energy through atmosphere
- (v) Sensing systems to receive, record and measure the electromagnetic radiation reflected from the earth surface features.

The analysis of remote sensing data is performed in two ways (Fig. 21.2) based on the natural and type of the data. Two types of data products are available: pictorial data and digital data. The pictorial data is analysed using visual image processing (VIP) techniques where as the digital data can be analysed using digital image processing (DIP) techniques with the help of computers.

There are number of digital image processing software like ERDAS, EASI/PACE, ENVI and IDRISI for digital data analysis. The third type of process is ground truth data analysis, the results of which can be used as an aid to the data analysis and for validation of the results of analysis for both VIP and DIP. The output of VIP and DIP are thematic maps and each thematic map can be considered as one layer which is input to GIS. To understand the data acquisition process, it is necessary to understand the electromagnetic spectrum and nature of radiation.

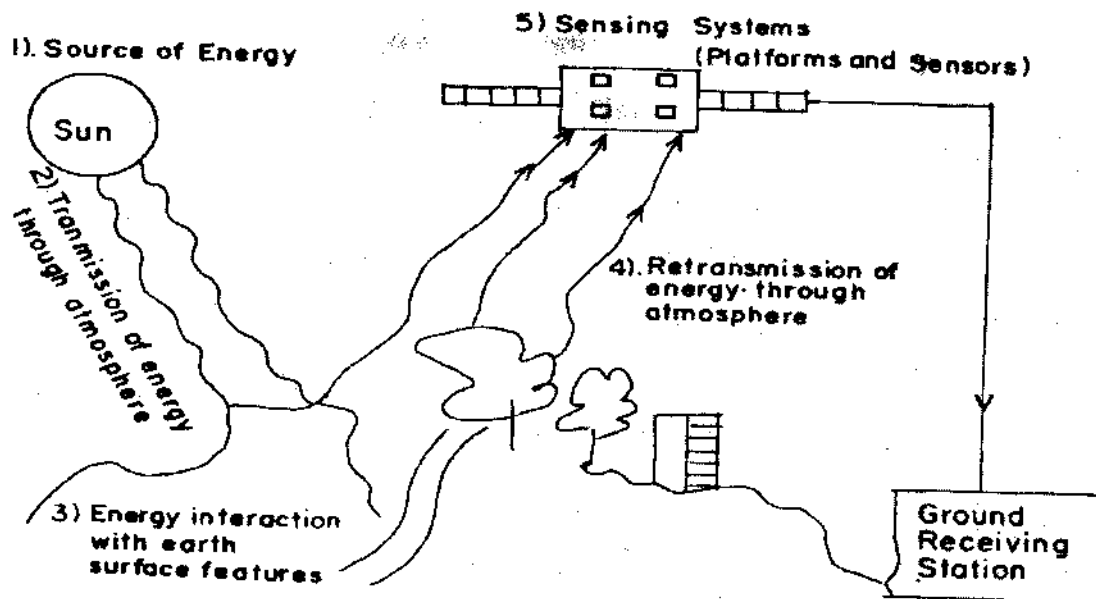


Fig. 21. 1 Components of Remote Sensing data Acquisition

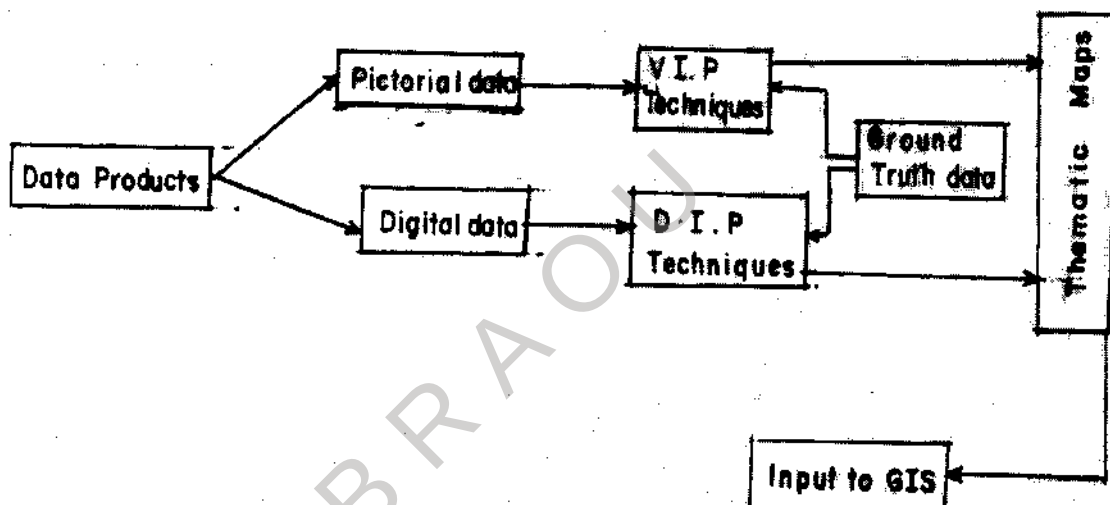


Fig. 21. 2 Components of Remote Sensing data Analysis

21.2.1 Electromagnetic Spectrum

Visible light is the only one of many forms of electromagnetic energy. Radio waves, heat, X-rays, and other familiar forms of energy are inherently similar and radiate in accordance with basic principles of wave theory. This theory described electromagnetic energy propagation in a harmonic, sinusoidal fashion (Fig. 21.3) at the velocity of light (C). The distance from one wave peak to the next is wavelength (λ) and the number of peaks passing a fixed point in space per unit time is the wave frequency (f). The wave theory obeys the following equation.

$$C = f\lambda \text{ ----- (1)}$$

Where

$$C = \text{constant } (3 \times 10^8 \text{ m/sec})$$

In remote sensing, it is most common to categorise Electro Magnetic (M) waves by their wave length location with EM spectrum. The unit used to measure wavelength along the spectrum is the micrometer (μm). A micrometer equals to $1 \times 10^{-6} \text{ m}$.

For our convenience, EM spectrum is assigned into different regions but no clear cut dividing line between one region to the next is possible. It should be noted that the portions of EM spectrum used in remote sensing lie along a continuum characterised by magnitude changes of many powers of 10.

The visible portion of EM spectrum is very small and it extends from about 0.4 to 0.7 μm . To the right side of the visible range lies reflected, infra-red, thermal infrared, microwave, television and radio-waves. On the other hand, to the left of the EM spectrum lies visible range ultra-violet, X-rays, γ -rays and cosmic rays (Fig 21.4).

The important distinction between reflected infrared and thermal infrared energy is that the thermal infrared energy is directly related to the sensation of heat but reflected infrared is not so.

In EM spectrum, another theory generally used to provide useful insights about EM energy is the interaction of matter. This theory is known as particle theory. It suggests that EMR comprises of many discrete units called photons or quanta and is expressed as

$$E = hf \text{ -----(2)}$$

Where

E = Energy of a quantum, Joules (J)

h = Planck's constant (6.626×10^{-34} J sec)

By relating the wave theory expression (1) and particle theory expression (2) and by substituting equation (1) into equation (2), the following is obtained.

$$E = hc / \gamma$$

The above equation demonstrates that the energy of a quantum is inversely proportional to its wavelength. The longer the wavelength involved the lower the energy content. The important application in remote sensing point of view is that the naturally emitted long wave length radiation (micro-wave emissions) of terrain features is more difficult to sense, than the radiation in shorter wave lengths (thermal, infra-red, etc.).

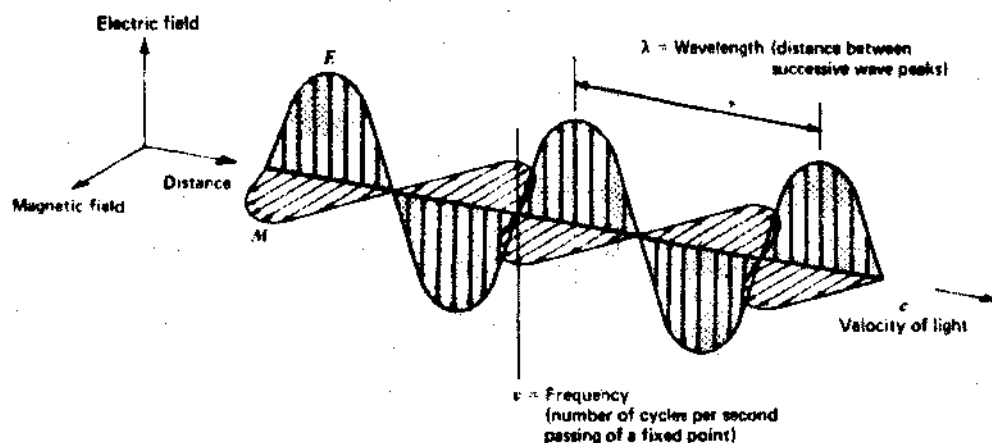


Fig. 21. 3 Showing electromagnetic wave propagation

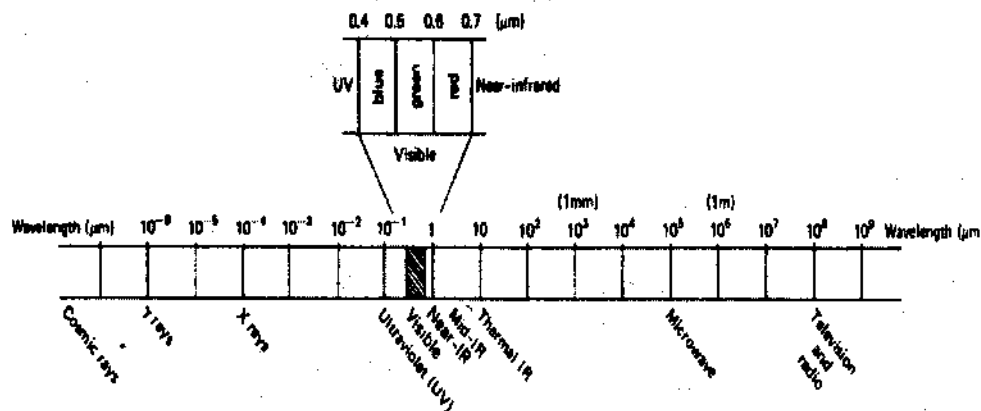


Fig. 21. 4 Showing the electromagnetic spectrum

21.2.2 Source of electromagnetic radiation

The EMR is generated whenever the size or direction of an electric or magnetic field fluctuates with time. The γ -ray radiation resulting due to disruption of atomic nuclei during nuclear fission or fusion and have shortest wavelengths in the electromagnetic spectrum. The x-rays, ultra-violet and visible range radiation is resulting in due to electron-shifts of the particles. The infrared and microwave radiation is resulting due to vibration and rotation of molecules. In nature all of these processes are related to temperature of emitting radiation which is generally above the absolute zero (-273.15°C). The 0°C is expressed as 273.15 K (Kelvin). Matter is capable of absorbing and remitting all EM energy, which it receives, is called blackbody. The total energy emitted by a black body is expressed as given below and it is known as Stefan-Boltzman law.

$$M = \sigma T^4$$

Where

M = Total of radiation per unit Wm^{-2}

T = absolute temperature

σ = Stefan-Boltzman constant ($5.7 \times 10^{-8} \text{ Wm}^{-2}, \text{K}^{-4}$)

At any particular temperature, a black body emits EMR with a range of wavelengths. However, its absolute temperature determines which wavelength transmits the maximum energy and is expressed by Wein's displacement law and is given as below.

$$\lambda_m = A/T$$

Where

λ_m = dominant wavelength at which the emittance is more

T = Temperature

A = Wein's constant = 2898

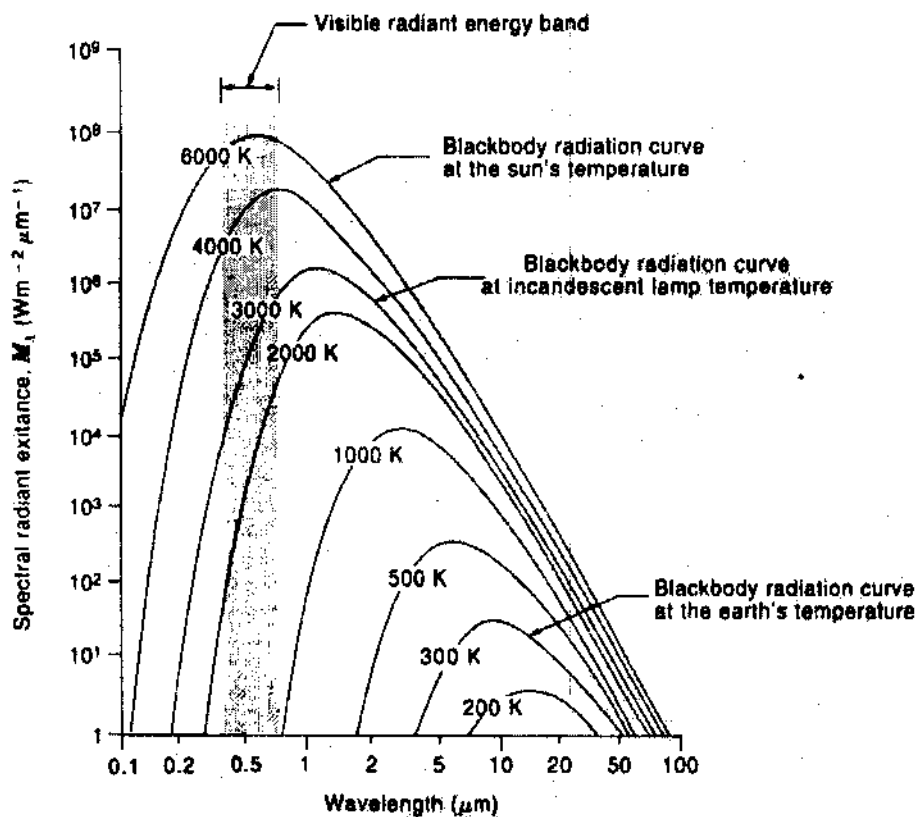


Fig. 21. 5 Showing spectral distribution of energy radiated from blackbodies at various temperatures.

The Wein's displacement law suggests that as the temperature increases, the total energy emitted rises rapidly and the wavelengths carrying becomes shorter. Thus a black body at 6000K, the surface temperature of the sun does not emit radiation with wavelengths shorter than 0.1 μm (Fig.21.5).

21.2.3 Energy interaction with atmosphere

The whole range of EM spectrum is available to the remote sensing detectors but only a few bands will be detected due to atmospheric effects. This radiation has to pass through the atmosphere and then back to the sensors mounted in the satellite. These effects are caused atmospheric scattering and absorption.

Many remote sensing sensors generally do not show the coverage of blue sky. This is caused by one of a number of phenomena resulting from diffusion of radiation and called scattering. When EMR interacts with particles smaller than its wavelength, then the degree of scattering is inversely proportional to the fourth power of wavelength and is known as Raleigh scattering e.g. molecules of oxygen and nitrogen etc. Because of this reason, many sensors omit the coverage of blue sky in remote sensing. The same can be achieved in panchromatic images using yellow filter. When the atmospheric particles are similar size to the wavelength of incoming radiation is called mie-scattering. Example-molecules of water and dust. The atmospheric absorption results in the effective loss of energy to atmospheric constituents. The main absorption of solar radiation in this regard is water vapour, carbon-di-oxide and ozone. The absorbance of EM energy in the atmosphere is restricted to specific wavelength bands. The waveband that passes relatively undiminished through the atmosphere is referred to as

atmospheric windows. The emitted heat energy from the earth is sensed through the atmospheric windows at 3 to 5 μm and 8-14 μm . The multispectral scanners sense simultaneously at various wave length bands in the visible through thermal spectral scanners. On the other hand, Radar is operated through a window in the range of 1 mm to 1 metre.

21.2.4 Energy Interaction with Earth Surface Features

The energy detected by remote sensing over a spectrum of EMR is partitioned between its source and the materials with which it interacts on its way to the detector (sensor). There are three kinds of spectra, which can be measured for any material. These are 1) absorption 2) reflection and 3) emissions (Fig. 21.6). An absorption or transmission spectrum is produced when the material is interposed between source and sensor. A reflected spectrum is measured when both the source and the detector are on the same side of the material. Lastly the material itself is the source for the emission spectrum. Applying the principle of conservation of energy the interrelationship of these three energy interaction are shown as

$$E_i(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda)$$

Where

E_i = Incident energy

E_R = Reflected energy

E_T = Transmitted energy

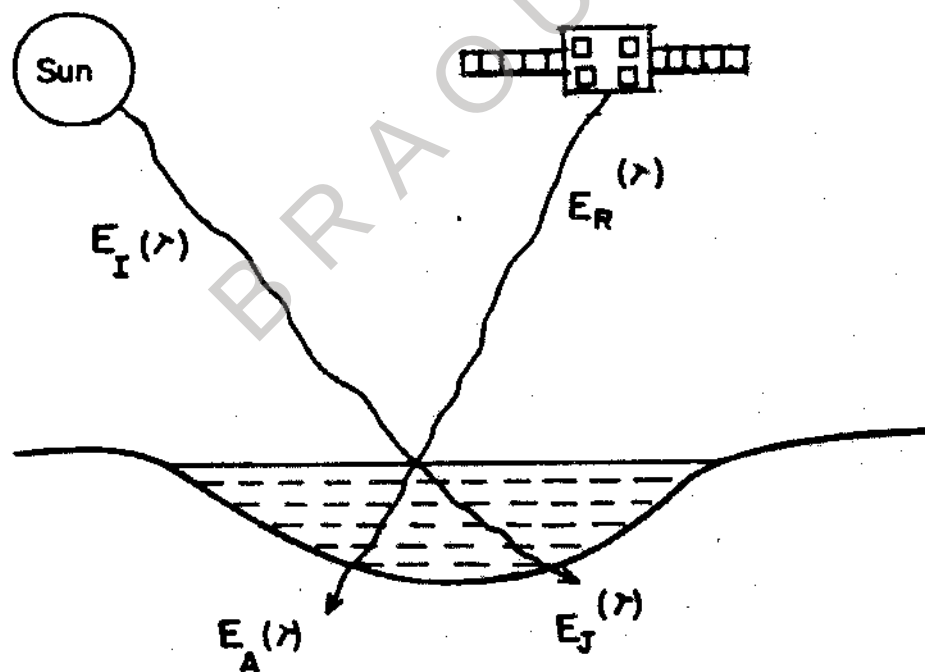


Fig. 21. 6 Energy interactions with Earth surface features

In the above cited energy balance equation, the energy reflected, absorbed and transmitted will vary for different features depending upon the material type and condition. Further, the different wave length bands depends on the basis of the surface features.

very recent satellite with high resolution than other existing satellites. The revisit time will be more frequent for higher latitudes and less frequent for latitude closer to the equator. The spatial resolution of IKONOS satellite data is 1 m x m, which is very powerful, and useful data for urban and other studies.

