LECTURE 1.

1.0 ORIGIN, STRUCTURE AND COMPOSITION OF THE EARTH

1.1 INTRODUCTION.

Welcome to Lecture 1 of this unit. To start with, stop and look around you wherever you are. Take a look at all the things that you see around you every day. For example, the pencil in your hand, where does the lead in the pencil come from? The room you are probably in is made up of bricks, metal and glass; all of these things come from the Earth. Just about everything around you that you use and see has some connection to the Earth. The Earth beneath your feet as you stand is made up of soil, rocks and minerals. Without the soil we would have no plants, no animals and hence no food! Many types of useful rocks and minerals are mined from the Earth to make products that we use all the time. Clearly, without the earth and its soils, rocks and minerals there would be no life. Do you find what I am saying hard to believe? Well, in this lecture topic we shall introduce the science of geology and discuss the important theories advanced for the origin of our planet earth. You will be able to illustrate and contrast the different structural components and composition of the earth right from its inner core to the outer surface.

OBJECTIVES

At the end of this lecture, you should be able to:

a). Define what is Geology
b). State the theories advanced for the origin of the Solar system.
c). Describe the merits and demerits of the theories advanced for the origin of the solar system.
d). Explain how the earth’s atmosphere and oceans were formed.
d). Illustrate with well labeled diagrams the structure and composition of the Earth.
e). Distinguish between Lithosphere and Asthenosphere.
f). Tabulate the distribution of chemical elements in the Earth’s crust.

1.2 WHAT IS GEOLOGY?

Geology is the study of the formation of the Earth. It is the study of rocks and minerals in the context of the Earth we live on and the different processes taking place on the earth. Geology is an applied science with many branches of study, for example:

Historical Geology – establishes the orderly arrangement of the many physical and biological processes occurring on Earth; Mineralogy - the study of the science of minerals; Petrology – the study of rocks in terms of their mineral composition, occurrences, etc. Paleontology - the study of past lives of fossils.

1.3 THE ORIGIN OF THE EARTH

The Earth, together with the other eight planets – Mercury, Venus, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto – and their moons form the planetary system. Together with the Sun, they form the solar system. Therefore, in order to understand the origin of the Earth, we must first understand the origin of the solar system.

What do you understand about the solar system?

Our solar system is a group of objects in space. These objects are kept in place by the sun's gravitation and is basically made up of the sun, the nine planets with their moons, and smaller bodies such as asteroids and comets.

1.4 THEORIES ADVANCED FOR THE ORIGIN OF THE SOLAR SYSTEM

There are two main theories advanced for the origin of the solar system. These are:

- The Evolutionary / Uniformitarian Nebular Theory, and
- The Catastrophic-Event Theory.

1.4.1 The Evolutionary / Uniformitarian Nebular Theory

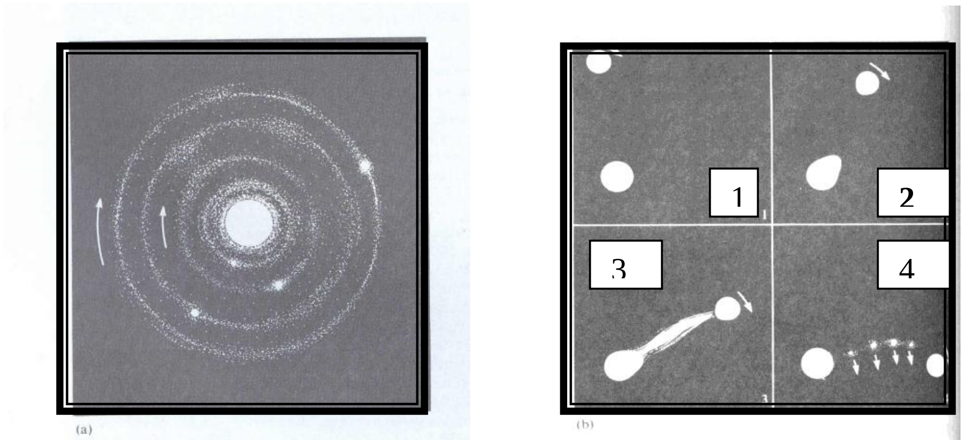
Its essential idea is that of a flat disc-shaped rotating cloud of gas and dust – referred to as Nebular – that gradually contracted and condensed under its own gravitational force to form the Sun. The variants of this theory include the development of several regularly spaced rings each of which aggregated to form a planet (see Fig. 1.1(a)). In its formation, the earth went through a molten period as the material contracted under its own gravitational force. Modern methods of dating rock material have shown the oldest fragments of meteorites and moon rocks to be close to 4.6 billion years old. The formation of the solar system is thus believed to have been substantially complete more than 4.5 billion years ago.

