7

EARTH'S INTERIOR AND MATERIALS OF ITS CRUST

7.1 INTRODUCTION

Perhaps the earth is the only known planet with developed life in the universe. Like most of the celestial bodies, the earth is spherical in shape. You also know that hot water and molten lava eject out from the earth's interior. This indicates that the temperature below the earth's surface is very high. World's deepest mining is limited only to the depth of less than 5 kilometers. These activities can be explained by getting a better understanding of the Earth's interior. In this lesson, we will study about the earth's interior and the materials that form the upper portion of the earth's crust.

7.2 OBJECTIVES

After studying this lesson you will be able to :

- explain the limitations of direct observations of the earth's interior;
- interpret the diagram showing layers of the earth's interior;
- Compare the different layers of the earth's interior with reference to thickness, temperature, density and pressure;
- distinguish between rock and mineral;
- classify rocks according to their mode of formation;
- highlight the characteristics of each type of rock;
- describe the economic significance of rocks.

7.3 EARTH'S INTERIOR

It is not possible to know about the earth's interior by direct observations because of its huge size and the changing nature of its internal composition. Through mining and drilling operations we have been able to observe the earth's interior directly only upto a depth of a few kilometers. The rapid increase of temperature below the earth's surface is mainly responsible for setting a limit to direct observation inside the earth. The temperature in the earth's interior is so high that it can even melt any tool used for drilling. This fact also restricts deep drilling, thus causing hindrance to direct observation of the materials of the earth's interior.

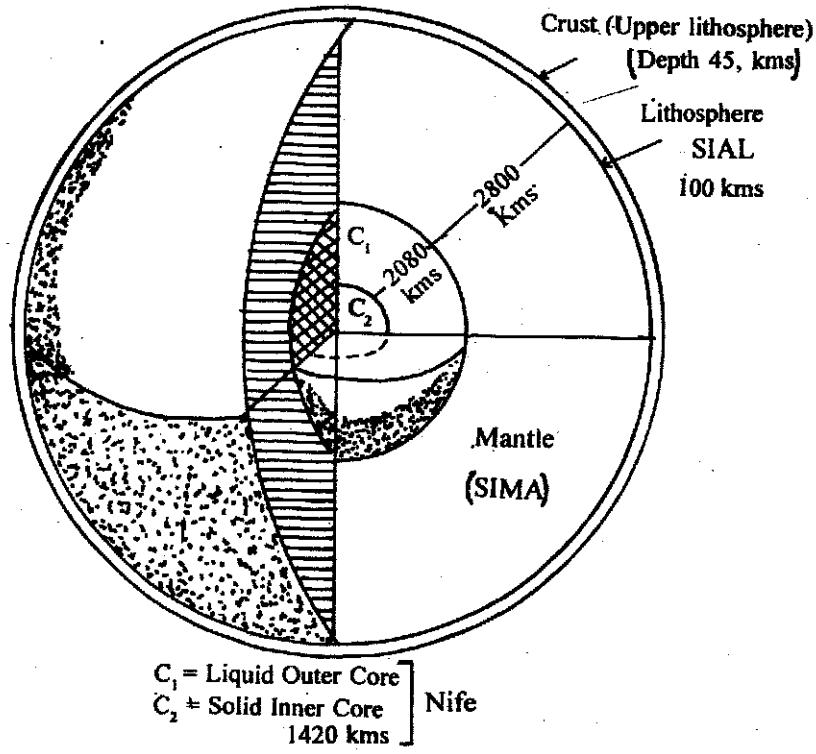

Fig. 7.1 Concentric Zones showing layers of the Earth's interior

The huge size of the earth and increasing temperature with depth has set a limit to direct observation of the earth's interior.

7.4 STRUCTURE OF THE EARTH'S INTERIOR

The above diagram (see fig. 7.1) shows the concentric layers of the earth's interior. The innermost layer surrounding the earth's centre is called core. Core is the most dense layer of the earth with its density more than 11.0. It is composed mainly of the iron and nickel thus commonly known as *Nife*. (Nickel+Ferrum). Core consists of two sub-layers. The inner one is solid (C_2 of fig. 7.1) and the outer one is semi -

liquid (C_1 of fig. 7.1). The layer surrounding the core is known as mantle, and is composed of basic silicates. Major constituent elements of mantle are magnesium and silicon, hence, this layer is termed as *Sima* (Silica+Magnesium). The density of this layer varies from 3.1 to 5.1. Mantle is surrounded by the outermost layer of the earth, known as lithosphere and its density varies from 2.75 to 2.90. Major constituent elements of lithosphere are silica (Si) and aluminium (Al), thus this layer is termed as *Sial* (Silica+Aluminium). The outermost part of the lithosphere in known as crust.