Check Your Progress

- Note: (a) Write your answers in the space given below.
(b) Compare your answers with the model answers given at the end of this unit.

1. What is Remote Sensing?

2. Name any two satellites.

21.5 GEOGRAPHICAL INFORMATION SYSTEM (GIS)

To answer apparently simple geographical questions like: What is the population of a particular city? What are the characteristics of the soils in a particular land? Are there any trends in the patterns of earthquakes in India which could help to predict future quakes? How has the distribution of urban and rural population changed between the past two censuses? All these questions are pertinent and require the proper and accurate data derived from several sources, and are integrated into a consistent form. The art of science, engineering and technology required to answer these geographical questions constitute the Geographical Information System (GIS). GIS is a generic term denoting the use of computers to create and depict digital representations of the Earth's surface. GIS is defined as computer based information system to store, retrieve, analyse, manipulate and display spatial information.

21.5.1 Overview of Information System

GIS might provide the medium for studying one or more of the fundamental issues that arise in using digital information technology to examine the surface of the earth or any related systems. The Resource Information System (RIS) for agricultural management, for instance, has to be considered multidimensional with attribute dimension, spatial dimension and temporal dimension. Geographic Information System (GIS) offers capabilities of integrating

multisector, multilevel and multi-period database and is a general-purpose technology for handling geographic data in digital form, and satisfying the following specific needs, among others:

- (i) The ability to pre-process data from large stores into a form suitable for analysis including operations such as reformatting, change of projection, resampling, and generalisation.
- (ii) Direct support for analysis and modelling, so that form of analysis, calibrations of models, forecasting, and prediction is all handled through instructions to the GIS.
- (iii) Post processing of results including such operations as reformatting, tabulation, report generation, and mapping.

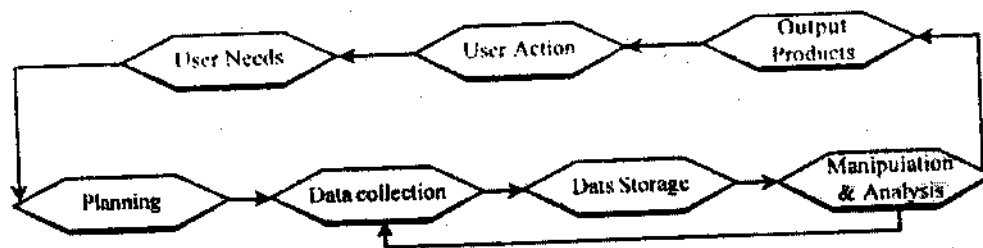


Fig21.8 Simplified information system overview

In all these operations, the typical GIS user now expects to be able to define requirements and interact with the system through a "user-friendly" intuitive interface icons and desktop metaphors. The function of an information system is to improve one's ability to make decisions. An information system is the chain of operations that takes us from planning the observation and collection of data, to storage and analysis of the data, and to the use of the derived information in some decision-making process. This brings us to an important concept that a map is kind of information system. A map is a collection of stored, analysed data, and the information derived from this collection is used in making decisions. Fig21.8 shows the simplified information system overview.

21.5.2 The Four Ms

There are four key activities that any urban planners or scientists or resource managers and others use geographic information for. They observe and measure environmental parameters and develop maps, which portray characteristics of the earth. They monitor changes in our surroundings in space and time. In addition, they model alternatives of actions and process operation in the environment. These, four activities are Measurement, Mapping, Monitoring and Modelling termed as key activities which can be enhanced by the using information systems technologies through GIS. Fig 21.9 explains these four Ms.

GIS technology is more different from traditional mapping and map analysis. GIS is based on a mathematical framework of primitive map analysis operations analogous to those of traditional statistics and algebra. From this perspective, GIS forms a toolbox for processing maps and fundamental concepts for spatial measurement. It provides a foundation for advanced analytic operations involving spatial analysis and measurement. Most of GISs contain analytic capabilities for reclassifying and overlaying maps. Any GIS system for the measurement of areas, distances, angles and so on requires two components, namely, a standard measurement unit and a measurement procedure.

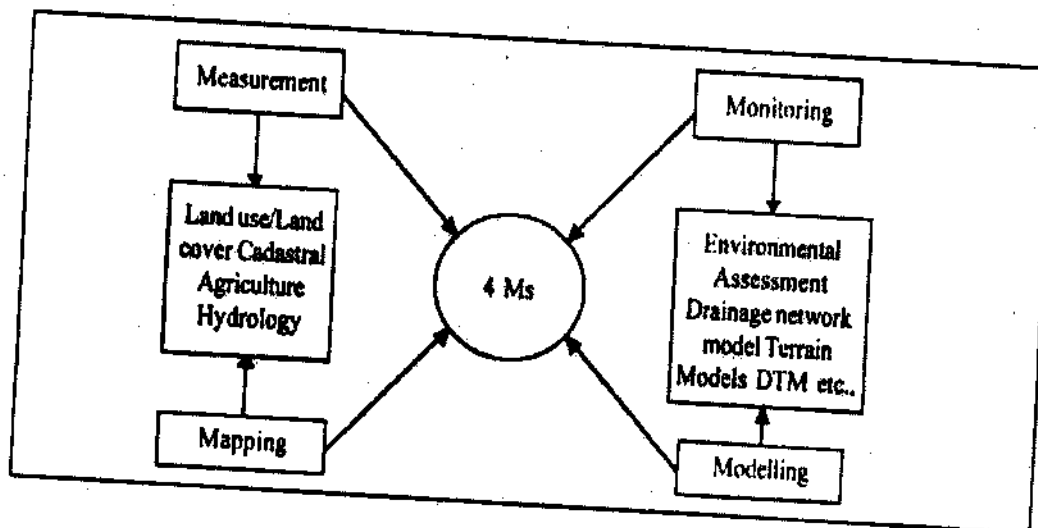


Fig.21.9 Schematic representation of Four Ms: Measurement, Mapping, Monitoring and Modelling.

Another major function of GIS capability is the study of environmental surroundings and the monitoring of environmental parameters (Burrough et al, 1988). Although analytical models have been linked to GIS for spatial measurement and resource assessment, the cross fertilisation between the modules of modelling, measurement and automated mapping allows the GIS user to monitor the environment and the earth systems.

In principle, it is possible to make a clear distinction between GIS and digital cartography. Mapping technology or digital cartography deals with map features and with associated attributes of colour, symbology, and name of annotation, legends, neatlines and north arrows. GIS includes the capabilities for storing, editing, and handling the relationships of attributes with their spatial entities along with the capabilities of digital cartography. A map, an ultimate product of digital cartography or GIS, is a very persuasive form of data display and a computer drawn map carries the authority of a powerful technology.

GIS applications now span a wide range, from sophisticated analysis and modelling of spatial data to simple inventory and management. They also dictate the development directions of much of the industry. However, several vendors have chosen to concentrate on the niche market for environmental applications and to emphasise support for environmental modelling. GRASS is a significant public domain GIS software developed by USA with substantial capabilities for modelling.

21.5.3 Contribution Disciplines

GIS is convergence of technological fields and traditional disciplines. GIS has been called an "enabling technology" because of the potential it offers for the wide variety of disciplines dealing with spatial data. Many related fields of study provide techniques, which make up GIS. These related fields emphasise data collections while GIS brings them together by emphasising integration, modelling and analysis. Thus GIS often claims to be the science of spatial information. Fig.21.10 shows the technical and conceptual development of GIS. The contributing disciplines for the evolution of a GIS are geography, cartography, remote sensing, surveying and photogrammetry, computer science technology, mathematics, and statistics.

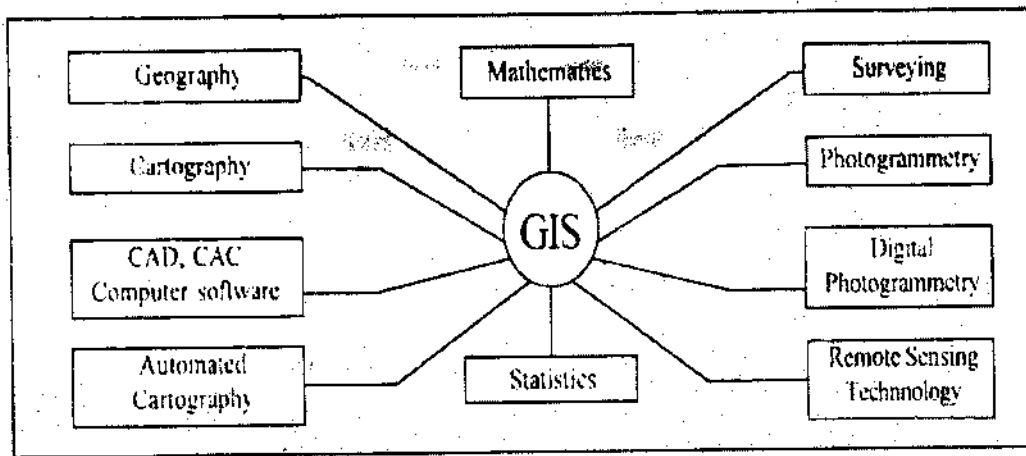


Fig. 21.10 GIS: the result of linking parallel developments in many separate spatial data processing disciplines.

Geography is broadly concerned with understanding the world and man's place in it. Geography has a long tradition in spatial analysis, and provides techniques for conducting spatial and a spatial perspective on research. Cartography is concerned with display of spatial information. It is now the main source of input data for GIS (maps) and has a long tradition in the design of maps, which is an important form of output from GIS.

Remote Sensing is becoming an important source of geographical data by providing digital images derived from space and the air. Remote sensing provides techniques for data acquisition and processing anywhere on the globe at a low cost and consistent update potential. While integrated with GIS, remotely sensed imagery can be merged with other data in a GIS providing real-time spatial information.

Surveying and Photogrammetry provide high quality data on positions of cadastral objects like land parcel and building, and topography. Aerial photogrammetry deals with the photographs taken by an aerial camera on board aircraft at different. Aerial photogrammetry is one of the most powerful data-capturing techniques for the creation of GIS spatial database. The relevant data can be extracted from the aerial photographs of various scales and may be used as input for GIS. Digital orthophotos provide the source of digital data. These products are scanned airphotos that have been rectified to eliminate displacement caused by variable elevation of the ground surface and the tilt of the camera. Properly registered with other digital data sets, these images can be used directly as backdrops for vector data or to provide a basemap for onscreen digitising. The user may abstract information on land use, vegetation type and other aspects of the landscape from the photograph.

Six characteristics of aerial photographs are of immense value as a data source for GIS. They are (i) wide availability (ii) low cost (iii) wide area views, (IV) time -freezing ability, (v) high spectral and spatial resolution and, (VI) three-dimensional perspective.

Computer Assisted Design (CAD) provides software, techniques for data input, display and visualisation, and representation. Particularly in 3-dimensions. Advances in computer graphics provide hardware and software for handling and displaying graphic objects. Data Base Management System (DBMS) contributes methods for representing data in digital form and procedures for system design and update. Artificial intelligence (AI) uses the computer to

make choices based on available data in a way that is seen to enhance the human intelligence and decision-making. Using AI, computer can act as an "expert" in such functions as designing maps, generalising map features and classification-

Several branches of mathematics, especially geometry and graph theory, are used in GIS system design and analysis of spatial data. Statistics is used to build models and perform spatial data analysis in GIS. Statistics is also important in understanding issue of error, quality and uncertainty In GIS data.

Availability of large quantities of spatial data in the form of digital aerial photograph, digital remote sensing imagery, advancement of computer hardware, software and software development, increasing demand of spatial information for management, and infrastructure development parameters, led have a system to handled all these requirement. In order to handle such data to meet these demands, to store, retrieve, handle, analyse, manipulate and display the results it requires computer base system. Such a system is Geographical information system (GIS).

21.5.4 GIS Architecture

According to the definition GIS deals with space-time data, and often but not necessarily, employs computer hardware and software. GIS can be understood as the subsystem nature within the framework of a main system. According to these investigators, GIS has the following generic subsystems:

- (i) A data input subsystem which is also called data capture subsystem
- (ii) A data storage and retrieval subsystem
- (iii) A data manipulation and analysis subsystem
- (iv) A reporting subsystem.

Each of the subsystems has been described in terms of functions that the respective subsystem performs. The data input/capture subsystem provides operational functions for acquiring data. The data management or data storage and retrieval subsystem stores and retrieves the data elements. The manipulation and analysis subsystem handles the transformation of data from one form to another and derivation of information from the data. The fourth subsystem output/reporting subsystem provides away for the user to see the data in the form of diagrams, maps, and/or tables. Fig.21.11 shows the architecture of all subsystems of GIS from a structural perspective.

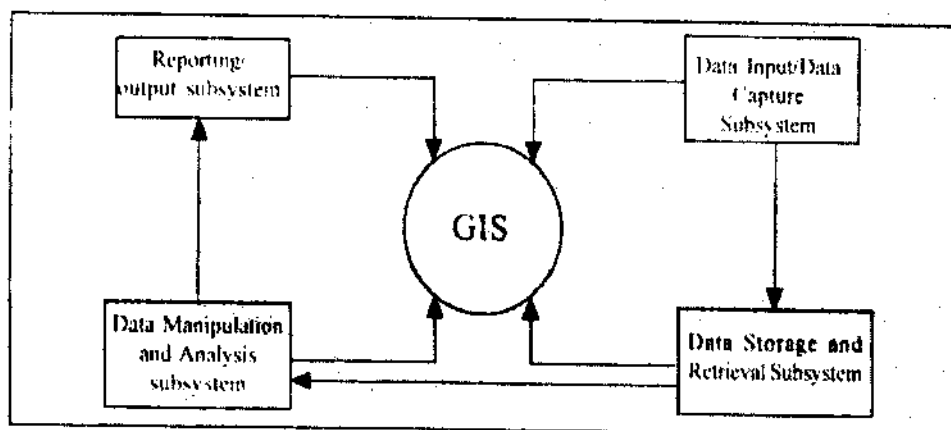


Fig. 21.11 Subsystem nature of GIS (structural perspective).

21.5.5 Components of a GIS

Geographical Information Systems have three important components, namely, computer hardware, sets of application software modules, and a proper organisational set up. These three components need to be in balance if the system is to function satisfactorily. GIS run on the whole spectrum of computer systems ranges from portable personal computers to multi-user supercomputers, and are programmed in a wide variety of software packages. Systems are available that use dedicated and expensive workstations, with monitors and digitising tables built in. In all cases, there are a number of elements that are essential for effective GIS operations. These include

- (i) the presence of a processor with sufficient power to run the software
- (ii) sufficient memory for the storage of large volumes of data
- (iii) a good quality, high resolution colour graphics screen and
- (iv) data input and output devices, like digitisers, scanners, keyboards, printers and plotters.

The general hardware components of a GIS include control-processing unit. Which is linked to mass storage units, such as, hard disk drives and tape drives peripherals such as digitiser or scanner, printer or plotter and Visual Display Unit (VDU). Fig.21.12 shows the major hardware components of a GIS.

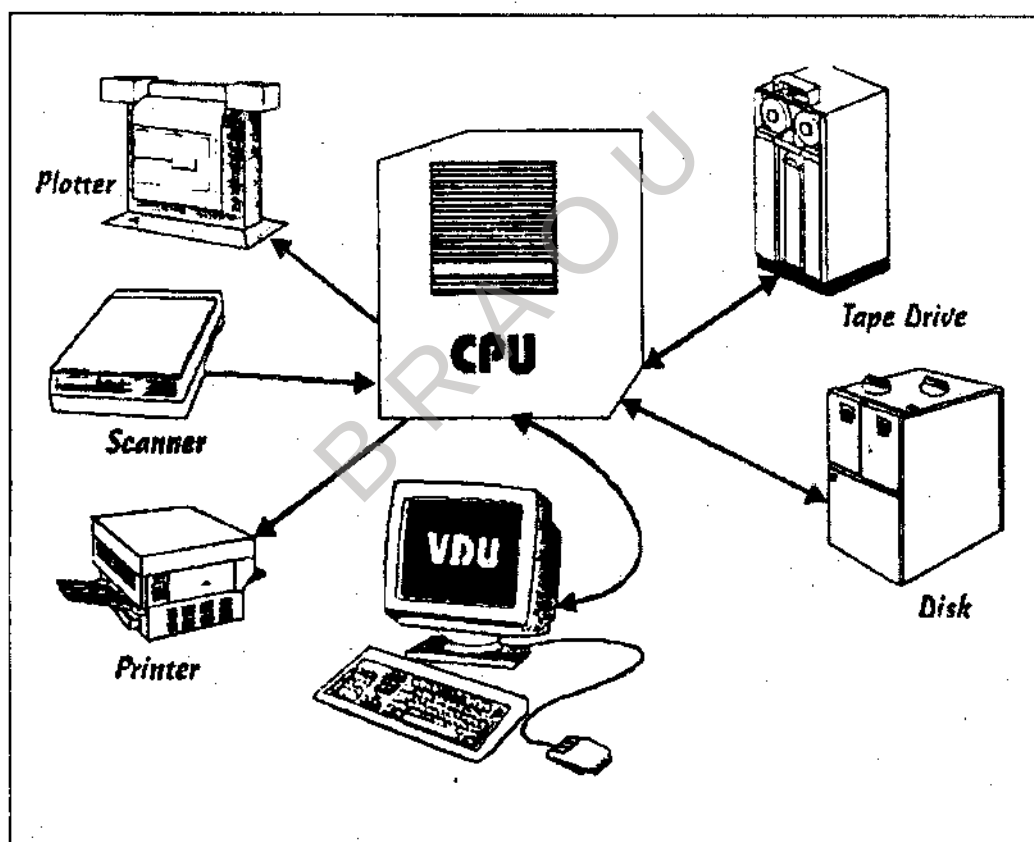


Fig. 21.12 Hardware components of GIS.

There are a number of essential software elements that must allow the user to input, store, manage, transform, analyse and output data. Therefore, the software package for a GIS consists of four basic technical modules. These basic modules are (i) data input and verification, (ii) data storage and database Management, (iii) data transformation and

manipulation, and (iv) data output and presentation. The GIS software package should have the capabilities performing all the four GIS subsystems. The GIS hardware and software govern the way in which geographical information can be processed but they do not themselves guarantee that any particular GIS will be used effectively.

21.5.6 GIS Data Models

Spatial analysis is a technology, which typically requires two types of information about spatial objects: attribute, and geographical or locational information. Given the diversity of analytical perspectives within GIS, it is difficult to define spatial data analysis. The results of such analysis depend upon the spatial arrangement of events. Events may be represented as geographical entities associated with the attributes. This section highlights these two types of information and their relationships. To the query, where the particular object is with respect to any co-ordinate system, the answer is the spatial or geographical or locational information. To the query, what that particular object is, the answer is the attribute data. Alternatively, It can be noted that the GIS consists of two types of data: spatial and attribute.