1.4.1.1 Significance of The Nebular Theory

The major merit of this theory is that it is widely accepted in explaining the distribution of planets along one plane through the Sun and the regular spacing among planets. However this theory came into some problems in the 19th Century when more data about the sizes, masses and spins of all the planets were determined. The major problem was about the period of spins. It is argued that if the Sun and its inner planets – Mercury, Venus and the Earth – which are relatively small, dense and rocky resulted from the contraction of the rotating nebular, they should be spinning faster than the outer planets – Jupiter, Saturn, Uranus and Pluto- which are usually large, lighter and gaseous, and not the other way round. This is not the case.

1.4.2 Catastrophic-Event Theory

This theory suggests the close approach of another condensed star to the Sun. The gravitational forces involved would cause huge tides to be raised on the star and the Sun until a cigar-shaped filament of stellar material became torn away from one or both and condensed between the two stars to form planets (see Fig. 1.1(b)).



(a) (b).

Figure 1.1(a). Schematic illustration of nebular theory for the evolution of the solar system from a rotating nebular that sheds rings during contraction. These condense to form the planets and their satellites, while the central part continues contracting to form the Sun.

(b). Illustration of the catastrophic-event theory. In 1, a condensed star approaches the Sun; in 2, both bodies are tidally distorted as a result of gravitational interaction, leading to 3, in which a filament of gaseous material is torn away from the Sun (or from the other star); in 4, the material condenses to form planets, and the star recedes.

1.4.2.1 Significance of the Catastrophic-Event Theory

The merit of this theory is that it overcame the problem of the variation of the planetary spin rates. However its major demerits came about when

(i). It was later realized through scientific studies that stellar material at temperatures exceeding a million degrees centigrade would rather disperse than condense into planets.

(ii). Statistical arguments advanced by astronomers showed that the chances of a close encounter between two stars are rather remote.

> Following this state of uncertainty, there have been various attempts to revive both classes of theories. At present there is evidence to favour aspects of both theories, but neither has gained unanimous support.

1.5 STRUCTURE AND COMPOSITION OF THE EARTH

1.5.1 The Early Earth

The Early Earth was very different from what it is today. It lacked the modern oceans and atmosphere and had a different surface from the present one. The primitive Earth was heated by several processes. Immediately after the Earth formed, the energy released by the decay of radioactive elements coupled with the heat from the colliding particles and the heat generated by the compression of the interior due to gravity produced some melting on the earth's interior. Melting allowed the heavier elements – Iron (Fe) and Nickel (Ni) – to sink while the lighter rocky fragments floated upwards. This segregation of materials which began early in the earth's history is believed to be still occurring but on a smaller scale. Hence the earth's interior is not homogenous but consists of shells or spheres of materials having different properties. Using the science of seismology, scientists have established that the Earth consists of three basic layers, namely the large iron rich **core**, the **mantle**, and a thin **crust** at the surface each with its own characteristics (see Figure 1. 2).

How were the earth's atmosphere and oceans formed?

The heating and subsequent differentiation of the early earth led to another important result: formation of the atmosphere and oceans. Many minerals that had contained water or gases in their crystals released them during the heating and melting, and as the earth's surface cooled, the water could condense to form the oceans. Without this abundant surface water, which in the solar system is unique to earth, most life as we know it could not exist.