* Core, mantle and lithosphere are the three main concentric layers of the earth's interior.
* Core is the innermost layer and has the highest density. It is made up mainly of nickel and iron.
* Mantle is the layer lying between the core and lithosphere. Its major constituents are silicon and magnesium.
* Lithosphere is the outermost layer of the earth and is mainly composed of silicon and aluminium.

INTEXT QUESTIONS 7.1

1. Give the most important factor limiting direct observation of the earths interior to a few kilometers _____.
2. Name the three layers of the earth's interior.

   (a)_____ (b)_____ (c)_____.
3. Name the innermost layer of the earth.

   _____.
4. What is the density of the core?

   _____
5. Which layer includes the earth's crust?

   _____.
6. Name the thinnest layer of the earth

   _____.

7.5 TEMPERATURE, PRESSURE AND DENSITY OF THE EARTH'S INTERIOR

(i) Temperature

Rise in temperature with increase in depth is observed in mines and deep wells. These evidences along with molten lava erupted from the earth's interior support that temperature increases towards the centre of the earth. The different observations

show that the rate of increase of temperature is not uniform from the surface towards the earth's centre.

It is faster at some places than at others. In the beginning this increase is at an average rate of 1°C for every 32 metres increase in depth. At such a constant rate of increase in temperature, at 10 km depth, the temperature will be approximately 300°C and at 40 km depth it will be 1200°C. At this rate, earth's interior should be in a molten state. Yet it is not so because the rocks buried under the pressure of several km thickness of overlying rocks melt at higher temperature than similar rocks at the surface. A basaltic lava rock which melts at 1250°C at the surface will melt at 1400°C at 32 km depth. The extra heat required for melting is produced by radioactivity. It is the result of breakdown of atomic nuclei of minerals emitting radiant energy in the form of heat from the rocks.

The behaviour of earthquake waves is another evidence for this phenomenon. They further confirm that the composition of different layers is as variable as is the rate of change of temperature. While in the upper 100 km, the increase in temperature is at the rate of 12°C per km, in the next 300 km it is 20°C per km but is only 10°C per km below it. Thus the rate of increase of temperature beneath the surface decreases towards the centre. The temperature at the centre is about 2000°C.Such a high temperature inside the earth may be due to chemical reactions under high pressure conditions and disintegration of radio active elements.

(ii) Pressure

The pressure also increases from the surface towards the centre of the earth due to huge weight of the overlying rocks. Therefore in deeper portions, the pressure is tremendously high. The pressure near the centre is considered to be 3 to 4 million times the pressure of atmosphere at sea level. At high temperature, the material beneath will melt towards the central part of the earth. This molten material under tremendous pressure conditions acquires the property of a solid and is probably in a plastic state.

(iii) Density

Due to increase in pressure and presence of heavier materials towards the earth's centers, the density of earth's layers also goes on increasing. Obviously the materials of the innermost part of the earth is very dense as already stated.

INTEXT QUESTIONS 7.2

1. What is the temperature at the centre of the earth?

2. How much is the pressure at the earth's centre?

3. Why does the density increase towards the centre of the earth?

7.6 MATERIALS OF THE EARTH'S CRUST

The outermost part of lithosphere is called crust. This is the most significant part of the earth because it is occupied by human. The material of the crust is made up of rocks. The rocks are of different types. They are hard like granite, soft like clay and loose like gravel. Rocks have a great variety of colour, weight and hardness.

Rocks are composed of minerals. They are aggregates or physical mixture of one or more minerals. Minerals on the other hand are made up of two or more elements in a definite ratio. They have a definite chemical composition. Crust is made up of more than 2000 minerals, but out of these, 6 are the most abundant and contribute the maximum to this uppermost part of the earth. These are feldspar, quartz, pyroxenes, amphiboles, mica and olivine.