The spatial data refers to the spatial locational information with respect to a defined co-ordinate system. In GIS, the spatial data may be modelled in the form of vector model or a raster model. The characteristics of these locational features are termed as attributes data. The raster data is grid cell based ways, namely, GRID model, IM-GRID Model and MAP Model. The vector data consists of three k of cartographic symbols, namely, point, line and 0.

'Entities' are things in the real world. 'Objects' are things in the digital world. Digital objects and associated attributes and values represent geographical entities. The distinction between entity and objects makes explicit the difference between things and their representations in a formal system. The entity or the field model is more appropriate and are particularly interesting for topographic elevations. Topographic data normally are represented in GIS as fields, either through grid based digital elevation models (DEMs) or as triangular tessellation. Robinson (1958) identified four kinds of geographical quantities. They are point, line, area, and volume. There are three kinds of cartographic symbols: point, line, and area. Robinson discusses 2-dimensional data on 'Mapping quantitative point, line, and area data', and separates volume data under the title 'Mapping 3-dimensional data'.

The frequency of geographical entities with indistinct boundaries has been known for some time; yet vector GIS is tuned to represent entities with crisp boundaries: whereas raster GIS does not represent entity boundaries at all. Thus, formal methods: for the representation of geographical entities with uncertain or graded boundaries is an important new area of study in GIS. Fuzzy set theory represents a possible approach to modelling entities with graded boundaries, but it has problems. Geographical entities and classification of geographical entities into categories is a well-known process both in everyday thinking and in scientific work. Various sub fields of geography have developed elaborate classifications for landforms, vegetation assemblages, and settlements. In brief, we can note that locational information about the spatial objects of concern is generally described by means of their position on a map or geographical co-ordinate systems.

Attributes: Attributes are the characteristics of the map features and holding of the descriptive information about the geographic features. Attributes are the non-spatial data associated with time and area entities. They are considered characteristics of entity. The GIS attributes are represented using colours, textures, and linear or graphic symbols like the gardens. The parks are shaded green. The church locations are designated using the special

symbol. The bus routes are drawn with specific line width and style as broken lines of 12 point's width. Contour lines are brown in colour, and so on. The actual value of the attribute that has been measured (sampled) and stored in the database is called attribute value. A classical example of attribute data associated with spatial entities of the environs of Hussain Sagar in Hyderabad may tell us that, a point represents a hotel, a line represents the road and area represents the boundaries of the lake. Each spatial entity may have more than one attribute associated with it; that is, a point representing the hotel may have a number of rooms, standard of accommodation and other related information.

Broadly speaking two types of attributes may be distinguished: **primary attributes** and **secondary attributes**. Socio-economic characteristics and physical properties of objects are some of the examples of primary attributes. Flows of Information levels, districts, capitals and mandal names are considered secondary attributes.

Topology: In GIS, topology is the term used to describe the geometric characteristic of objects, which do not change under transformations and are independent of any co-ordinate system. The topological characteristics of an object are also independent of scale of measurement. Topology as it relates to spatial data consists of three elements, namely, adjacency, containment and connectivity. Topology may be defined as constituting those properties of geometrical figures that are invariant under continuous deformation. Broadly topology can be explained any two ways. Firstly, topologically spatial relationships with the entity, which are learned by human beings at a very early age. Secondly, topology consists of metric aspects of spatial relations, such as, size, shape, distance and direction. Many spatial relations between objects are topological in nature, including adjacency, containment and overlap.

Adjacency and containment describe the geometric relationships, which exist between area features. Areas can be described as being adjacent when they share a common boundary. For example, boundary of the area of Municipal Corporation of Hyderabad and Secunderabad is common, or may be adjacent. Containment is an extension of the adjacency that describes area features, which may be wholly contained within another area feature such as an island within a lake. Connectivity is a geometric property used to describe the linkages between line features like road network. The geometric relationship between spatial entities and corresponding attributes are very crucial for spatial analysis and integration in GIS.

In other cases, metric properties, such as, distance or direction, expressed either quantitatively or qualitatively, may determine the meanings of various terms, for example, both 'north of any 'near' normally refine the 'disjoint' topological relation, and are ill-defined for non-disjoint entities. Spatial relations between disjoint entities, which neither touch nor overlap, are characterised by a system of distinctions that is, essentially independent of the system used to describe and classify spatial relations for non-disjoint entities. Some of the spatial relations between disjoint objects are distance, direction, and reference frames.

Distance may be pure Euclidean distance. In natural language 'hedge' words such as 'about' are often associated with approximate numerical distance. Distance may be given in qualitative rather than metric terms, dividing distance into just three categories: 'at', 'near', and 'far'. Direction may be either qualitative or quantitative. Direction is an orientation specified relative to some reference frame. Directional relations are thought of as being between points. Directions are not so straightforward between spatially extended entities, since a large range of directions may exist, between any point in one entity and any point in the other. Reference frames are used in discourse and spatial reasoning. Geographically, in many cultures, a

this, remote sensing and GIS have become very important and have been associated with each other.

This unit focuses upon the importance of remotely sensed data as an input to GIS, and describes some of the ways in which they may be managed for operational use. Key characteristics and source of remotely sensed data commonly employed as input to GIS are described, as key minimum set of GIS facilities required to support the use and effective management of remote sensing data. In short, this chapter is designed to inform managers of the sources and potential of remotely sensed data so that they can discharge their responsibilities for monitoring or operations with maximum effectiveness but at minimum cost.

Remote sensing data can be readily merged with other sources of geo-coded information in a GIS. This permits the overlapping of several layers of information with the remotely sensed data, and the application of a virtually unlimited number of forms of data analysis. On the one hand, the data in a GIS might be used to aid in image classification; on the other hand, the land cover data generated by a classification (through VIP and DIP) might be used in subsequent queries and manipulations of the GIS database. Remotely sensed data is almost always processed and stored in raster data structures. When working simultaneously with an Image processing system and raster geographic information system, it is usually easy to move data between the two. Typically, a single theme of information is extracted from the remotely sensed data. The combination of image processing and GIS technologies is astounding. As indicated earlier, they both are coming closer and it is now becoming extremely difficult to differentiate each other. The hardware was almost similar, and now software is being integrated. The problem of transfer of data is also being circumvented. Private companies are combining their efforts in this direction.

22.2 REMOTE SENSING AND GIS SYNERGY

The relationship between remote sensing and GIS has received considerable attention in literature and, indeed, remains the subject of a continuing discussion. Much of this discussion revolves around the scientific and technical issues relating to integration of the two technologies. Remotely-sensed images can be used both as a source of spatial data within GIS and to exploit the functionality of GIS in processing remotely sensed data. Despite this, the actual progress towards the goal of full integration is surprisingly slow. While this is undoubtedly due to the technical challenge of accessing, manipulating, and visualising vector, raster, and tabular data simultaneously, it seems unlikely that technical constraints have been the sole barrier to achieving full integration. It might be argued that competing imperatives in both remote sensing and GIS have tended to draw attention away from the issue of integration. The recent focus on monitoring global environmental change using coarse spatial resolution sensors and the assimilation of the data that they produce in various environmental simulation models has deflected some of the attention away from the traditional issues of large-scale mapping. These are more closely allied to the concerns and use of GIS. Similarly, one can see a number of other developments in the application of multimedia technology within GIS that have consumed much of the research and development effort in the field of GIS.

There are at least two reasons why the issue of integration is likely to receive fresh impetus in the near future. The first is the increasing availability of data from the very high spatial resolution as well as commercial satellites that are scheduled for launch over the next few

years. These will produce data appropriate to many of the large-scale mapping projects in which GIS has often been used, and is likely to compete directly with the traditional aerial photographs market. The second is that these high-resolution images require the development of new data processing algorithms, such as, syntactic (or structural) pattern-recognition techniques, to extract the maximum amount of information about the observed scene. There is a considerable overlap between the objectives and functionality of these techniques and those used in mainstream GIS, at least in terms of their potential for spatial analysis. This may also bring the two communities closer together.

Check Your Progress

Note: a) Space is given below to write your answer.

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

1. Remotely sensed images can be used as a source of ----- data within GIS

22.3 RASTER DATA FOR GIS

GIS users routinely require timely input data in order to optimise their systems for analysis and decision making. In many instances, raster data are preferred. Typically in the past, only a single type of photography or imagery was acquired for a given application. While this is still true, users are increasingly addressing more sophisticated applications, which require multiple images from different regions of the electromagnetic spectrum and/or different dates, at scales ranging from local studies to global investigations. These more sophisticated investigations are employing data with a variety of spatial, spectral, and temporal resolutions. More importantly, applications that require the integration of both raster and vector data have been evolved. Processing and analysis of these data are improved when an analyst has access to collateral information, often in vector format, for an area covered by the imagery being analysed. In addition, raster data from satellite sensors have inherent information content beyond their use as an image backdrop. Indeed, it is important to note that most operational base cartographic products produced by mapping organisations around the world are compiled using photogrammetric techniques to process remotely-sensed data.

While remotely sensed data is used in making maps, they are also being employed to measure a variety of environmental parameters. Surface and cloud top reflectance, albino, soil and snow water content, fraction of photosynthetically active radiation, areas and potential yield of given crop types, and the height and density of forest lands are but a few of the measurements that can be made with the aid of remotely sensed data. Such data measured and/or mapped over a time constitute the basis for monitoring. As we measure map, and monitor environmental features and phenomena we can then employ the data generated as Input to models. Remote sensing data is being employed today in a wide variety of modelling

activities. Finally, environmental planners, resources managers and public policy decision-makers are employing remotely sensed data within the context of GIS to improve the management skills and efficiency.

Thus there is a wide variety of satellite-based sensors currently providing operational raster remotely sensed data for GIS developers and users. Our emphasis here is upon information on the sources of that satellite remote sensed data being operationally acquired for use within GIS today. The spatial, spectral, and temporal characteristics of these systems vary according to specific design goals and engineering trade-offs. Once the remotely sensed data has been converted to a desired data type, transferring this data to a raster GIS is relatively simple. Header and trailer records or files may need to be modified during the conversion process. In our experience, most operational image processing and raster Geographic Information Systems provide mechanisms to read and write pixel raster arrays.

22.4 VECTOR DATA FOR GIS

Much work is involved when transferring raster data derived from remote sensing systems to a vector-based GIS. In the following paragraphs we present only the outline of the process. One possible sequence based on derived continuous data, such as, vegetation abundance, involves extracting the contours of abundance (often called isolines) on the image processing system, and converting these raster representations of contour lines to vectors. The vectors may then be passed to the GIS, along with labels to indicate values associated with the contour lines. When working with information which has been classified into discrete categories, like land use or rock type, appropriate transformations are made to convert the continuous multivariate brightness data into discrete categories. Then to isolate the implicit homogeneous polygons in the derived image the pixels that form the boundaries of the areas are detected. This is exactly like the skeletonizing algorithms used in conversion process. These boundary pixels may be used to develop the vectors surrounding the areas, and attribute values and class names are assigned to the bounded areas

It is important to understand that the conversion processes are limited by the underlying data, in terms of precision and accuracy. A 512-by-512 array of 24-bit pixels, displayed on a high-quality colour monitor, may be very satisfying to the analyst. However, the vectors that are developed from this discrete array may look poor on a high-quality plotter, since the plotter has many more addressable positions than the image display screen. Often, the analyst will smooth the plotted lines on the final product to make a more pleasing presentation.

22.5 NEED FOR INTEGRATION

Recently, it has been proved that Digital Terrain Models (DTMs) can be developed using GIS technology. The widespread distribution of Landsat and SPOT Imagery in the case of Canadian GIS, and the availability of digital elevation models and street files in many other countries have certainly led to applications well beyond those used to justify the data's compilation. In another example, the digital database was created for the wastelands and their aerial extent using ARC/INFO GIS. The spatial data used for this database was derived from the analysis of IRS LISS satellite data. This data is then integrated with GIS along with other collateral data. With better resolution and improving software, GIS and remote sensing combination are meeting the topographical mapping requirements. Remote sensing and GIS have almost become an unavoidable source for crosschecking or updating in digital surveying. Furthermore, the GIS software can now accept the Global Positioning System

(GPS) information in their program as an additional advantage. For example the ARC/INFO GIS software now accepts GPS data through its geo link module. Experiments have been carried out for various applications through such efforts. It is not always transitional land based information, which is generated, but unconventional themes have also been tackled. Urban and regional planning are obvious offshoots. Environmental issues related to ground cover such as forests, water bodies and wastelands also serve as examples.

Along with the above application areas, more research work should be oriented towards the development of application oriented remote sensing software that can be easily integrated with GIS. A recent development in this field has been integration of raster based data in conventional vector based GIS software like ARC/INFO. Apart from raster/vector conversion facilities in the GIS packages, vector overlays on remote sensing or other raster data is now possible. This has, to certain extent, facilitated the remote sensing data integration with GIS. Any software should support the functions like live link, direct usage of compressed data in GIS, automatic registration of GIS and remote sensing data, projection support, preparation of ortho-images and image maps, and solution based functions for specific application.

The future GIS and image processing software are likely to include at least some of the above functions. However, integration of GIS and remote sensing data are being carried out in different institutions and laboratories with different rates of manual/digital involvement. The remote sensing discipline has developed a number of different techniques for transforming general-purpose data sets into thematic information for many related fields for subsequent analysis using GIS.

In other instances, discrete categories of surface cover may be distinguished through a classification algorithm. Many different decision rules may be developed to isolate or characterise components of the earth's surface. Often, a sequence of discriminating steps is required to provide an acceptably accurate or precise result. For example, simple binary decision rule may be able to exclude water bodies from consideration. Finally, an unsupervised classification can then permit us to focus on cultivated vegetation. This example is over simplified, but illustrates a general principle that is parallel to the use of interpretative keys in photo interpretation.

22.6 SOFTWARE FOR INTEGRATION

A wide variety of photogrammetric, image processing and statistical analyses are utilised to extract information from raster data. The systems to accomplish such processing range from the relatively simple PC-based desktop mapping, soft copy photogrammetry and combined image processing/GIS system to complex analytical stereoplotters, orthophotoscopes, mainframe and super computer-based image processing GIS systems. The choice of the hardware and software to be employed in any remote sensing/GIS application depends upon a wide range of factors. These include: cost, type of application, timeliness required in data production, level of understanding/training of the staff involved and the appropriateness, accessibility, and availability of the input data; hardware, and software. In addition to these facilities, a digitiser or/and a scanner must be available to convert the paper-based data to digital base through the process of digitisation.

To accomplish the integration of remotely sensed data into vector based GIS requires all the additions of relatively sophisticated image processing packages to these systems. For instance, ESRI's ARC/INFO, Arc/View, and ARC/GRID software accomplish much of this integration. Correspondingly, some raster based image processing systems have considerable

GIS functionality. ERDAS/Imagine, ER Mapper, EASI/PACE, and Intergraph's MGE Base imager (MAI) version are examples of the systems that are commercially available today. An important consideration in linking any of these system to a vector based GIS is the grid interface between the two systems and the file structure of the systems. The managers should take care involved, and advice must be sought from users, before going forward with an attempt to link raster and vector system for a particular applications area.

In addition to this, spatial patterns, point attributes, line attributes and area attributes are also discussed in this section, since the understanding of these concepts are essential in applying GIS to any project.

22.7 SPATIAL CHARACTERISTICS

As discussed in the previous unit, GIS can be viewed as a combination of 4 subsystems, namely, (i) Data input subsystem (ii) Data storage and Retrieval subsystem (iii) Data analysis and manipulation subsystem and (iv) Data input / map production subsystem. This system's approach allow for the processing of spatial data into information and used to make decisions of remote sensing and GIS to produce a map model, the spatial characteristics of the terrain of interest are to be determined. To understand the spatial characteristics and to derive the appropriate spatial data, its spatial location with respect to reference system should be known.

22.7.1 Spatial Location

There are, broadly, three references system or co-ordinate systems by which the spatial data can be located. The three systems are:

- (i) Geographical co-ordinate system
- (ii) Grid co-ordinate system
- (iii) Non co-ordinate system

The geographical co-ordinate system is in terms of longitudes and latitudes measured from Survey of India toposheet. The grid co-ordinate system is in the form of number of grids drawn on the bases of parallels and horizontal lines by which the data location may be known with the help of grid location for example, remote sensing data. The non co-ordinate system is based on the proximity and vicinity of the associated features. The classical example of this type of co-ordinate system is just as postal system.

22.7.2 Spatial patterns

The spatial pattern is defined as a set of arrangements of spatial features. Generally there are three types of patterns,

- (1) Regular
- (2) Clustered
- (3) Random

If the distribution of point, line and/or area features are arranged systematically, such distribution is said to be regular (Fig.22.1a). If the distribution of features are arranged in the form of number of groups of similar hidden properly, they are called as clustered spatial patterns (Fig.22.1b) and the distribution doesn't follow any principle and appears in a very zigzag way, such pattern is called as random spatial pattern (Fig.22.1c).

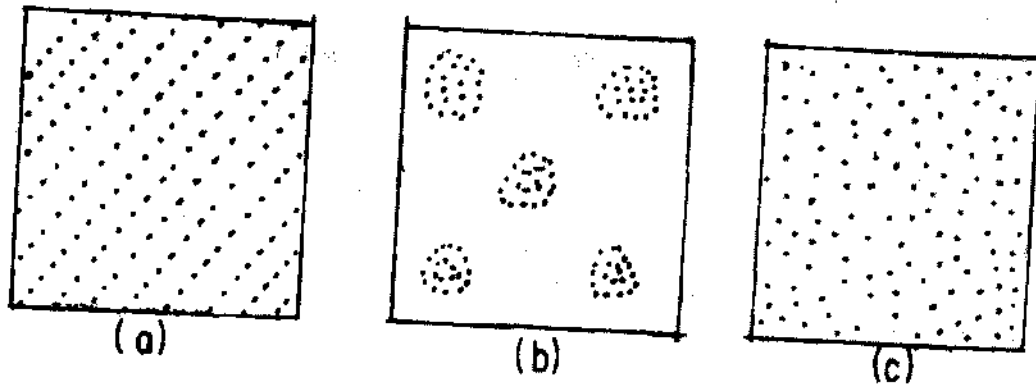


Fig. 22.1 Type of spatial patterns

22.7.3. Point attributes

Point attributes, like historical monuments, open wells etc. may be classified by nominal and ordinate variables based on the value of data and its nature. GIS software, like ARC/INFO allow us to isolate, select, quantify and locate point attributes.