The earth's early atmosphere was quite different from the modern one. The first atmosphere had little or no free oxygen in it. It probably consisted dominantly of carbon dioxide, the gas most commonly released from volcanoes (aside from water). Oxygen-breathing life of any kind could not exist before the first simple plants – the single-celled blue-green algae- appeared in large numbers to modify the atmosphere. The remains are found in rocks several billion years old. They manufactured food by photosynthesis, using sunlight for energy, consuming carbon dioxide, and releasing oxygen as a by-product. In time, enough oxygen accumulated that the atmosphere could support oxygen-breathing organisms.

1.5.2 The Nature of the Interior

How do geologists know what the Earth's interior is made of?

First, scientists can estimate the starting composition of the whole solar nebula from analyses of stars. Experiments and theoretical calculations can be combined to show what solids would condense out of such a cloud and at what temperatures. Geologists can also infer aspects of the earth's bulk composition from analyses of certain meteorites believed to have formed at the same time as, and under the conditions similar to, the earth. Geophysical data (e.g. from seismic studies) demonstrate that the earth's interior is zoned and also provide information on the different densities of the different layers. These and other kinds of data indicate that the earth layers are of different composition (see Figure 1.2)

The inner core and crust are solid, but the outer core is liquid and the mantle layers are semi-liquid. The core is made up of mostly iron and nickel, and the upper mantle of minerals such as olivine and pyroxene. The continental crust consists of granitic rocks (enriched with silicon and Aluminium elements - SIAL) and the oceanic crust consists mainly of basaltic rocks (enriched in Silicon and Magnesium elements – SIMA). Table 1.1 gives a summary of the nature and composition of the Earth.

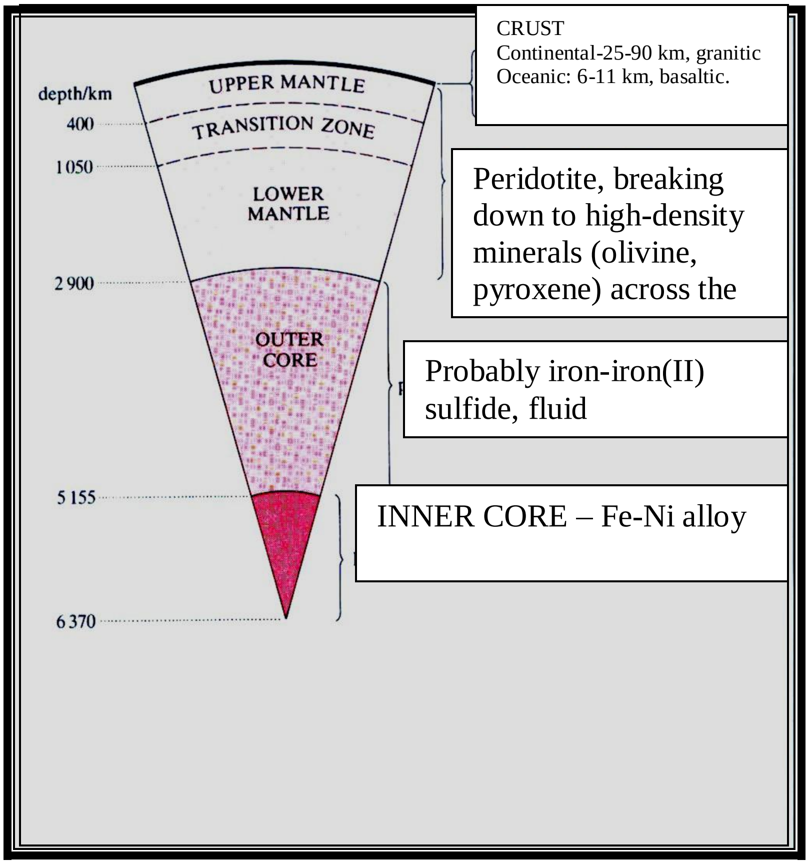


Figure 1.2. Diagram showing the structure and composition of the Earth's interior.

Table 1.1. The nature and composition of the Earth's interior.

NATURE	**LAYERS**	**THICKNESS**	**COMPOSITION**
Solid	Inner Core	1, 255 km	85% Iron (Fe) & some nickel (Ni)
Liquid	Outer Core	2, 220 km	Nickel – Iron
Semi-liquid	Mantle	2, 895 km	Peridotite – Olivine, pyroxene
Solid	Crust Continental crust Oceanic crust	16 – 40 km	 Granitic rocks (SiAl) Basaltic rocks (SiMa)

Taken as a whole, the abundance of chemical elements in the Earth's crust are as tabulated in Table 1.2.