Granite is a rock and its constituent minerals bound together are quartz, feldspar and mica which make it a hard rock. Change in the ratio of these minerals give rise to granites of different colours and hardness. The minerals containing metals are called metallic minerals. Haematite, a major iron ore is a metallic mineral. Ores are metallic minerals which can be profitably mined. Rocks are of immense economic importance to us.

* Rock is an aggregate or physical mixture of one or more minerals, forming the solid part of the earth's crust.
* Mineral is a naturally occurring inorganic substance which possesses certain physical properties and has a definite chemical composition.

7.7 TYPES OF ROCKS

Rocks differ in their properties, size of particles and mode of formation. On the basis of mode of formation rocks may be grouped into three types :

(a) Igneous

(b) Sedimentary and

(c) Metamorphic

(a) IGNEOUS ROCKS

The word igneous is derived from the Latin word 'ignis' meaning fire. Igneous rocks are formed by the cooling of highly heated molten fluid material, known as magma. The word magma is derived from a Greek word which means 'dough'. It requires a greater quantity of heat to melt the rocks under overlying pressure than at the surface. We do not know the exact depths at which magma forms but probable it is formed at different depths not exceeding 40 km. Molten rocks produce an increase in volume which is responsible for causing fractures or cracks in the crust. The overlying pressure gets weakened along these openings, thus forcing out the magma through them. Otherwise it can't escape due to great overlying pressure.

When magma is ejected to the surface, it is called lava. Igneous rocks are formed from solidified molten magma below or on the earth's surface. As they comprised

the earth's first crust and all other rocks are derived from them, these are called the parent of all rocks or the 'primary rocks'. In simple words, all rocks can be described as of igneous origin because at one time or another, they were erupted to the surface. A younger series of igneous rocks is still being formed. About 95% of the volume of outermost 16 km of the earth is composed of them. These are largely hard and massive because of their magmatic origin and are crystalline in appearances.

On the basis of their mode of occurrence, igneous rocks can be classified as : extrusive or volcanic rocks and intrusive rocks.

(i) Extrusive igneous rocks are formed by cooling of lava on the earth's surface. As lava cools very rapidly on coming out of the hot interior of the earth, the mineral crystals forming these rocks are very fine. These rocks are also called volcanic rocks. Gabbro and basalt are very common examples of such rocks. These rocks are found in volcanic areas. Deccan plateau's regur soil in India is derived from lava.

(ii) Intrusive igneous rocks are formed when magma solidifies below the earth surface. The rate of cooling below the earth's surface is very slow which gives rise to formation of large crystals in the rocks. Deep seated intrusive rocks are termed as plutonic rocks. Granite and dolerite are common examples of intrusive rocks. The huge blocks of coarse granitic rocks are found both in the Himalayas and the Decean Plateau.

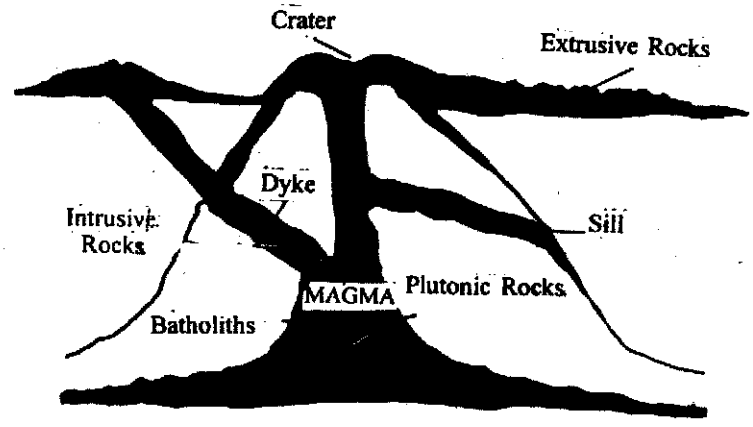

Fig. 7.2 Igneous Rocks

Let us look at the Fig. 7.2. It illustrates that magma on cooling produces rocks of different shapes and sizes depending on the space available after it forces itself into the crust. Common forms of instrusive igneous rocks are batholiths, sills and dukes etc. Batholiths are huge masses of solidified magma. They vary in size; some are as much as several hundred kilometers across and thousands of kilometers thick. They generally form the core of the major mountains, as shown in this diagram. Their irregular dome shaped roofs sometimes appear on the surface after erosion of millions of years. *Sill* is the horizontal intrusion of solidified magma between the layers of pre-existing rocks. *Dyke* is similarly a more or less vertical formation

from few metres to several kilometers in length and from few centimeter to hundreds of metres in thickness.