22.7.4. Line Attributes

Line attributes contain nodes indicating either beginning or ending of a line. These can be identified with the attributes based on the level of data management i.e. nominal, ordinate, interval and ratio variables. For example, railroads, streets, fault lines, fracture zones and streams are considered as line attributes. The principle techniques of measuring line attributes are:

- Length calculation: Pythagorean theorem
- Azimuth calculation: Trigonometry
- Shape calculations: Sinuosity

22.7.5 Area Attributes

Area attributes can be defined, separated and retrieved on the basis of category, class or magnitude of the feature of interest. The shapes of the area features can be determined by means of the principles of geometry, contiguity, homogeneity and heterogeneity.

22.8 GIS DATABASE CREATION

Fundamentally, GIS database consists of four types. They are (i) topographic data derived from topographical maps and satellite imageries (ii) thematic data from the analysis of remotely sensed images supported and validated by field surveys (iii) collateral data collected from various related organisations like Groundwater departments etc. and (iv) field data collected through the intensive field work also called as primary data. These data products are in the form of either paper based maps or tabular data. If the data is in the form of paper based maps, these maps are to be converted into corresponding digital database. The conversion is done by means of a process called as digitisation. Digitisation is a process of converting a paper-based map to its digital model with the help of software, for example, AutoCAD.

If the data is in the form of tabular data, it should be entered to the system through keyboard entry or floppy drive or CD-drive. This entire database is then converted, through the process of cleaning, editing and inputting, to the database compatible to existing GIS software, viz.

ARC / INFO. In the process of cleaning and editing of raw data care should be taken to make the database free from all errors.

22.9 GIS DATA ANALYSIS TOOLS

Data analysis subsystem of GIS is heart of GIS and solves all the geographic problems. Most of the GIS software is more market driven rather than academic requirements for solving very difficult problems. Some of the methods of analysis are spatial measurements, reclassification, buffer analysis, map overlay analysis, modelling surfaces, Digital Terrain Modelling (DTM), network analysis models, mathematical modelling techniques, geostatistical modelling, and statistical analysis tools. Out of these methods, only two important methods are given in this unit. The two methods are map overlay analysis and buffering techniques.

22.9.1 Map overlay Analysis

Because each cell in a two-dimensional array can only hold one number, different geographical attribute must be represented by separate sets of Cartesian arrays, known 'overlays'. The overlay idea for separating data is not restricted to computer cartography, having been used by cartographers for a very long time. Fig 22.2 illustrates the overlay concept in which each separate attribute is described and mapped separately.

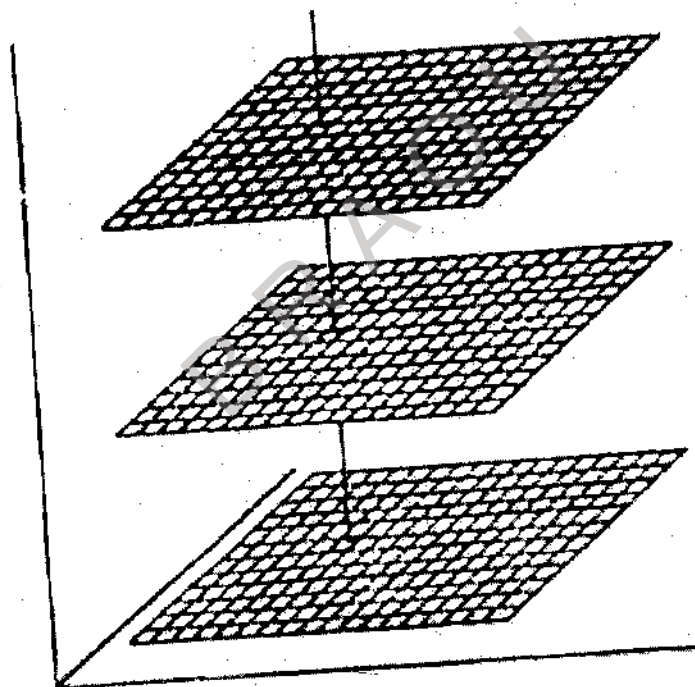


Fig. 22. 2 Three-dimensional arrays used for coding map overlays in raster database structures.

In its simplest form, the overlay concept is realised in raster data structures by Staking two-dimensional arrays. This results in a three-dimensional structure as shown in fig. 22.3. The overlay concept is essential equivalent to the 'picture function' in digital image processing, a 'data plane' in remote sensing or 'image-based' Storage, and it is fundamental to most raster image processing.

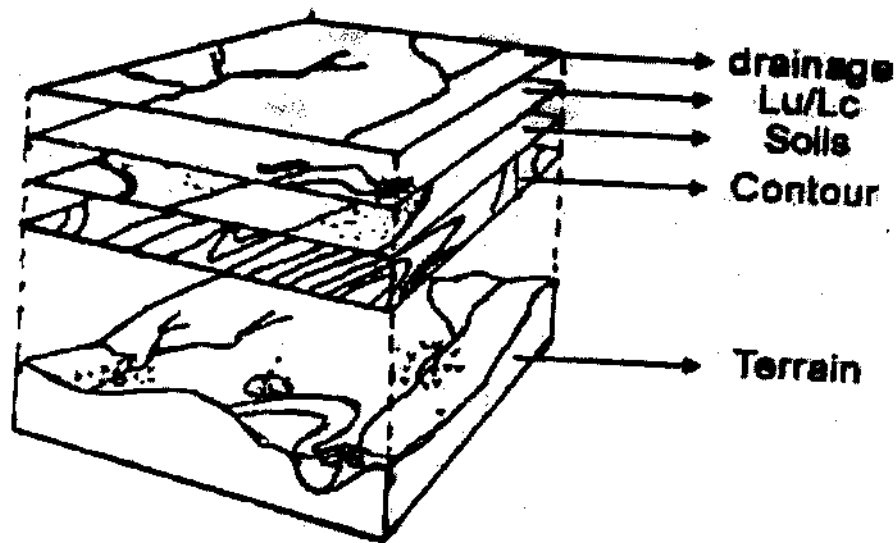


Fig. 22.3 The 'overlay' concept, the real world is portrayed by a series of overlays in each of which one aspect of reality has been recorded (E.g. topography, soil type, roads, rivers etc.).

22.9.2 Buffering Techniques

A Buffer is defined as a polygon created through reclassification at a specified distance from a point, line and for area as a zone of influence around an entity or around individual objects or multiple objects. The creation of an existing objects. Mainly, buffers are three types: (i) point buffer (ii) line buffer and (iii) area buffer. Creating buffer zones around point features or entity is a circle simply drawn around each point as centre and the area of influence under study as the radius of the circle (Fig. 22.4.a). Line buffers can be created by measuring a specified difference in all directions from the line target objects (Fig 22.4.b) An area buffer (Fig 22.4.c) can be created by measuring the distance with an area measured from its outer perimeter.

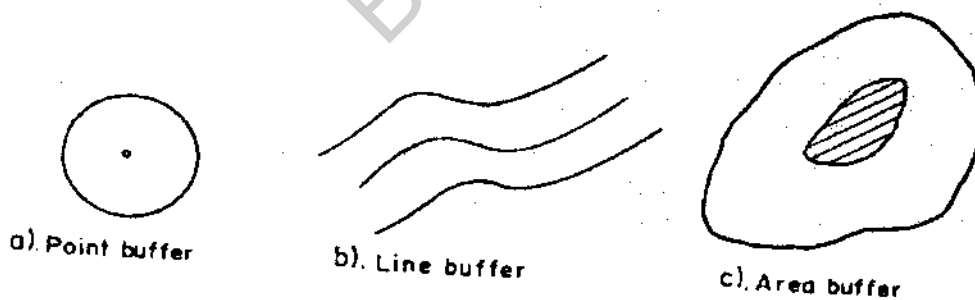


Fig. 22.4 Types of buffers

22.10 APPLICATIONS

This section deals with the applications of GIS, remote sensing, and both in combination. In many respects applications are the most important aspects of GIS since the only real point of

working with geographical information system is to solve substantive real-world problems. GIS is perhaps best considered a methodology or collection of tools which when applied can bring great benefits. Remote sensing and GIS can contribute a great deal to our study of patterns and processes on the surface of the Earth and to create decision support systems. Even though the innovation of GIS is itself quite recent, it is possible to classify applications as traditional, developing, and new. Traditional GIS application fields include military, government, education, and utilities. The developing GIS application fields of the mid 1990's include a whole raft of general business uses like, banking and financial services, transportation logistics, real estate, and market analysis. New application areas, which are probably due for take off in the next decade include small office/home office and personal or consumer applications.

Operational activities are the basic day-to-day activities of many organisations. The tactical activities are typically the domain of middle managers and strategic activities involve senior management. A list of various application areas is given in the table 22.1.

Table 22.1 Application areas of Remote Sensing and GIS

Agriculture and Soils

Crop acreage estimation / condition / yield prediction
Soil categorisation/resources/erosion assessment/watershed management

Geology

Lithological discrimination / structural mapping / drainage analysis
Mineral exploration / coal fire mapping
Oil field detection / explorations / geochemical analysis / seismic studies-analysis

Ocean resources

Wealth of oceans / explorations / productivity / SST / potential fishing zone,
Coral reef mapping
Low tide / high tide marking

Forestry and Environment

Loss of biological diversity / biosphere reserves / ecologically hot spot areas/
Wet land environment
Forest cover mapping & surveillance / forest stock mapping / deforestation-
afforestation
Grassland mapping

Major river valley projects

Coral reef mapping
Disaster warning mitigation
Climatic change and greenhouse gases-atmospheric aerosols, atmospheric winds

Wild life habitat assessment

Zoom cultivation-desertification.

Street network-based applications

Vehicle routing and scheduling
Location analysis-site selection- evacuation plans

Natural resource-based applications

Management of wild and scenic rivers, recreation resources, flood plains, wet lands,
Agricultural lands, aquifers, forests, wild life etc.
Environmental Impact Analysis (EIA)
Viewshed analysis
Hazardous or toxic facility siting
Ground water modelling and contamination tracking

- Wild life habitat analysis, migration routes planning
- Land parcel- based applications**
 - Zoning, sub division plan review
 - Land acquisition
 - Environmental Impact statements
 - Water quality management
 - Maintenance of ownership

Facilities management

- Locating underground pipes, cables
- Balancing loads in electrical net works
- Planning facility maintenance
- Tracking energy use.

Check Your Progress

- Note: a) Space is given below to write your answer.
b) Compare your answer with the one given at the end of the unit.

2. Name any two software for the integration of Remote Sensing and GIS.

3. Name any two applications where Remote Sensing and GIS together are useful.

22.11 SUMMARY

Remote sensing data can be used as an input to GIS. The remote sensing data can be readily merged with other sources of geo-coded information in a GIS. This permits the over lapping of several layers of information with remotely sensed data. The combination of image processing in remote sensing and GIS are coming closer and it is now becoming extremely difficult to differentiate. The hardware was almost similar and software is being integrated. Remotely sensed data can be used as a source for spatial data for the GIS. Data for GIS can be grouped as raster data and vector data. The integration of remote sensing and GIS is essential for accuracy. The spatial data is integrated in the GIS along with the other collateral data to take policy decision in the fields of socio-economic development. For urban and regional

planning integration is must. Environmental resources related to forests, water bodies and water lands study is to be undertaken with integration.

For the integration of remote sensing data with GIS, certain types of software are required. The main software available in these fields are ESRI, ARC/INFO, ARC/VIEW, ARC/GRID, etc. are in GIS and ERDAS, ER Mapper, EASI/PACE etc in remote sensing. There are several applications with remote sensing and GIS and both in combination. Remote sensing and GIS can contribute a great deal on the surface of the earth to create decision support systems. Traditional GIS applications include military, government, education and utilities. These fields are useful in the scientific study of agriculture, geology, ocean resources, forestry, disaster management, natural resources management etc.

22.12 CHECK YOUR PROGRESS-MODEL ANSWERS

- 1) Spatial
- 2) ARC/VIEW, ARC/INFO
- 3) Forest management, Natural resources management, geology, water resources etc.

22.13 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines each.

1. Explain the integration and software of remote sensing and GIS.
2. Describe the applications of remote sensing and GIS.

II. Answer the following in about 10 lines each.

1. Remote sensing and GIS synergy.
2. GIS Database creation.
3. GIS Applications in natural resources management.

UNIT: 23 WATERSHED MANAGEMENT

Contents

- 23.0 Objectives
- 23.1 Introduction
- 23.2 Concept
- 23.3 Watershed Definition
 - 23.3.1 Concept of Sustainability
 - 23.3.2 Watershed Classification
- 23.4 Delineation and codification of watershed
 - 23.4.1 Codification system:
- 23.5 Watershed Characteristics
- 23.6 Strategic View of Watershed Management
 - 23.6.1 People Participation
 - 23.6.2 Remote sensing and GIS in water resources management
- 23.7 Watershed Management - A case study
 - 23.7.1 Landuse/Land cover (LU/LC) map
 - 23.7.2 Hydrogeomorphology map
 - 23.7.3 Slope Map
 - 23.7.4 Groundwater Prospect map
- 23.8 Watershed Management of Andhra Pradesh
- 23.9 Summary
- 23.10 Check Your Progress - Model Answers
- 23.11 Model Examination Questions
- 23.12 Glossary

23.0 OBJECTIVES

In this unit, watershed management, its strategies along with the characteristics of watershed are described.

After studying this unit, you will be able to

- explain about watershed management
- describe the watershed characteristics
- explain the watershed management in Andhra Pradesh

23.1 INTRODUCTION

As we enter the third millennium, we are witnessing a gale of bewildering change and transformation. Communication is well on its way to becoming instant. Knowledge based processes and an electronic network blankets the globe. And yet, there are several things that never change. Like for instance the basic needs of which water is the most important.

In India, sustainable development of rural areas is one of the major efforts. This involves conservation of land and management of water resources, for which the bet physiological unit is a watershed/drainage basin. Characterisation and analysis of watershed are prerequisites for watershed management. Watershed characterisation and its productivity can be achieved by using watershed concept. General principles, approaches and guidelines relevant to integrated

water resources management are numerous and each has their areas of appropriate application. In 1992, an international conference on water and environment was held in DUBLIN with the aim of promoting changes in those concepts and practices which are considered fundamental to the improved water resources management and suggested specific principles, which are popularly known as FOUR DUBLIN principles.

- I. Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.
- II. Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels.
- III. Women play a central part in the provision, management and safeguarding of water.
- IV. Water has an economic value in all its competing uses and should be recognised as an economic resource.

The four Dublin principles significantly contributed to the agenda '21' recommendation adopted at the United Nations conference on Environment and Development in Rio de Janeiro, 1992. These core principles have been restated and elaborated at major International Water Conferences in Harare and Paris, 1995. In the recently held (2002) World Summit on Sustainable Development at Johannesburg, South Africa, the heads of states resolved the following among others.

- To halve the number of people without access to safe drinking water and adequate sanitation by 2015.
- Commitment to significantly reduce bio-diversity loss by 2010.
- Cease destructive fishing practices and establish marine protected areas and network, by 2012.
- Halve the number of the world's poor living on less than a dollar a day by 2015.

In India, out of 329 million ha geographical area, an estimated 175 million ha. Of land are subject to some kind of degradation namely soil erosion by water and wind, water logging, soil salinization and alkalinization shifting cultivation, etc. Frequent floods and drought further compound the problem. There are about 0.43 million villages, which do not have adequate drinking water. Timely and reliable information on the nature, extent, spatial distribution and temporal behaviour of natural resource is pre-requisite for their optimal utilisation. With the increasing pressure of the ever growing human and cattle population deforestation, erosion of soil, indiscriminate use of chemicals, fertilisers, and pesticides and also of water, a severe threat to our ecosystem has resulted. Land degradation is on the increase posing a serious ecological challenge to the habitat. With proper planning, scientific approach and efficient management, it is possible to increase the productivity of these "waste" lands while creating employment opportunities for the poor.

Check Your Progress

- Note:
- a) Space is given below to write your answer.
 - b) Compare your answer with the one given at the end of the unit.

- I. Write the pre requisites for watershed management.

2. Write the four Dublin principles.

23.2 WATERSHED CONCEPT

The significance of watershed strategy is traced back to two independent historic events. We attempt to restore alpine in the last quarter of nineteenth century and the conservation movement of those has pushed the watershed to the surface. However it is FAO, which has been playing the catalytic role for the last five decades at the international plane in campaigning for the watershed approaches. The land restoration and torrent control techniques and the vegetation manipulation and soil and water conservation techniques along with conceptual and theoretical inputs have formed the basis for the watershed strategy.

23.3 WATERSHED DEFINITION

Watershed is a spatial unit with complex relations among its entities. It is defined by stream pattern with rainwater collected through surface and subsurface runoff and culminating at the common point down the stream. In other words, watershed is a geohydrological unit draining at a common point by a system of streams (Fig. 23.1).

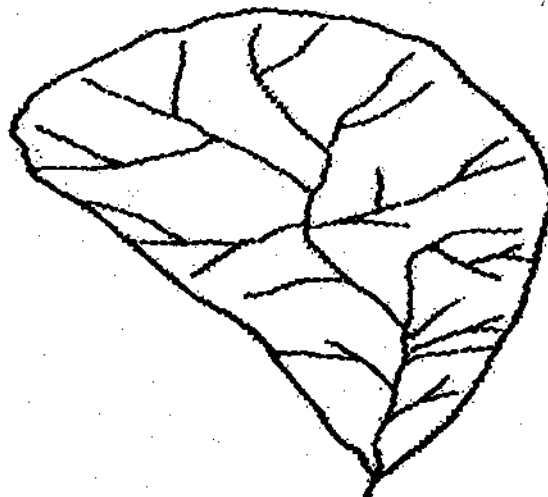


Fig. 23.1 Typical watershed

Thus a watershed encompasses all the land and water area that contributes runoff to a common point. It is a topographically delineated area draining into a single channel. The depth of a watershed may extend from the top of the vegetation to the confining geologic strata beneath. Every watershed is as unique as a finger print. No two watersheds are exactly same. The term watershed strictly refers to the divide separating one drainage basin from the other. But, over the years, watershed has been identified with a drainage basin or a catchment area. Watersheds of the small streams are the sub-watersheds of the larger stream. Watershed may be nearly flat or may be highly undulated. Each and every water and land area is a part of one watershed or the other.

Human and animal populations are part of the watershed community. The hydrological regime of watershed has inalienable relationship with flora, fauna, soil and climate on a temporal basis in terms of resource exploitation. The indiscriminate exploitation of the resources without proper planning causes severe set back to sustainable development.

23.3.1 Concept of Sustainability

Concept of sustainable development attracted worldwide attention since the publication of Brunt land report in 1987. Sustainable development is defined as the one that meets the needs of the present without comprising the ability of the future generation in meeting its own needs. Sustainable development should be based on economic development over a long period. It depends on interactions among three systems viz. the biological system, economic system and the social system.

Biological system: To maintain genetic diversity and biological productivity.

Economic system: Basic needs such as reduction of poverty, equality enhancement and increase in useful goods and services need to be addressed.

Social system: To ensure cultural diversity, institutional sustainability, social justice and participation.

23.3.2 Watershed Classification

For proper planning and development of watershed basin, it is essential to have a 'frame work of watersheds'. The size of a watershed is governed by the size of streams or river. Size of the watershed/hydrologic unit is of practical importance in land and water resources development. The aims and objectives of a particular development programme define a workable size of the watershed. For example a multipurpose irrigation-cum-hydel project would have its watershed spread over thousands of square kilometres where as a far from pond, the size may be a few hectares only. The size of the watershed will also differ with different stages between macro and micro levels of planning and implementation of development programmes. The classification of watershed is given in Table 23. 1.

Table 23.1 Classification of watershed

Sl.No.	Designation	Size
1.	Sub watershed	100-500 sq km
2.	Milli watershed	10-100 sq km
3.	Micro watershed	1-10 sq km
4.	Mini watershed	<1 sq km

23.4 DELINEATION AND CODIFICATION OF WATERSHEDS

The river basins of the Indian subcontinent are distinctly delineated into six water resource regions (Fig.23.2). They are:

1. Indus drainage
2. Ganges drainage
3. Brahmaputra drainage
4. All drainage flowing into Bay of Bengal (except 2 & 3)
5. All drainage flowing into Arabian Sea (except 1)
6. Western Rajasthan mostly ephemeral drainage

Regions into Basins: Each water resource region has been divided into basins which constitute individual big rivers like Krishna, Narmada, Chambal or a combination of smaller ones which are contiguous to each other like the basin between Cauvery and Krishna.

Basins into catchments: Each basin has been divided into a number of catchments, which mostly cover the main tributaries, or group of contiguous small tributaries or individual streams.

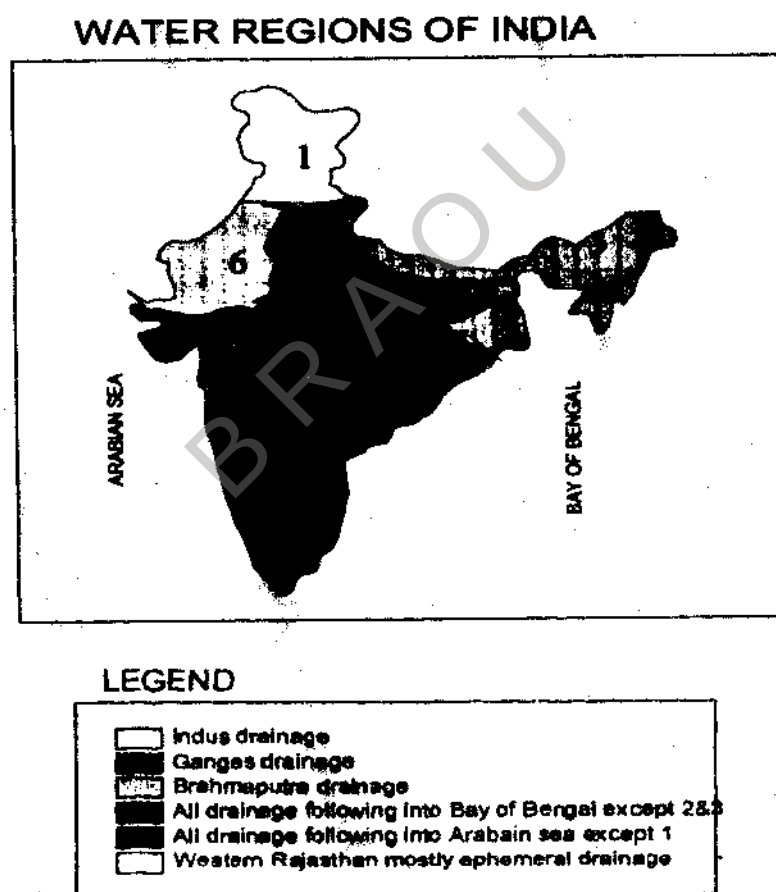


Fig.23.2

Catchments into Subcatchments: Catchments are further divided into a number of sub catchments, which are mainly smaller tributaries and streams.

Subcatchments into watersheds: Each sub catchment has been divided into a number of

watersheds, which are the smallest sized hydrologic units in the macro level category.

23.4.1 Codification system:

Model watershed codification is shown in Fig.23.3.

Water resource regions are assigned Arabic number 1, 2, 3...

Basins are assigned letters A, B, C....

Catchments are assigned Arabic number 1, 2, 3...

Sub catchments are assigned letters as A, B, C.....

Watersheds are assigned Arabic number 1, 2, 3....

Hence watersheds will have the codes like 1A1A1, 2B 2A3, 3A5C4 etc.

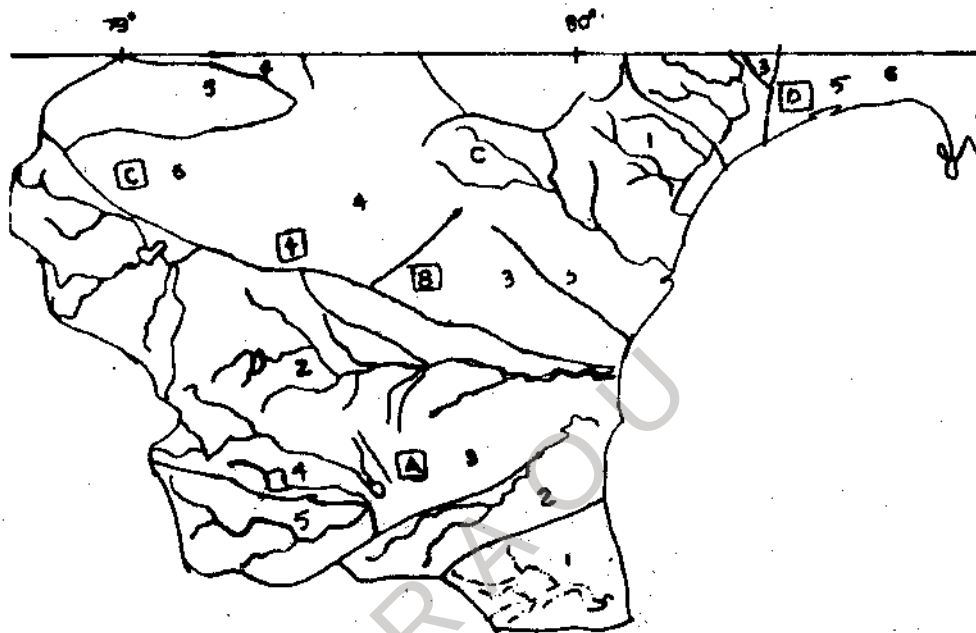


Fig.23.3 Model Watershed Codification

Hydrologic unit statistics: The hydrologic units of the country are delineated as follows:

1) Water resource regions -	6 No's
2) Basins -	35 No's
3) Catchments -	112 No's
4) Sub catchments -	500 No's
5) Watersheds -	3237 No's

Check Your Progress

- Note:
- a) Space is given below to write your answer.
 - b) Compare your answer with the one given at the end of the unit.

1. What is watershed? Explain.

23.5 WATERSHED CHARACTERISTICS

Watershed characterisation denotes taking stock of the resources available and identification of problems.

Resources: Soil resources, water resources (surface & ground water) agricultural systems, land configuration etc.

Problems: 1. Soil related problems such as salinity, solidity, soil erosion, physical features like gravelliness, stoniness etc.

2) Land problems such as slope gradient, physiographic differences such as hills, sheet rock exposures, mesa, butte systems.

Erosion has to be studied with respect to soil, hydrological surveys, vegetation, resources survey, live stock resources, socio-economic survey, infra-structural survey, contour survey, climatological review etc. are the general characteristics to be considered to evaluate watersheds.

Watershed characteristics are evaluated in terms of its

- 1) Physiography (size, shape, slope, drainage etc.)
- 2) Edifice conditions
- 3) Land use
- 4) Vegetative cover
- 5) Rainfall
- 6) Socio-economic factors

Uncontrolled, unplanned, unscientific land use and interventions in the following activities lead to the watershed deterioration. Viz. 1. Agricultural land, 2. Grassland, 3. Forestland, 4. Shifting cultivation, 5. Unscientific mining and construction.

23.6 STRATEGIC VIEW OF WATERSHED MANAGEMENT

Watershed management may be defined as the process of formulating and carrying out a course of action involving manipulation of natural, agricultural and human resources of a watershed to provide resources that are designed by and suitable to the watershed community, but under the condition that soil and water resources are not adversely affected. Watershed management must consider the social, economic and institutional factors operating with in and outside the watershed. Watershed management practices are those changes in land use vegetative cover and other non-structural and structural actions that are taken on a watershed to achieve watershed development objectives. Hence, management in an integrated and inter disciplinary approach is necessary.

For the last two decades, development of dry land agriculture on watershed basis has been a national strategy for sustained productivity and rational utilisation of natural resources. Only

adopting the watershed approach can properly develop the total resource. In this approach, development is not confined just to agricultural lands alone, but covers all the areas, starting from the highest point of the area (ridgeline) to the outlet of the natural stream. Watershed management usually involves the use, by the people of the watershed area, of natural resources in a watershed, especially the land, water and vegetation, with the active participation of their institutions and organisations and in harmony with the ecosystem.

23.6.1 People Participation

As the management of watershed aims at creating a self-supporting system essential for sustainability, the people's participation is the key to the success of any soil/water conservation programme. People's participation may be defined as employing a method where the associated communities are motivated to function and contribute as a group to perform a predetermined task. It is important to distinguish between people's co-operation and people's participation. Mobilising people's participation would require much more intensive interaction where in the communities would be required to be involved in the process of planning, implementation and management of the programmes to the extent possible. Community participation could also be visualised as an important mechanism, through which the responsibilities of management of land and water resources could be transferred to the people so that a more holistic and sustainable development of these resources can take place.

23.6.2 Remote sensing and GIS in water resources management

Watershed management needs exhaustive data and information, which are very dynamic in nature and temporal changes over time and space due to natural and external influence on agro-climatic environs. Collection of data in remote and inaccessible areas through conventional methods is difficult. Moreover the collected data are often inadequate; outdated and time consuming besides being expensive. Remote sensing technology provides synoptic and unbiased information on large areas at periodical intervals. The application of remote sensing in water resources management includes surface water inventories, flood assessment and flood plain mapping, snow mapping, watershed models etc. Resource management requires analysing phenomena, processes and their interaction throughout space and time. The resource information system for resource management should have multidimensional approach i.e. spatial dimension, attribute dimension and temporal dimension. Geographic information system offers such capabilities as they integrate multi-sector, multilevel and multi-period database. GIS is a computerised database system for capture, storage, retrieval, analysis and display of data.

23.7 WATERSHED MANAGEMENT -A CASE STUDY

An integrated watershed management may be explained through the consideration of the following individual watershed situated in a semiarid region. A drought prone region of Prakasam district in Andhra Pradesh, which lies in the Racherla mandal and situated in between 78°50' - 79°05' E longitude and 15°20' -15°40' N latitude, extending in an area of 412.8 sq km, is considered for systematic study. Various thematic layers are generated and an ideal integrated watershed management model has been developed.

Objectives: The objectives of watershed development project are:

- i. To promote the economic development of the village population through a) optimum use of natural resources, b) employment generation and development of human and other economic resources of the area.

- II. To encourage restoration of ecological balance through a) People's participation b) adoption of simple/local affordable technology.
- III. Special emphasis on socially and other wise disadvantaged sections of the Watershed community through. a) equitable distribution of the benefits, b) greater access to income-generating opportunities and for their human resource development.

Methodology: The widely accepted and the most suitable methodology for the integrated management of watershed development consists of the following three steps.

- I. Drainage basin/watershed - Quantification through the preparation of maps like
 - 1) Land use/land cover, 2) Hydro geomorphology, 3) Soils, 4) Geology, 5) Groundwater, 6) Slope map, 7) Drainage net work map
- II. Data base (attribute) creation of socio-economic data and other relevant information:
- III. Integration of all the information (map information and socio-economic details). Maps, the total basic integrated land and water resource units may be generated with each unit representing the typical geologic, geomorphic, pedologic, slope, hydrologic and current land use settings.

Action Plan: Based on the information available with research stations of agricultural institutes, available reports and research findings, specific guidelines are to be developed. With the application of guide lines on each basic Integrated and water resource units (output obtained on the integration of all the generated maps), specific alternative action plans are to be suggested. The general action plans to be suggested for semiarid/rain fed areas may be categorised as:

- 1) Drought proofing works, 2) soil and water conservation measures for non-agricultural lands, 3) soil and water conservation measures for agricultural lands, drought proofing works.

1. Drought proofing works: Drought is a state of persistent imbalance between water availability and water need particularly in the context of agriculture. Depleted water table, low production of food grains, loss of soil moisture, non-availability of fodder and fuel wood degraded forestlands, etc., are some of the consequences of drought. To mitigate these adverse affects, drought-proofing works are to be envisaged with people's participation.

A) Rain water harvesting structures.

- 1) mini-percolation tanks
- 2) check dams
- 3) farm ponds
- 4) desalting for conversion into mini-percolation tank

B) Soil moisture conservation.

- 1) vegetative barriers,
- 2) soil erosion control measures,
- 3) irrigation water management

C) Fodder/Fuel wood/Forest development

- 1) Fodder fuel wood plantation
- 2) Fodder/silvi pasture development
- 3) Afforestation
- 4) Conservation of flora and fauna

D) Shelter belt/shrub plantation along all the roads

E) Rain water harvesting structures

- 1) check dams,
- 2) percolation tanks

2. Soil and water conservation measures for non-agricultural lands: These lands are the sources of maximum sediment and run off and cause environmental hazards like formation of gullies, droughts siltation, landslides etc. The following are some of the measures to be adopted.

- 1) Contour trenching, 2) Gully control structures, 3) Revegetation 4) Quarrying, 5) Afforestation, 6) Silviculture.

3. Soil and water conservation measures for agricultural lands: Soil conservation in the basic program required to be under taken for both the development and management of resources. To achieve sustained agricultural production, suitable land treatments according to land problems/capabilities are to be proposed. Adoption of soil conservation measures will reduce soil erosion, nutrient losses, reduction in sedimentation reduction, runoff and thereby pressure to moisture in the soil profile besides improving the ground water recharge. The various conservation measures to be adopted under this category are 1) levelling, 2) terracing farm bunding, 3) nala bunding, 4) strip cropping, 5) legume and grass, 6) plantation of tree and vegetation cover etc.

4. Socio-economic impact analysis: In pursuing natural resources management, there is a need to accord priority to social equity considerations besides economic and natural conditions. The basic right for all people to have access to water of adequate quantity and quality for the sustenance of human well being must be universally recognised. Therefore to set things right a holistic perspective was needed in our country for the sustainable development of rural areas. The socio-economic backwardness of the relevant villages falling in the watershed area is to be estimated by considering the parameters namely, concentration of SC population, ST population, literacy, basic amenities, health facilities, educational institutions and dominance of occupation etc. In watershed treatment plans priority should be given to areas that ranks first in terms of 1) social backwardness, 2) economic backgrounds, and 3) areas lacking basic amenities.

23.7.1 Landuse/Land cover (LU/LC) map

The spatial information on LU/LC and their pattern of change is essential for planning, utilisation and management of land resources. Information on LU/LC permits a better understanding of the land utilisation aspects on cropping patterns like fallow land, forest and grazing land, waste land, water bodies etc. which are very vital for development and planning. In this watershed level-III classification is performed. The main LU/LC classes encountered here are cropland, deciduous forest, land with/without scrub, fallow land, barren sheet rock area and water bodies.

23.7.2 Hydrogeomorphology map

The primary purpose of undertaking hydrogeological studies is to examine the influence of morphological characteristics on the occurrence and movement of ground water. Geological and climatological change influence in the evolution of landforms and each geomorphological

process develops its own particular assemblage of landforms. Metamorphosed sedimentary rock forms the major part of geology. The major geomorphic features encountered in the area are pediplain, pediment, valley fill, bazada etc. The groundwater availability in valley fill region is excellent due to sedimentation.

23.7.3 Slope Map

Slope information is useful in understanding the topography, geomorphology, soil types and their erodibility, surface drainage etc. A slope map is essential for planning an irrigation project where the catchment area is hilly. Base map, drainage map and slope map will be prepared from SOI toposheets. Slope map is used in sediment yield calculation.

23.7.4 Groundwater Prospect map

Groundwater prospects (Fig.23.4) are estimated using geomorphology as a base besides slope, drainage and LU/LC.

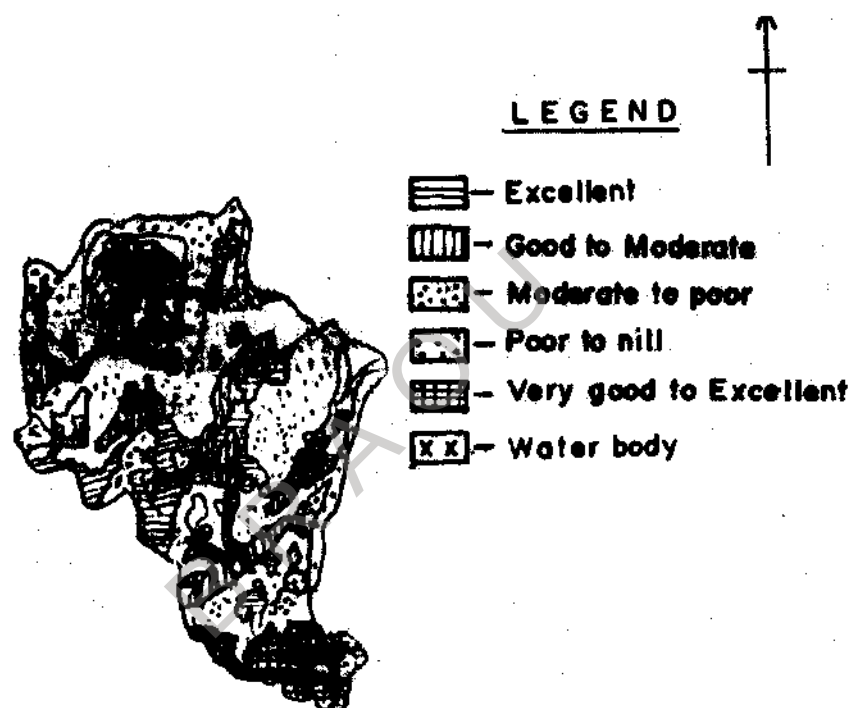


Fig.23.4 Groundwater Prospect Map

23.8 WATERSHED MANAGEMENT OF A.P.

In Andhra Pradesh waterland has been identified to be around 19.78% of the total geographical area. Around 42,000 watersheds covering an area of 2.25 million hectares are under implementation. Besides this the development of degraded forest area of an extent of approximately 0.3 m ha, under joint forest management, has been taken up through Vana Samrakshana Samithi, Neeru -Meeru programmes of the Government of A.P. (May, 2000) with a view of execute soil and moisture conservation works to generate employment to the rural poor and to improve ground water recharge thereby contributing to the growth and development of forests under sustainable development.