On the basis of chemical properties, igneous rocks are classified into acidic and basic rocks. These are formed as a result of solidification of acidic or basic lava. Acidic igneous rocks are composed of 65% or more of silica. These rocks are light coloured, hard and very strong. Granite is an example of an acidic rock. Basic igneous rocks contain less than 55% of silica and have more of iron and magnesium. These rocks are dark coloured and weak enough for weathering. Gabbro, basalt and dolerite are examples of basic rocks.

* Igneous rocks are formed by the solidification of hot molten material called magma or lava.
* Extrusive igneous rocks are formed by cooling of lava on the earth surface e.g. basalt, gabbro.
* Instrusive igneous rocks are formed by solidification of magma below the earth's surface, e.g. granite.

INTEXT QUESTIONS 7.3

1. Define the term mineral.

_____

2. Give the names of any three minerals which are found extensively on the earth's crust.

_____

3. Give a term for each of the following :

(i) Deep seated intrusive igneous rock.

_____

(ii) A hot sticky molten material erupted on the earth's surface.

_____

4. How are dykes and sills formed ?

(i)

_____

(ii)

_____

5. Tick (✓) the correct answer

(i) Igneous rocks are formed due to

(a) cooling (b) heating (c) neither cooling nor heating

(ii) Which one of the following is an example of intrusive igenous rock?

(a) Granite (b) Basalt (c) Gabbro

(iii)Primary rocks are the result of

(a) sedimentation (b) solidification (c) metamorphism

(b) SEDIMENTARY ROCKS

These rocks are formed by successive deposition of sediments. These sediments may be the debris eroded from any previously existing rock which may be igneous rock, metamorphic or old sedimentary rock. Sedimentary rocks have layered or stratified structure. The thickness of strata varies from few millimeters to several metres. So these rocks are also called stratified rocks. Generally, these rocks have some type of fossil between their strata. Fossil is the solid part or an impression of a prehistoric animal or plant embedded in strata of sedimentary rocks. Sedimentary rocks are widely spread on the earth surface but to a shallow depth.

The individual rock particles are first broken from rocks and then transported by running water, ocean currents, glaciers or even by wind from one place to another. The process by which rock forming material is laid down is called sedimentation or deposition. It may settle in calmer waters of lakes or oceans or at places where the transporting agent has no longer enough energy to carry them farther. These are identified as riverine, lacustrine (formed by lake), glacial or aeolian (formed by wind) sedimentary rocks with reference to their deposition near rivers, lakes, glacier or deserts respectively.

The sediments are often loose, unconsolidated, soft rock material, in the beginning like sand and clay, but in course of time they get hardened to a compact material by excessive pressure and cementation to form sedimentary rocks. The deposition of sediments in the beginning is generally horizontal but it may get tilted afterwards due to movements in the earth's crust. Sandstone, shale, limestone and dolomite are examples of sedimentary rocks.

Sediments get sorted by the transporting agents. Sediments of different sizes may get bound by cementing material under suitable conditions. Conglomerate is an example of such a sedimentary rock. This type of formation of consolidated material is termed as mechanically formed sedimentary rock. The consolidation of organic matter derived from plants and animals forms sedimentary rocks of organic origin. Coal and limestone are organic sedimentary rocks. The sediments may also result from chemical reaction. Direct precipitation of minerals from their solution in water may give rise to sedimentary rocks of chemical origin. Gypsum, rock salt and nitre are examples of such sedimentary rocks.

Huge folded mountains of the world like Himalayas, Andes etc. are made up of sedimentary rocks. All the alluvial deposits of the world are also due to sedimentary accumulations. All river basins, particularly their plains and deltas, e.g. Indo- Gangetic plain and Ganga-Brahmaputra delta are good examples of sedimentary accumulations.

* Sedimentary rocks are formed by the successive deposition of sediments.
* These rocks have layered structure, therefore they are also known as stratified rocks.
* Fossil is the solid part or an impression of a prehistoric animal or plant embedded in sedimentary rocks in which they are buried.