Check Your Progress

- Note: a) Space is given below to write your answer.
b) Compare your answer with the one given at the end of the unit.

4. What are the main objectives of watershed development?

23.9 SUMMARY

The basic needs of human beings such as water and food are a must to any society irrespective of its social and economic development. Development of rural areas may be achieved through land conservation and water management. During the international conference on water and environment (1992-Dublin), four crucial principles, popularly known as Dublin principles, are identified for the improved water resources management.

Water is a finite natural resource and may be considered as an economic resource. People's participation in general and women's role in particular is vital for water resources management. Soil erosion by water and wind, water logging, soil salinisation and/alkalisation are some of the reasons of land degradation in India.

The correct information on the nature, extent, spatial distribution and temporal behaviours of natural resources is pre-requisite for their optimal use. Rising land degradation poses a serious threat to the ecosystem. Productivity of wastelands can be achieved through proper planning, scientific approach and efficient management.

Watershed is a spatial unit with complex relations among its entitles and may be defined as a geohydrological unit draining at a common point by a system of streams. Each watershed is unique in its characteristics.

After the publication of Brunt land report in 1987, the concept of sustainable development attracted worldwide attention. Sustainable development aims at meeting the needs of the present without compromising the ability of the future generation in meeting its own needs. Sustainable development depends on the interaction among biological, social and economic systems.

Size of watershed is of practical importance in land and water resources development. All the river basins of the Indian sub continent are delineated into six water resource regions. Water resource regions up to watershed level are classified and assigned with Arabic numbers/alphabetical letters as per codification system (watershed Atlas of India).

Uncontrolled and unplanned land use practices leads to watershed deterioration. The process of formulating and carrying out a course of action involving natural resources comprises

watershed management. The extent of waste lands in A.P. amounts to 19.70% of the total geographical area. The Govt. of A.P. launched Neeru-Meeru programme with the primary objective of improving ground water and employment of the rural poor.

The main objective of watershed management are 1) to promote rural economy, 2) to make efforts to restore the ecological balance, 3) to accord priority to improve the living conditions of socially and otherwise deprived classes. Integrating the spatial information and collateral data to evaluate the current status/position of watershed. Specific action plans are suggested with the help of certain decision rules framed using available scientific knowledge of relevant areas. Action plan includes drought-proofing works and soil and water conservation measures for non-agricultural and agricultural lands. The basic right for all people to have access to water of adequate quality and quantity for the human being sustenance is to be universally recognised.

23.9 CHECK YOUR PROGRESS-MODEL ANSWERS

- 1) Characterisation and analysis of watershed are prerequisites for watershed management.
- 2)
 - A. Fresh water is a finite and vulnerable resources.
 - B. Water development and Management should be based on participatory approach.
 - C. Women has to play critical role in water management
 - D. Water has an economic value; these four are Dublin Principles.
- 3) Watershed is a geohydrological unit draining at a common point by a system of streams.
- 4) To promote economic development, to maintain ecological balance are the main objectives of watershed.

23.10 MODEL EXAMINATION QUESTIONS

I. Answer the following in 30 lines each.

1. What are the reasons for natural resources depletion? Add a note on the natural resources scenario at global and national levels?
2. What are the objectives of watershed management? Make a schematic mention about the methodology and action plan for natural resources management.

II. Answer the following in 10 lines each.

1. Write an account of Dublin principles and watershed management.
2. Mention the importance of watershed size in development plans.
3. Write an essay on action plans for watershed management
4. What is the role of socio-economic component in watershed management?

23.11 GLOSSARY

Finite	:	limited
Participatory approach	:	taking part in the execution of management activities
Sustainable	:	using a resource currently with out hindrance to the requirements of coming generations.

UNIT : 24 COMPUTER APPLICATIONS IN GEOLOGY

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24.0 OBJECTIVES

This unit is aimed to bring out the use of computers in geology.

At the end of this unit, you will be able to

- explain the data processing
- explain the need of computer in prospecting and exploration
- describe the methods of data handling
- describe the use of computer in geochemical prospecting
- describe the methods of minimising the errors

24.1 INTRODUCTION

The management and manipulation of data is one of the essential processes of science. The ability of computers to perform repetitive tasks quickly and without error makes it a natural tool for managing large amounts of information. However, it is up to the user to determine what data should be stored in machine-readable form, how it should be stored and what programs/machines will be used to manage the data. The large number of programs for mainframe computers, minicomputers and microcomputers offers the geologist many choices but the basic principles of different types of systems can be described in similar terms.

A geoscientist tries to understand the physical processes that operate within and on the Earth and other planets. Geologist has to interpret the history of geologic events, evaluate a

events, and anticipate future ones. To do so, there is need to use the conceptual tools of physics, chemistry, biology, and mathematics and our geoscientific intuition. A large amount of data is generated and so there is need to manage datasets. For better understanding, comparison with other datasets and with conceptual or theoretical models of how the earth or other planets work is must. Computers help to learn about and gain intuition related to conceptual tools, and they help to manage and manipulate datasets and often to generate predictions that we compare with our data (Hypothesis-testing). Computers in themselves are only the means to get to the understanding, evaluation, and anticipation that we seek. We have to be careful to be scientists (geology leads the activity), rather than technicians (the method or tool or computer leads the activity).

24.2 SCOPE OF COMPUTERS IN GEOLOGY

The mineral explorationist uses a variety of geologically oriented computer-hosted databases. These include compilations of information on a single specimen or drill hole; results of local or regional mapping, geochemical or geophysical surveys; production data from a mine, mining district, province, nation, or continent; and topical bibliographies on mineral deposits and related subjects.

Recent applications include mathematical statistics for problem solving in Earth Sciences and much attention is given in new developments in quantitative stratigraphy, spatial analysis, application of image analysis, multivariate statistical analysis in mineral resources evaluation and geostatistical crustal abundance models.

Computers are also used in groundwater modelling, for groundwater pollution studies, etc. Computer applications are more importance in remote sensing and satellite image interpretation.

24.3 COMPUTERS TODAY

Computer is a machine that can perform arithmetic operations and is fast and accurate electronic symbol manipulating system that designed and organised to automatically accept and store input data, process then and produce output results. The basic organisation of a computer system includes input, processing and output devices. The central processing unit (CPU) consists of primary storage section where the input and output results are stored, the arithmetic logic section where the calculations are performed and control section where it is balc to maintain order and direct operation of the entire system. Computers are of four types – Microcomputers, Minicomputers, Mainframe computers and Superpower computers and these differ in processing, speed, storage capacity and the cost. Most computers are multiprocessors where several instructions can be processed at the same instant. Mainframe computers are classified as first to fourth generation computers depending upon diodes, transistors, large-scale integrated circuits (LSI) and very large-scale integrated circuits (VLSI). Computers can be classified as digital computer, which is counting device that, operates on discrete data, analog computer where they deal with variable measured along a continuous scale and hybrid computers system where analog data are converted into number and supplied to a digital component in the system.

Data processing consists of gathering the raw data input, evaluating and bringing order of it, and placing it in the proper perspective so that useful information will be produced. The data can be organised and then processed by the use of sequential (batch) or direct access. Direct

access processing consists directly locating and updating any record in the file without the need to search through a lengthy sequence of other records. Data entry for the sequential processing can be done by punched cards, magnetic tape, floppy disks (diskette) and optical character readers (OCR). Data entry devices for Direct Access Processing are teleprinter terminals, point of sale terminals, optical scanner terminals, visual display terminals (a keyboard is used to enter data into CPU). The direct Access Secondary storage is Magnetic disks, which are the most popular medium for storage. The storage capacity varies from about 30 million to 300 million characters. The other storage devices are Mass storage devices, Magnetic bubble storage, charged couple device and optical disks. Vast amount of data being stored in computers, many organisations are moving into Data Base Management Systems (DBMS). Such systems are special software packages, somewhat akin to electronic libraries.

The computer output media are punched papers, tape drives and magnetic devices where output results can be stored. High-speed line printers are rapidly moving chains or bands of print characters 20,000 lines/minute. The other devices are drum printer, alphanumeric display devices, graphic terminal output, dot matrix printer/plotter, pen plotter, film recorders etc.

The programming language consists of all the symbols, characters and usage that communicate with computers. Every language has instructions that fall into input/output instruction, calculation instructions, logical instructions and storage/retrieval and movement instructions. Major High level languages used are FORTRAN, BASIC, COBOL, PL/I, RPG, ALGOL, and PASCAL. COBOL is used for business purpose and for scientific purpose. FORTRAN, BASIC and PASCAL is common language. These High order languages are converted to machine language by compiler in CPU where computations are performed in this language and reconvert them to object program/results.

The DEC-10 System available at TIFR is multiprocessor with 2 CPU having total memory 502 Mega Words. The computations are performed on time sharing process. Direct-access of magnetic disks is available for data storage. Apart from the above two chain line printers and magnetic drives are available for the output results. For graphic methods two drum plotters and tetronix terminal are used.

24.4 DATA PROCESSING

Computer methods are extensively used in geological sciences towards processing of large amount of geological, geochemical data for proper interpretation; thereby the geologist may be able to grasp its full significance. A set of numbers is much more abstract than the collection of objects and properties to which it refers. Many mathematical and statistical concepts are in general use in geological process.

1. Summarisation of a set of measurements to give an overview of the general properties and distribution.
2. Transformation of data to reveal the properties more clearly.
3. Regression analysis to explore the dependence of the property on another or a group of others.
4. Correlation, principal component analysis and factor analysis to investigate the relationships between pairs and group of variables.
5. Trend surface analysis by which the distribution pattern of the variables with

reference to its co-ordinates, where local components can be separated from regional trend.

These statistical methods can be applied to any amount of data, provided the data is collected in a systematic way. To make comparison between different populations and to integrate information derived from many visual patterns are supplemented by the computer ability to detect the complexity of data.

The principal multivariate methods used in earthsciences are factor analysis, time series analysis and regression or trend analysis; factor analysis is useful in finding common underlying factors in independent variable. In the geological field the application of factor analysis to determine the interrelationship between chemical, lithological and biological constituents in recent and ancient sediments is known. In this exercise, grouping of sampled localities into similar areas revealing meaningful pattern are used for the interpretation of the environmental history of sedimentary basins.

In the time series analysis, data collected at successive intervals of time are analysed. The time factor in the time series analysis is the relative time scale since the actual time factor is an unknown entity. For example, observation made during the course of a geological traverse may be subjected to time series analysis. Several aspects of the formation including grain size, porosity, fossil distribution and so on may be used to introduce order into an irregular and erratic appearance of data and the exercises may well lead to meaningful interpretations.

Studies have shown that the trend surface analysis is applicable to local as also regional structural features. The application of the trend surface analysis to structural problems is useful in predicting projected depths of geological formation and in delineating structural discontinuities.

24.5 COMPUTERS IN EXPLORATION GEOLOGY

Computer applications in exploration geology usually result in the production of maps or other graphic displays. These include small-scale regional maps and large-scale or prospect maps.

Regional Maps: These are generally considered to be those that are made on a scale of 1:250,000 or smaller. They cover a geologic region, province or basin. They give an overview for play development and computer activity and permit the placing of individual prospects in their proper perspective. Displaced detail is limited so that one should not attempt to use closely spaced symbols that may overlap or obscure the main purpose of the map. Small-scale drilling density maps are often better if the number of wells in some unit, such as township, is contoured rather than simply posting all locations. The same is true for penetration maps on formation basis. However, these are all a matter of density and judgement; the option lies with utility and ease of visual interpretation. Computers and graphic display devices can produce a variety of useful and visually pleasing regional maps. Some of the maps are:

- a) **Drilling density maps:** Well symbols are preferred, but contours can be used in areas of dense drilling
- b) **Depositional environment maps:** Stratigraphic and fossil information maps that can be used on geologic interpretation or multivariate analysis and

- c) **Comparison maps:** Comparing some geologic feature such as structure with oil occurrence can quickly evaluate large areas for prospects and for the best mapping techniques e.g. Isopach maps, Potentiometric maps.

24.5.1 Local and Prospect Maps

Local maps are generally considered to those on a scale larger than 1:250,000. Prospect maps display detail and interpretation beyond that contained in the well information and are a product of geologic deduction and imagination. Kinds of local and prospect maps useful are:

Drilling density maps: All wells should be posted.

Production and oil-show maps: Individual wells with details should be posted.

Economic and report generation: Computer-generated statistical probabilities can be used to forecast success and economic return from prospects. Word-processing systems can easily produce clean, accurate reports.

Check Your Progress

- Note: a) Space given below for writing your answer.
b) Compare your answer with the one given at the end of this unit.

1. What is the scale of regional maps?

2. What are the multivariate methods used in geology?

24.6 STRUCTURAL GEOLOGY

Structures within the earth are very complex and imaginative. Computers can be used to visualise the structures and their interrelation. Data on structures, such as strike and dip of faults, folds, joints, etc. can be collected and made use to know their extent and direction. Data once collected can be stored and any additions/corrections can be easily made and latest models can be constructed. Many times the structures are of more than one generation.

Using computers can help us and also make things easier for a structural geologist. Surface data can be used to get a model of subsurface structures. Most of the structural features are

not exposed on the surface, identifying the trend of these structures is most difficult problem faced by the structural geologist. For classroom teaching of structural geology, computers can be more effectively used. Students lack a clear grasp of the structures, so conceptualising the model structures, help them to have good picture.

Parametric studies on stress distribution and ground displacement around, joints, lineaments can be made using 2-D finite difference package.

24.7 MINE PLANNING AND OPERATION

With the increasing size and complexity of equipment, greater depths with difficult geomining and hostile environment conditions; present day mine planning requires the collection and evaluation of greater volume of numerical data from a number of engineering disciplines than ever before. Processing of these data for evolving an optimal and cost effective alternative without the aid of computers is simply impracticable.

The principal aim of mine planning, once a site has been selected, is to design mine layout and schedules that allow operations to be optimised, resource recovery maximised and costs minimised. Before the use of computers, a lot of manual work had to be carried out. The same can be done on computers within a short period with a facility to evaluate various alternatives for decision-making.

One of advantages of computer aided mine planning and design is that the planner is rapidly able to assess multiple strategies and variations. In the era of computers, numerical models are being increasingly used in the mining arena to optimise extraction ratio, prediction of ground conditions, rock blasting, etc.

A number of graphics software packages for blast induced vibration data analysis are available such as VIBAN - developed by CMRI (Central Mining Research Institute), ICI Australia developed VIBREX USBM developed PATCH.

24.8 GEOCHEMICAL EXPLORATION

The purpose of geochemical exploration survey is the discovery of abnormal geochemical patterns, or geochemical anomalies, related to mineralisation. The recognition of something abnormal, however, requires an understanding of what is normal. From this the concepts of the background, or typical range of an element in a naturally occurring material, together with the threshold, or lower limit of values that are worth considering as anomalous, and contrast, or ratio of anomalous to background values have come up. When the field data are plotted on plans or sections, these parameters may become almost intuitively obvious, so that the recognition of anomalies worthy of follow-up becomes a relatively simple matter.

The recognition of anomalies is not always so easy. Some geochemical surveys involve the collection of hundreds or thousands of samples, each one to be analysed for ten or more elements. The sheer time and effort involved in tabulating and plotting results, becomes a major cost of the survey. Errors easily creep in and require additional time for checking.

Furthermore, the anomalies are not always easy to recognise by simple inspection of the distribution of a single element. Ratios of elements or groups of elements may indicate the presence of mineralisation, or statistical treatment may be necessary before the anomalous

patterns can be recognised. Some of the statistical methods of interpretation making using computers are cumulative frequency curves in the recognition of anomalous sample populations, in the consideration of the accuracy and precision of geochemical analyses.

24.9 DATA HANDLING BY COMPUTER

In large surveys involving thousands of samples, computer data handling is useful for organising the data, recording data in tables, and plotting maps. The major advantages of the computer are the ease and speed of handling large volumes of data, and the relative freedom from errors once the data have been entered into a proven system and verified.

24.9.1 Recording of Data

The initial stage in data handling is to record the sample numbers and locations (co-ordinates), along with any relevant field data, such as sample type and depths, drainage, contamination and geology. This information should be recorded in the field on forms from which it can be easily transferred to cards or other computer readable media. Care must be taken in choosing symbols for non-numerical data so that the computer can be easily manipulate the data. Numerical codes for sample types and site characteristics are usually preferable to letters. If sample locations are recorded on a map, the co-ordinates may be easily obtained on punched cards or other computer readable form using a digitizer.

24.10 COMPUTER GENERATED MAPS

Computer generated maps are useful in large multi-element surveys, first as plots of the data, and second for smoothing out and bringing out the broader patterns in the data. However, in all computer work, the original data should be frequently consulted in order to understand the origin of unusual features, because such an understanding may lead to improved interpretation.

The simplest type of computer-generated map is a plot of the sample location and element content for each sample. A cheap method of producing such a map utilises the computer line printer. Limitations of the line printer are the resolution, which is limited to the space occupied by one character (about 0.2 cm wide), and overlapping of numbers and characters from adjacent sample sites. Alternatives to the line printer are pen type plotters, photography of cathode ray tubes, and laser graphic plotters.

24.11 GROUNDWATER MODELLING

The widespread availability of digital computers has come to development of mathematical models of aquifers. Applications are expanding, programming techniques are steadily improving, and computer capabilities are growing so that it is safe to say that almost any type of groundwater situation can be studied by means of a digital computer model. Hybrid computer models combine a resistance network with a digital computer.

24.11.1 Hybrid computer models

A combination of a digital model and resistance network analog, known as hybrid computer model, has been developed to reduce the lengthy computer time. The digital computer provides the input data, such as sources, sinks, and aquifer properties and boundaries; these

are expressed in electric form by a digital-analog converter and connected with the resistance network by means of a distributor. After the analog relaxes the system, the node voltages are fed back to the digital computer through a multiplexer and an analog converter.

24.11.2 Modelling for groundwater management

The development and use of improved mathematical tools are necessary to foster more efficient groundwater management. Digital computer models serve as tools with considerable capability for aiding in decision making related to the various uses, both actual and potential, of groundwater systems.