(c) METAMORPHIC ROCKS

Most rocks in mountainous regions show an evidence of change. All these in course of time become metamorphic or changed forms of rocks. Metamorphic rocks are formed under the influence of heat or pressure on sedimentary or igneous rocks. Tremendous pressure and high temperature change the colour, hardness, structure and composition of all types of pre-existing rocks. The process through which original rock is changed to metamorphic rock either due to heat or pressure or both is known as metamorphism or 'change of form'.

Heat causes the minerals to recrystallise in the rock. The process of change by heat is called thermal or contact metamorphism. When molten magma or lava comes in contact with surrounding rocks it bakes them and changes them into metamorphic rocks. Similarly the formation of metamorphic rocks due to tremendous pressure is known as dynamic or regional metamorphism. Slate, gneiss, schist, marble and diamond are good examples of metamorphic rocks. Metamorphic rocks are hard and tough in comparison to the parent rocks from which they are formed. Examples of metamorphic rocks are given in the table 7.1 with their parent rock from which they have been formed.

Table 7.1

Showing Parent Rock and it Metmorphic Changed Form

NAME OF THE ROCK	TYPE OF ROCK	NAME OF THE MATAMORPHIC ROCK
Limestone	Sedimentary Rock	Marbles
Dolomite	Sedimentary Rock	Marble
Sandstone	Sedimentary Rock	Quartzite
Shale	Sedimentary Rock	Slate
Slate	Metamorphic Rock	Phylite/Schist
Coal	Sedimentary Rock	Graphite/Diamond
Granite	Igneous Rock	Gneiss
Phyllite	Metamorphic Rock	Schist

Different type of metamorphic rocks are found all over the world. In India, marble is found in Rajasthan, Bihar and Madhya Pradesh, whereas slates are available in plenty in Orissa, Andhra Pradesh and Haryana. In Kangra and Kumaun regions of Himalayas, slates of different colours are found.

* Metamorphic rocks are formed by the effect of heat or pressure on sedimentary or igneous or even metamorphic rocks
* Thermal metamorphism is the process by which a rock under-goes change as a result of great heat.
* Dynamic metamorphism is the modification of rock, by tremendous pressure during extensive earth movements.

7.8 ECONOMIC SIGNIFICANCE OF ROCKS

Man has been interacting with the surface of the earth since long. With time and advancement in technology he is making diffe ent uses of rocks and minerals. The importance of rocks is given below :

(a) **Soils :** Soils are derived from rocks. Soils provide food for mankind and other agricultural products are the base for many industries.

(b) **Building Material :** Rocks are the source of types of building material directly or indirectly. Granite, gneiss, sandstone, marble and slates are extensively used in the construction of buildings. Tajmahal is made of white marble, Red Forts of Delhi and Agra, are made of red sandstone. Slates are used for roof purposes in different parts of India.

(c) **Mineral Source :** Minerals are the foundation of the modern civilization. Metallic minerals provide all metals ranging from very precious gold, platinum, silver, copper to aluminium and iron. These metals are obtained from different rocks.

(d) **Raw Material :** Certain rocks and minerals are used as raw material for many industries. In cement industry and limestone kilns different type of rocks and minerals are used for production of finished goods. Graphite is used in crucible and pencil manufacturing as raw materials.

(e) **Precious Stones :** Precious stones and metals are obtained from different metamorphic or igneous rocks. Diamond is a precious stone used in jewelry and is a metamorphic rock. Similarly other precious stones like gems, rubies and sapphires are obtained from different type of rocks.

(f) **Fuel:** Fuel in the form of coal, petroleum, natural gas and nuclear minerals are derived from different rocks.

(g) **Fertilizer :** Fertilizers are also derived from some rocks. Phosphatic fertilizers are obtained from phosphorite mineral found in abundance in some parts of the world.

* Rocks and minerals are the main source of all metals, precious stones, solid, fuel and raw materials for industries.

INTEXT QUESTIOS 7.4

1. What is a fossil?

2. In which type of rocks fossils are found?

3. Give single term for each of the following

(i) Process of the formation of metamorphic rock due to pressure.

(ii) Rocks which contain strata.