Majority of the groundwater modelling is concerned with flows; however, mass-transport for handling groundwater quality, pollution and dispersion are increasing. With present day focus on the groundwater related pollution studies, computer has become an indispensable tool for preparing concentration contour maps, pollution source maps, ground water quality maps such as Piper diagrams, Schoeller diagrams, Wilcox diagrams for classifying irrigation waters.

24.12 REMOTE SENSING, SATELLITE IMAGARIES

With the advancement of science and technology and also for proper utilisation of the data computers have become indispensable. Application of remote sensing methods in mineral exploration, pollution studies, resource management huge data sets are created. To handle these data sets and get meaningful and proper conclusions computers are widely used. Without the aid of computers the management of such huge data from satellites would have gone out of control and proper interpretation could not have been made. The usage of computers in these fields has made the data available more integrative and also to try to link up with the existing field data. Correlation of the ground field data and remote sensing data is becoming easier with computers.

Vector analysis for creation of selective, global topology from multiple, selective themes. Performing user defined spatial queries, buffer zonation, thematic mapping, area merging are made easier using computers. Raster analysis is also not possible without the aid of computers.

24.13 ERROR CHECKING

For a database to be of real use, it must be error-free as possible; when using the database for mineral exploration, there have been several situations where anomalous values of metalliferous elements have been determined to be caused by analytical standards remaining unnoticed in the database. This could cause needless and expensive fieldwork in the following up such spurious anomalies. The task is to ensure that the analytical data, the field description, and ancillary information are all correct and associated with the correct sample.

In a very large database, it is impractical to check every analytical result by hand against the hard-copy output from the analytical device, although this was done in the early days before machine-to machine data transfer techniques were developed and must still be done for any data entered by hand. Errors that do occur are often the result of aborted computer file transfers or format describing it to the DBMS (Data Base Management Systems). Using the facilities of a DBMS and knowledge of the analytical results expected and the possible

sources of errors, it is reasonably easy to devise a strategy to pick out most errors. Errors may often be detected by inspecting the extremes of values for the elements. For example, if nearly all copper values fall in the range 50-300 ppm and a small batch lies in the range 1,000-10,000 ppm, then there may be a format problem or a transposition with an element such as Barium. If an element is quoted as the oxide in percent it cannot have values over 100. pH values cannot be greater than 14 and usually are in the range 4-8.5.

The location of each sample is normally taken from the field card information, although for some areas locations have been digitised from the sample sites plotted on stable-base topographic maps in the field. Locational errors can be checked by a knowledge of the sampling area: any location falling outside this area, determined either by defining eastern and northern limits or by plotting a site map and overlapping it on a topographic map, should be detected.

After a computer check for gross errors, a manual check of all sample locations is made. The site is located on the stable base map using the grid reference in the computer database and compared with the grid reference and free text description of the site given on the field card. Any corrections or refinements are made; the field card corrected and amendments made to the computer database.

Errors in the flagging of samples (routine, standard, duplicates, etc.) potentially are disastrous and must be weeded out. Fortunately, the routine samples outnumber the others by an order of magnitude, so it is easy to produce lists of the non-routine samples in the database and check them off against the master lists and the field cards. Some computer checking also is possible. For example, standards should have no associated locations and blank water samples should have no associated analytical data.

Finally, a proportion of the data must be thoroughly checked manually. The samples to be checked may be selected on the basis of random number generators, every *n*th sample or one or two per batch or results from the analytical device, but it is essential that a manual check be performed and that no errors are found. Only then can it be said that the data are ready for use.

24.14 ROLE OF OPEN SOURCE SOFTWARE

Increased dependence on computerisation with integration of Internet technologies makes IT security a major area of concern. Virus attacks, data theft, snooping and data loss due to various reasons often levy a huge economic burden on the computerisation efforts.

Switching over to Open Source Software (OSS) addresses many of the above concerns and has many advantages. Immediately visible is the meagre capital investment, lower total cost of ownership, better technology, stability and total freedom from many of the security concerns. OSS programs are programs whose licenses permit users the freedom to run the program for any purpose, to modify the program and to freely redistribute either the original or modified program. In particular, this means that source code must be available.

Check Your Progress

- Note:
- a) Space given below for writing your answer.
 - b) Compare your answer with the one given at the end of this unit.

3. What are the advantages of computer aided mine planning and design?

4. What are the limitations of line printers?

24.15 SUMMARY

The advent of the computer has ushered in a revolution in several scientific disciplines. Computer, whether virus resistant or not, are status symbols in large organisations. However, geologists have not taken to computers with avidity, possibly because of their traditional qualitative training. Where as acceptance of quantitative methods is of paramount importance in computer science. Computers are slowly making inroads into the realm of geology and the use of the computer in treating geological data falls into the categories of data processing and problem solving. Gone are the days when storage and assimilation of limited amount of data were simple. With rapid progress in several disciplines of earth sciences, the frontiers of knowledge are expanding explosively and a large quantum of data is generated. The arrival of computer in the geological field assures the synthesis of data. The petroleum industry has advantageously adapted to computer to synthesise data pertaining to bore holes with the result it is possible to have quick access to data for recovering information in any form or desired sequence.

The statistical methods can be applied to any amount of data, provided the data is collected in a systematic way. To make comparison between different populations and to integrate information derived from many visual patterns are supplemented by the computer ability to detect the complexity of data.

The principal multivariate methods used in earth sciences are factor analysis, time series analysis and regression or trend analysis; factor analysis is useful in finding common underlying factors in independent variable.

Computer applications in exploration geology usually result in the production of maps or other graphic displays. These include small-scale regional maps and large-scale local or prospect maps. Regional Maps are generally considered to be those that are made on a scale of 1:250,000 or smaller. They cover a geologic region, province or basin. Local maps are generally considered to those on a scale larger than 1:250,000. Prospect maps display detail

and interpretation beyond that contained in the well. One of advantages of computer aided mine planning and design is that the planner is rapidly able to assess multiple strategies and variations. In the era of computers, numerical models are being increasingly used in the mining arena to optimise extraction ratio, prediction of ground conditions, rock blasting, etc. A number of graphics software packages for blast induced vibration data analyses are available.

The purpose of geochemical exploration survey is the discovery of abnormal geochemical patterns, or geochemical anomalies, related to mineralisation. The recognition of something abnormal, however, requires an understanding of what is normal. The recognition of anomalies is not always so easy. Some geochemical surveys involve the collection of hundreds or thousands of samples, each one to be analysed for ten or more elements. The sheer time and effort involved in tabulating and plotting results, becomes a major cost of the survey. Errors easily creep in and require additional time for checking.

The initial stage in data handling is to record the sample numbers and locations (coordinates), along with any relevant field data, such as sample type and depths, drainage, contamination and geology. Computer generated maps are useful in large multi-element surveys, first as plots of the data, and second for smoothing out and bringing out the broader patterns in the data. The simplest type of computer-generated map is a plot of the sample location and element content for each sample.

Majority of the groundwater modelling is concerned with flows; however, mass-transport for handling groundwater quality, pollution and dispersion are increasing. With present day focus on the groundwater related pollution studies, computer has become an indispensable tool for preparing concentration contour maps, pollution source maps, ground water quality maps such Piper diagrams, Schoeller diagrams, Wilcox diagrams for classifying irrigation waters. For a database to be of real use, it must be error-free as possible; when using the database for mineral exploration, there have been several situations where anomalous values of metalliferous elements have been determined to be caused by analytical standards remaining unnoticed in the database.

24.16 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Regionally maps are generally considered to be those that are made on a scale of 1:250,000 or smaller.
2. The principal multivariate methods used in earth sciences are factor analysis, time series analysis and regression or trend analysis, and factor analysis.
3. One of advantages of computer aided mine planning and design is that the planner is rapidly able to assess multiple strategies and variations.
4. Limitations of the line printer are the resolution, which is limited to the space occupied by one character (about 0.2 cm wide), and overlapping of numbers and characters from adjacent sample sites.

24.17 MODEL EXAMINATION QUESTIONS

I. Answer the following questions in 30 lines each.

1. Explain the different types of data processing methods.
2. Explain the use of computer in exploration studies.

3. Write on the use of computer in mine plan and design.
4. Discuss the steps of minimising error handling of geological data.

II. Answer the following questions in 10 lines each.

1. Explain the scope of computers in geology.
2. What are regional maps?
3. What are the groundwater modelling techniques using computers?

* * *

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SYLLABUS

BLOCK - I : MINERAL EXPLORATION - I

- Unit - 1 : Exploration Principles and Strategies
- Unit - 2 : Geophysical Methods
- Unit - 3 : Geochemical and Geobotanical Methods
- Unit - 4 : Exploratory Drilling

BLOCK - II : MINERAL EXPLORATION - II

- Unit - 5 : Physiographic and Mineralogical Guides
- Unit - 6 : Stratigraphic and Lithological Guides
- Unit - 7 : Structural Guides
- Unit - 8 : Sampling and Estimation of Ore Reserves

BLOCK - III : MINERAL ECONOMICS - I

- Unit - 9 : Principles of Mineral Economics
- Unit - 10 : Indian Mineral Resources
- Unit - 11 : Mineral Resources of Andhra Pradesh
- Unit - 12 : Marine Mineral Resources

BLOCK - IV : MINERAL ECONOMICS - II

- Unit - 13 : Classification of War Minerals
- Unit - 14 : National Mineral Policy - Importance
- Unit - 15 : Conservation and Substitution of Minerals
- Unit - 16 : Growth of Mineral Industry - Mineral Legislation

BLOCK - V : ADVANCED ASPECTS OF GEOLOGY - I

- Unit - 17 : Plate Tectonics
- Unit - 18 : Engineering Aspects of Geology
- Unit - 19 : Natural Resources Management
- Unit - 20 : Environmental Geoscience

BLOCK - VI : ADVANCED ASPECTS OF GEOLOGY - II

- Unit - 21 : Remote Sensing and GIS Principles
- Unit - 22 : Remote Sensing and GIS Applications
- Unit - 23 : Watershed Management
- Unit - 24 : Computer Applications in Geology

ADDRESSES OF COURSE REVISION TEAM

Editor

Dr. V. Sudarshan
Department of Applied Geochemistry
Osmania University
Hyderabad - 500 007

Associate Editor

Dr. P. Madhusudhana Reddy
Department of Geology
Dr. B.R. Ambedkar Open University
Road No. 46 Jubilee Hills
Hyderabad - 500 033

Writers

Dr. M. Anji Reddy
Centre for Environment
Jawaharlal Nehru Technological
University
Masab Tank
Hyderabad - 500 028

Dr. U.V.B. Reddy
Department of Applied Geochemistry
Osmania University
Hyderabad - 500 007

Dr. P. Gnaneshwar
Department of Geology
P.G. College of Science
Saifabad, Hyderabad - 500 004

Dr. P. Madhusudhana Reddy
Department of Geology
Dr. B.R. Ambedkar Open University
Road No. 46
Jubilee Hills
Hyderabad - 500 033

Dr. P. Venkateswarlu
Centre for Environment
Jawaharlal Nehru Technological
University, Masab Tank
Hyderabad - 500 028

Dr. K. Satyanarayana Reddy
Department of Geology
Andhra University
Visakhapatnam - 530 003

Dr. B. Srinivas
Department of Applied Geochemistry
Osmania University
Hyderabad - 500 007

FACULTY OF SCIENCE
THIRD YEAR (3 YEAR DEGREE COURSE) EXAMINATION
MODEL QUESTION PAPER
GEOLOGY

Course – IV Mineral Exploration, Mineral Economics and Advanced Aspects

Time: 3 Hours

Max. Marks: 70

Section: A

Note: A) Answer any three questions in about 30 lines each.
B) Each question carries 15 marks.

1. Explain the various factors that influence the choice of an exploration method.
2. Describe the different methods in practice for estimating the volume of a given deposit.
2. Explain the mineral resources of Andhra Pradesh.
4. Describe the concepts of national mineral policy.
5. Explain the theory of plate tectonics.
6. Describe the applications of remote sensing and GIS.

Section: B

Note: A) Answer any five questions in about 10 lines each.
B) Each question carries 5 marks.

7. Explain the Geophysical methods employed for location of petroleum deposits.
8. Explain the pathfinder element.
9. What are gossans?
10. Explain the importance of En-echelon Structure in mineral exploration.
11. What is the Concept of mineral economics?
12. Write about the classification of war minerals.
13. What is the effect of atmospheric pollutants on human health.
14. Classify the natural resources with examples.
15. Explain the scope of computers in geology
16. Explain the Dublin principles and watershed management.

* * *

FACULTY OF SCIENCE
THIRD YEAR (3 YEAR DEGREE COURSE) EXAMINATION
MODEL QUESTION PAPER
Assignment - I

GEOLOGY

Course – IV Mineral Exploration, Mineral Economics and Advanced Aspects

I. Answer the following questions in about 30 lines each.

1. Describe the basis for geophysical prospecting and outline the scope of methods briefly.
2. Describe briefly the importance of drilling in mineral exploration, mention various methods and types of drills.
3. Minerals that are present and their relative proportions serve as practical guides in ore search. Discuss.

II. Answer the following questions in about 10 lines each.

1. Describe the Geobotanical guides.
2. Explain the pathfinder element.
3. What is Limonite Boxwork?

* * *

FACULTY OF SCIENCE
THIRD YEAR (3 YEAR DEGREE COURSE) EXAMINATION
MODEL QUESTION PAPER
Assignment - II

GEOLOGY

Course – IV Mineral Exploration, Mineral Economics and Advanced Aspects

I. Answer the following questions in about 30 lines each.

1. Elaborate the basic principles of mineral economics and show its importance in national economy.
2. Explain the mineral resources of Andhra Pradesh.
3. Explain the conservation measures of minerals

II. Answer the following questions in about 10 lines each.

1. What are Manganese nodules? Explain.
2. Explain the application of strategic minerals in war.
3. Describe the Petroleum resources of Andhra Pradesh.

* * *

FACULTY OF SCIENCE
THIRD YEAR (3 YEAR DEGREE COURSE) EXAMINATION
MODEL QUESTION PAPER
Assignment - III

GEOLOGY

Course – IV Mineral Exploration, Mineral Economics and Advanced Aspects

I. Answer the following questions in about 30 lines each.

1. Discuss the geological conditions that contribute towards the stability of a bridge.
2. What are the objectives of watershed management. Make a schematic mention about the methodology and action plan for natural resources management.
3. What is Geographic Information Systems (GIS)? Explain the contributing disciplines.

II. Answer the following questions in about 10 lines each.

1. What are mantle plumes? What is their role in the plate tectonics?
2. Describe the impact of CO₂ on global climate with reference to greenhouse effect.
3. Explain the scope of computers in geology.

* * *

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are having almost similar characters. IRS P4 is an oceanographic satellites which is discussed in the following section IRS has application potential in a wide range of disciplines such as management of agricultural resources, inventory of forest resources, geological mapping, estimation of water resources, study of coastal hydrodynamics and water quality surveying.

The sensor payload system consists of two push-room cameras (LISS-II) of 36.25 m resolution and one camera (LISS-I) of 72.5 m resolution employing linear Charge Coupled Device (CCD) arrays as detectors Each camera system images in four spectral bands in the visible and near IR region. The camera system consists of collecting optics, imaging detectors, in-flight calibration equipment and processing devices.

21.4.4 System overview of IRS—ID

The IRS-ID is a three axes body stabilised satellite, similar to IRS-1 C. Since IRS-1C and ID are similar in respect of orbital characteristics and sensor capabilities, the details of IRS ID are discussed as it is very recent satellite. It will have an operational life of three years in a near polar, sun synchronous orbit at a mean altitude of 780 Km. The payload consists of three sensors, namely, Panchromatic camera (PAN), linear imaging and self scanning sensor (LISS-III) and wide Field sensor (Wifs).

The satellite is equipped with an On-Board Tape Recorder, capable of recording limited amount of specified sensor data. Operation of each of the sensor can be programmed. The payload operation sequence for the whole day can be loaded daily on to the on-board command memory when the satellite is within the visible range. The second segment consists of:

1. A Telemetry Tracking and Command (TTC) segment comprising of a TTC network.
2. An Image segment comprising of data acquisition, data processing and product generation system along with data dissemination centre. The over view of IRS-ID mission is to provide optimum satellite operation and a mission control centre for mission management, spacecraft operations and scheduling. The sensor characteristics of PAN, LISS III and Wifs are given below, as they are very latest sensors.

Panchromatic camera (PAN) : The panchromatic camera provides data with a spatial resolution of 5.2 – 5.8 m (at nadir) and a ground swath between 63 km-70 km (at nadir). It operates in the 0.5- 0.75 microns spectral band. This camera can be steered upto $\pm 26^\circ$ (storable upto ± 398 km across the track from nadir), which in turn increases the revisit capability to 3 days for most part of the cycle and 7 days in some extreme cases.

Linear Imaging and Self Scanning Sensor (LISS-III): The LISS III sensor provides multispectral data collected in four bands of the visible, near infra-red (V, NIR) and short wave infra-red (SWIR) regions. While the spectral resolution and swath in the case of visible (two bands) and NIR (one band) regions are between 21.2 m and 127 km – 141 km respectively. They are between 63.6 m to 70.5 m and 133 km to 148 km for the data collected in SWIR region.

Wide Field Sensor (WIFS): WiFS sensor collects data in two spectral bands and has a ground swath between 728 km to 812 km with a spatial resolution of 169 m to 188 m.

21.4.5. Ikonos Satellite

Ikonos Satellite launched on September 24th, 1999 by U.S.A using Athena II launch manufactured by Lockheed marthin from Vandenberg. Air Force base, California. This is a

very recent satellite with high resolution than other existing satellites. The revisit time will be more frequent for higher latitudes and less frequent for latitude closer to the equator. The spatial resolution of IKONOS satellite data is 1 m x m, which is very powerful, and useful data for urban and other studies.

Check Your Progress

- Note: (a) Write your answers in the space given below.
(b) Compare your answers with the model answers given at the end of this unit.

1. What is Remote Sensing?

2. Name any two satellites.

21.5 GEOGRAPHICAL INFORMATION SYSTEM (GIS)

To answer apparently simple geographical questions like: What is the population of a particular city? What are the characteristics of the soils in a particular land? Are there any trends in the patterns of earthquakes in India which could help to predict future quakes? How has the distribution of urban and rural population changed between the past two censuses? All these questions are pertinent and require the proper and accurate data derived from several sources, and are integrated into a consistent form. The art of science, engineering and technology required to answer these geographical questions constitute the Geographical Information System (GIS). GIS is a generic term denoting the use of computers to create and depict digital representations of the Earth's surface. GIS is defined as computer based information system to store, retrieve, analyse, manipulate and display spatial information.

21.5.1 Overview of Information System

GIS might provide the medium for studying one or more of the fundamental issues that arise in using digital information technology to examine the surface of the earth or any related systems. The Resource Information System (RIS) for agricultural management, for instance, has to be considered multidimensional with attribute dimension, spatial dimension and temporal dimension. Geographic Information System (GIS) offers capabilities of integrating

21.5.5 Components of a GIS

Geographical Information Systems have three important components, namely, computer hardware, sets of application software modules, and a proper organisational set up. These three components need to be in balance if the system is to function satisfactorily. GIS run on the whole spectrum of computer systems ranges from portable personal computers to multi-user supercomputers, and are programmed in a wide variety of software packages. Systems are available that use dedicated and expensive workstations, with monitors and digitising tables built in. In all cases, there are a number of elements that are essential for effective GIS operations. These include

- (i) the presence of a processor with sufficient power to run the software
- (ii) sufficient memory for the storage of large volumes of data
- (iii) a good quality, high resolution colour graphics screen and
- (iv) data input and output devices, like digitisers, scanners, keyboards, printers and plotters.

The general hardware components of a GIS include control-processing unit. Which is linked to mass storage units, such as, hard disk drives and tape drives peripherals such as digitiser or scanner, printer or plotter and Visual Display Unit (VDU). Fig.21.12 shows the major hardware components of a GIS.

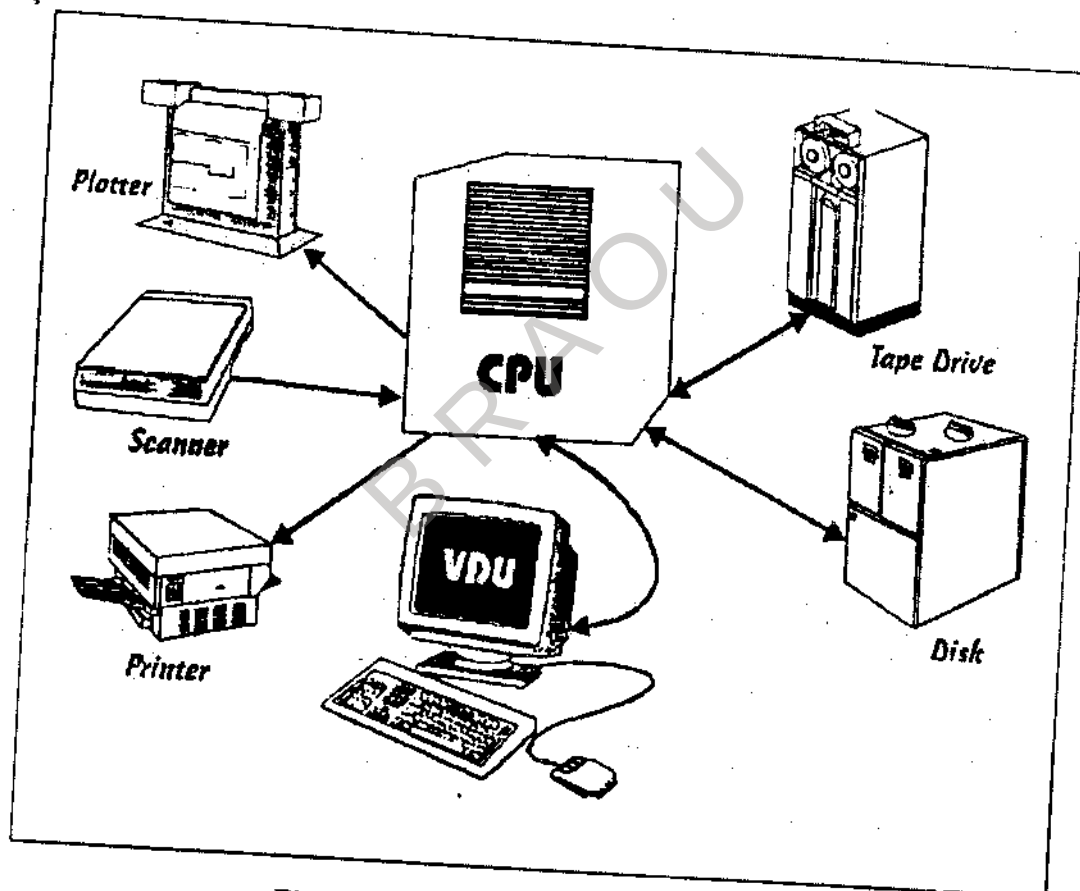


Fig. 21.12 Hardware components of GIS.

There are a number of essential software elements that must allow the user to input, store, manage, transform, analyse and output data. Therefore, the software package for a GIS consists of four basic technical modules. These basic modules are (i) data input and verification, (ii) data storage and database Management, (iii) data transformation and

manipulation, and (iv) data output and presentation. The GIS software package should have the capabilities performing all the four GIS subsystems. The GIS hardware and software govern the way in which geographical information can be processed but they do not themselves guarantee that any particular GIS will be used effectively.

21.5.6 GIS Data Models

Spatial analysis is a technology, which typically requires two types of information about spatial objects: attribute, and geographical or locational information. Given the diversity of analytical perspectives within GIS, it is difficult to define spatial data analysis. The results of such analysis depend upon the spatial arrangement of events. Events may be represented as geographical entities associated with the attributes. This section highlights these two types of information and their relationships. To the query, where the particular object is with respect to any co-ordinate system, the answer is the spatial or geographical or locational information. To the query, what that particular object is, the answer is the attribute data. Alternatively, it can be noted that the GIS consists of two types of data: spatial and attribute.

The spatial data refers to the spatial locational information with respect to a defined co-ordinate system. In GIS, the spatial data may be modelled in the form of vector model or a raster model. The characteristics of these locational features are termed as attributes data. The raster data is grid cell based ways, namely, GRID model, IM-GRID Model and MAP Model. The vector data consists of three kinds of cartographic symbols, namely, point, line and 0.

'Entities' are things in the real world. 'Objects' are things in the digital world. Digital objects and associated attributes and values represent geographical entities. The distinction between entity and objects makes explicit the difference between things and their representations in a formal system. The entity or the field model is more appropriate and are particularly interesting for topographic elevations. Topographic data normally are represented in GIS as fields, either through grid based digital elevation models (DEMs) or as triangular tessellation. Robinson (1958) identified four kinds of geographical quantities. They are point, line, area, and volume. There are three kinds of cartographic symbols: point, line, and area. Robinson discusses 2-dimensional data on 'Mapping quantitative point, line, and area data', and separates volume data under the title 'Mapping 3-dimensional data'.

The frequency of geographical entities with indistinct boundaries has been known for some time; yet vector GIS is tuned to represent entities with crisp boundaries: whereas raster GIS does not represent entity boundaries at all. Thus, formal methods: for the representation of geographical entities with uncertain or graded boundaries is an important new area of study in GIS. Fuzzy set theory represents a possible approach to modelling entities with graded boundaries, but it has problems. Geographical entities and classification of geographical entities into categories is a well-known process both in everyday thinking and in scientific work. Various sub fields of geography have developed elaborate classifications for landforms, vegetation assemblages, and settlements. In brief, we can note that locational information about the spatial objects of concern is generally described by means of their position on a map or geographical co-ordinate systems.

Attributes: Attributes are the characteristics of the map features and holding of the descriptive information about the geographic features. Attributes are the non-spatial data associated with time and area entities. They are considered characteristics of entity. The GIS attributes are represented using colours, textures, and linear or graphic symbols like the gardens. The parks are shaded green. The church locations are designated using the special

symbol. The bus routes are drawn with specific line width and style as broken lines of 12 point's width. Contour lines are brown in colour, and so on. The actual value of the attribute that has been measured (sampled) and stored in the database is called attribute value. A classical example of attribute data associated with spatial entities of the environs of Hussain Sagar in Hyderabad may tell us that, a point represents a hotel, a line represents the road and area represents the boundaries of the lake. Each spatial entity may have more than one attribute associated with it; that is, a point representing the hotel may have a number of rooms, standard of accommodation and other related information.

Broadly speaking two types of attributes may be distinguished: **primary attributes** and **secondary attributes**. Socio-economic characteristics and physical properties of objects are some of the examples of primary attributes. Flows of Information levels, districts, capitals and mandal names are considered secondary attributes.

Topology: In GIS, topology is the term used to describe the geometric characteristic of objects, which do not change under transformations and are independent of any co-ordinate system. The topological characteristics of an object are also independent of scale of measurement. Topology as it relates to spatial data consists of three elements, namely, adjacency, containment and connectivity. Topology may be defined as constituting those properties of geometrical figures that are invariant under continuous deformation. Broadly topology can be explained any two ways. Firstly, topologically spatial relationships with the entity, which are learned by human beings at a very early age. Secondly, topology consists of metric aspects of spatial relations, such as, size, shape, distance and direction. Many spatial relations between objects are topological in nature, including adjacency, containment and overlap.

Adjacency and containment describe the geometric relationships, which exist between area features. Areas can be described as being adjacent when they share a common boundary. For example, boundary of the area of Municipal Corporation of Hyderabad and Secunderabad is common, or may be adjacent. Containment is an extension of the adjacency that describes area features, which may be wholly contained within another area feature such as an island within a lake. Connectivity is a geometric property used to describe the linkages between line features like road network. The geometric relationship between spatial entities and corresponding attributes are very crucial for spatial analysis and integration in GIS.

In other cases, metric properties, such as, distance or direction, expressed either quantitatively or qualitatively, may determine the meanings of various terms, for example, both 'north of any 'near' normally refine the 'disjoint' topological relation, and are ill-defined for non-disjoint entities. Spatial relations between disjoint entities, which neither touch nor overlap, are characterised by a system of distinctions that is, essentially independent of the system used to describe and classify spatial relations for non-disjoint entities. Some of the spatial relations between disjoint objects are distance, direction, and reference frames.

Distance may be pure Euclidean distance. In natural language 'hedge' words such as 'about' are often associated with approximate numerical distance. Distance may be given in qualitative rather than metric terms, dividing distance into just three categories: 'at', 'near', and 'far'. Direction may be either qualitative or quantitative. Direction is an orientation specified relative to some reference frame. Directional relations are thought of as being between points. Directions are not so straightforward between spatially extended entities, since a large range of directions may exist, between any point in one entity and any point in the other. Reference frames are used in discourse and spatial reasoning. Geographically, in many cultures, a

reference frame based on cardinal directions seems, dominant for geographical spaces, whereas viewer-centred or object-centred reference frames often dominate over bodily or tabletop ('manipulatable') spaces and entities.

Cognitive Models

Both entities and fields exist in cognitive models. Entities are typically conceptualised as being organised by dimensionality in points, lines, areas and volumes. Entities often have indistinct boundaries, a fact, which is at odds with typical GIS representation schemes. Entities are also categorised, and since many aspects of nature form a continuum, categories may be relatively arbitrary and thus subject to disparate cultural differences. Spatial relations, on the other hand, seem to be very similar in disparate cultures and languages. Cognitive spatial relations are predominantly topological but metric factors such as distance and direction often refine the relations and characterise prototypical relations.

There is a very real sense in which all representations are cognitive. Mathematics is, after all a formalisation of how at least some people think. The cognitive view of spatial relations, however, emphasises the importance of human subjects being testing, preferably under laboratory-controlled conditions, in defining the nature of the spatial representations that are needed for geographical information systems and spatial analysis. Many geographical distributions, such as, those of soil variables are inherently complex, revealing more information at higher spatial resolution apparently without limit. Geographical data modelling is the process of discretisation that converts complex geographical reality into a finite number of database records or objects. Objects have geographical expressions points, lines, and also possess descriptive attributes, for example, collection of water samples from different wells, in which the location of the well creates point object (with the address of the location) and associated water quality parameter is its attribute value. A major difficulty arises in the case of the object models. Many geographical objects have inherently fuzzy spatial extents. One common solution to this problem is to allow objects to have multiple representations, which depend on the scale. For example, a river might be a single line at scales smaller than 1:50,000, but a double line at larger scales.

Six field models are in common use in GIS: (i) irregular point sampling, (ii) regular point sampling, (iii) contours, (iv) polygons, (v) cell grid modelling, and (vi) triangular network models. The object models are commonly used to represent man-made facilities. For example, an underground pipe more naturally represents as a linear object than as a value in a layer. Pipes can cross each other in object model, but cause problems in a field model.

Check Your Progress

- Note a) Space is given below to write your answer.
b) Compare your answer with the one given at the end of the unit.

3. What is GIS?

4. What are the hardware components of GIS?
-
-
-
-

21.6 SUMMARY

Remote sensing is an art, science and technology of obtaining reliable information about an object, environment and any phenomenon by recording and measuring electromagnetic energy through a device which is not in the touch with the object. Remote sensing can be broadly explained by means of data acquisition, data analysis, and ground truth data analysis. In remote sensing two types of data products are available, namely pictorial data and digital data. The pictorial data is analysed using visual image processing technique and digital data can be analysed using digital image processing technique. There are number of digital image processing software like ERDAS, EASI/ PACE, ENVI and IDRISI for digital data analysis. For validation of data ground truth investigations are must. The output of VIP and DIP are thematic maps and can be considered as one layer of information, which is input to GIS.

There are three distinct groups of earth resources satellites. The first group of satellites record visible and near visible wavelengths. Landsat series of satellites are examples. The second group of satellites carries sensors that record thermal infrared wavelengths; the IRS series and SPOT satellite series are examples. Group three satellites record microwave lengths. The sea sat series and ERS are examples.

GIS is defined as computer based information systems to store, retrieve, analyse, manipulate and display spatial information. GIS might provide the medium for studying one or more of the fundamental issue that arise in viewing digital information about the surface of the earth or any related systems. There are four key activities in GIS. Those are measurement, mapping, monitoring and modelling. GIS technology is more different and needs mathematical knowledge for the analysis. The GIS development needs knowledge from different disciplines, namely geography, cartography, CAD computer software, automated cartography, mathematics, statistics surveying, photogrammetry, digital photogrammetry and remote sensing. The components of GIS are CPU, VDU, plotter, scanner, printer tape drive and disk drive. The software package of GIS consists four basic technical modules namely data input and verification, data storage and management, data transformation and manipulation and data output and presentation.

21.7 CHECK YOUR PROGRESS - MODEL ANSWERS

1. Remote sensing is defined as an art, science and technology of obtaining reliable information by recording electromagnetic energy without touching the object.
2. Indian remote sensing satellite (IRS) land sat satellite, IKONOS satellite.
3. GIS is defined as computer based information system to store, retrieve, analyse, manipulation and display spatial information

4. CPU, VDU, plotter, scanner, printer tape drive and disc drive.

21.8 MODEL EXAMINATION QUESTIONS

I. Answer the following in about 30 lines each.

1. What is remote sensing? Explain remote sensing physics.
2. Describe the remote sensing platform and sensor.
3. What is Geographic Information Systems (GIS)? Explain the contributing disciplines.
4. What are the components of GIS? Explain the data models of GIS.

II. Answer the following questions in about 10 lines each.

1. Electromagnetic spectrum.
2. Characteristics of sensing systems.
3. The four MS in GIS.
4. GIS Architecture.

BRAOU

UNIT-22 REMOTE SENSING AND GIS APPLICATIONS

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22.0 OBJECTIVES

In this unit, applications of remote sensing and GIS are discussed.

After studying this unit, you will be able to

- explain the synergy between Remote Sensing and GIS.
- describe the integration of RS data in GIS platform and spatial characteristics.
- explain the GIS database can be created for any project along with analysis tools.
- describe the list of application areas.

22.1 INTRODUCTION

Remote Sensing and Geographical Information System (GIS) are linked both historically and functionally. In a historic context, some of the early work leading to the development of GIS revolved around methods to provide better access to aerial photographic coverage of specific areas. GIS facilitates the storage of and the access to many diverse data types. GIS, correctly employed, also permits the data held within a database to be readily updated. The synergy that exists between remote sensing and GIS technologies is built on the foundation that, for many applications, remote sensing can be employed effectively and efficiently to update GIS data layers. Such data layers in a GIS can, appropriately employed, improve the interpretability and information extraction potential has remotely sensed data. Earlier studies on the application of GIS technique for creating decision support systems and other computer based spatial information extraction have revealed that 75% to 85% of the spatial data layers have been derived from the analysis of aerial photographs and satellite image data. As a result of

this, remote sensing and GIS have become very important and have been associated with each other.

This unit focuses upon the importance of remotely sensed data as an input to GIS, and describes some of the ways in which they may be managed for operational use. Key characteristics and source of remotely sensed data commonly employed as input to GIS are described, as key minimum set of GIS facilities required to support the use and effective management of remote sensing data. In short, this chapter is designed to inform managers of the sources and potential of remotely sensed data so that they can discharge their responsibilities for monitoring or operations with maximum effectiveness but at minimum cost.

Remote sensing data can be readily merged with other sources of geo-coded information in a GIS. This permits the overlapping of several layers of information with the remotely sensed data, and the application of a virtually unlimited number of forms of data analysis. On the one hand, the data in a GIS might be used to aid in image classification; on the other hand, the land cover data generated by a classification (through VIP and DIP) might be used in subsequent queries and manipulations of the GIS database. Remotely sensed data is almost always processed and stored in raster data structures. When working simultaneously with an image processing system and raster geographic information system, it is usually easy to move data between the two. Typically, a single theme of information is extracted from the remotely sensed data. The combination of image processing and GIS technologies is astounding. As indicated earlier, they both are coming closer and it is now becoming extremely difficult to differentiate each other. The hardware was almost similar, and now software is being integrated. The problem of transfer of data is also being circumvented. Private companies are combining their efforts in this direction.

22.2 REMOTE SENSING AND GIS SYNERGY

The relationship between remote sensing and GIS has received considerable attention in literature and, indeed, remains the subject of a continuing discussion. Much of this discussion revolves around the scientific and technical issues relating to integration of the two technologies. Remotely-sensed images can be used both as a source of spatial data within GIS and to exploit the functionality of GIS in processing remotely sensed data. Despite this, the actual progress towards the goal of full integration is surprisingly slow. While this is undoubtedly due to the technical challenge of accessing, manipulating, and visualising vector, raster, and tabular data simultaneously, it seems unlikely that technical constraints have been the sole barrier to achieving full integration. It might be argued that competing imperatives in both remote sensing and GIS have tended to draw attention away from the issue of integration. The recent focus on monitoring global environmental change using coarse spatial resolution sensors and the assimilation of the data that they produce in various environmental simulation models has deflected some of the attention away from the traditional issues of large-scale mapping. These are more closely allied to the concerns and use of GIS. Similarly, one can see a number of other developments in the application of multimedia technology within GIS that have consumed much of the research and development effort in the field of GIS.

There are at least two reasons why the issue of integration is likely to receive fresh impetus in the near future. The first is the increasing availability of data from the very high spatial resolution as well as commercial satellites that are scheduled for launch over the next few