(iii) Rocks formed by the effect of heat or pressure on sedimentary or igneous rocks.

(iv) Sedimentary rocks deposited in lakes

4. Tick (✓) the correct answer ;

(i) Marble is

(a) a sedimentary rock (b) an igneous rock (c) a metamorphic rock (d) a plutonic rock

(ii) An example of sedimentary rock is

(a) granite (b) marble (c) sandstone (d) basalt

WHAT YOU HAVE LEARNT

Earth is a spherical body. The direct observations into its interior are limited to a depth of a few kilometers. Temperature, pressure and density increase from the earth's surface to its centre. Earth's interior is divided into three concentric layers; lithosphere, mantle and core. Lithosphere is the thinnest and outermost layer, mantle is middle one whereas core is the innermost and the most dense layer of the earth. Uppermost part of lithosphere is known as crust. The material of the crust is composed of rocks. Rock is composed of one or more minerals. Minerals have a definite chemical composition. On the basis of their mode of formation, rocks are

classified into three types - igneous, sedimentary and metamorphic. Igenous rocks are formed by the solidification of molten lava or magma. Granite, basalt and gabbro are examples of igneous rocks. Molten material solidified beneath the earth's surface to form intrusive and above the earth surface to form extrusive igneous rocks. Sedimentary rocks are formed by the consolidation of sediments. These are layered and may contain fossils. Shale, limestone and sandstone are examples of sedimentary rocks. Metamorphic rocks are formed by the effect of heat or pressure on any pre-existing rock. Rocks are of immense use to us. They provide precious metals and stones, building material and fuel etc. for our use.

TERMINAL QUESTIONS

1. What are the limitations of direct methods in the determination of the earth's interior ?
2. Draw and label a diagram showing earth's interior and its density and depth of each layer.
3. Distinguish between a rock and a mineral with suitable examples.
4. Discuss the classification of various types of rocks on the basis of their mode of formation. Support your answer with examples.
5. Explain in brief the economic significance of rocks and minerals.
6. Compare the processes of formation of metamorphic and sedimentary rocks.

CHECK YOUR ANSWER

INTEXT QUESTIONS

7.1

1. Rapid increase of temperature below the earth's surface

2. (a) Lithosphere (b) Mantle (c) Core

3. Core or Nife

4. (i) More than 11.0

5. Lithosphere

6. Lithosphere

7.2

1. 2000°C 2. 3 to 4 million times the atmospheric pressure at sea level. 3. Due to immense pressure of overlying rocks and the presence of heavier materials.

7.3

1. Mineral is a naturally occurring inorganic substance which posseses physical properties and has a definite chemical composition. 2. Feldspar /Quartz/ Pyroxenes/Amphiboles/Mica/Olivine 3. (i) Plutonic rocks (ii) Lava 4. (i) When the magma cools in their sheets in vertical fractures within the earth's crust dykes are formed and (ii) when it solidifies in horizontal starta it is called a sill. 5. (i) cooling (ii) Granite (iii) Solidification

7.4

1. Fossil is the solid part or an impression of a prehistoric animal or plant embedded in sedimentary rocks in which they are burried. 2. Sedimentary rocks. 3. (i) Dynamic metamorphism (ii) Sedimentary rocks/Stratified rocks (iii) Metamorphic rocks. (iv) Lacustrine 4. (i) a metamorphic rock (ii) Sandstone.

TERMINAL QUESTIONS

1. The rapid increase of temperature below the earth's surface. Mining activity restricted to few kilometres. High temperature melts drilling tools.

2. See Fig. 7.1 - Concentric zone showing layers of Earth's interior.

3. Rock is the solid part of the crust composed of minerals. They are aggregates or physical mixture of one or more minerals for e.g. granite. Minerals are inorganic substances made up of one or more elements in a definite ratio, e.g. feldspar. Change in the ratio of minerals give rise to different rocks.

4. Igneous rocks, sedimentary rocks and metamorphic rocks (give definition of each with examples of each type of rock).

5. See economic significance of rock (para 7.8)

6. Sedimentary rocks are formed due to weathering, erosion and deposition of rock fragments of older rocks which become hard due to compaction, chemical changed or cementation of organic matter, whereas metamorphic rocks are formed due to the pressure and high temperature of the magma when it comes in contact with both igneous and sedimentary rocks.