Table 1.2. Average chemical composition of the Earth's crust.

Element	**% by Weight**
Oxygen	46.71
Potassium	2.58
Sodium	2.50
Calcium	3.65
Silicon	27.69
Aluminium	8.07
Iron	5.05
Magnesium	2.74
Titanium	0.62
Hydrogen	0.14

From Table 1.2 it can be seen that silicon and oxygen are two most abundant elements in the Earth's crust. It is for this reason that the most abundant minerals of the earth's crust are the silicate minerals – consisting essentially of silicon-oxygen tetrahedral, that are linked in a variety of ways.

1.5.3 Lithosphere and Asthenosphere

Starting at a depth of about 100 km below the earth's surface, rocks in the mantle usually reach high temperatures and they lose much of their strength. This region of the upper mantle where rocks become easily deformed is called the Asthenosphere (or weak sphere). In the approximate outer 100 km of the earth, is a region where rocks are harder and more rigid than those in the asthenosphere. This hard outer layer is called the Lithosphere (or rock sphere), which is rigid, cool and brittle (see Figure 1.3).

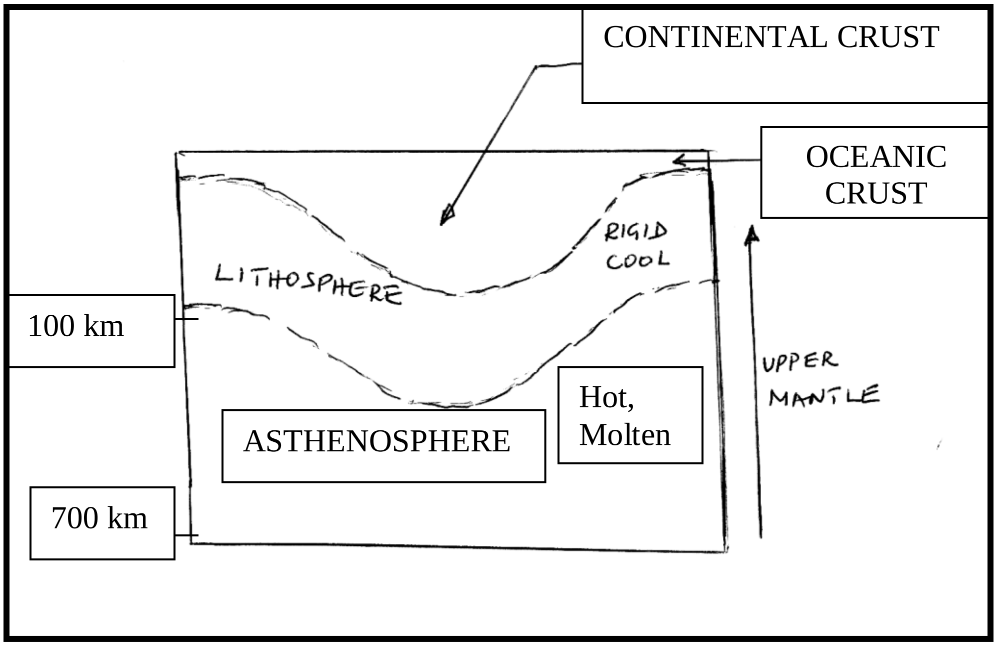


Figure 1.3. Diagram showing the structural relationship of Lithosphere and Asthenosphere)

SUMMARY

The solar system formed about 4.5 billion years ago. The origin of the Earth is intimately tied to that of the solar system. Broadly speaking there are two prominent theories for the origin of the Solar System: the **evolutionary nebular theory** and the **catastrophic-event theory**. At present there is evidence to favour aspects of both theories, but neither has gained unanimous support.

The earth's interior is not homogenous but consists of shells or spheres of materials having different properties. Using various research methods, scientists have established that the Earth consists of three basic layers, namely the large iron-rich **core**, the **mantle**, and a thin **crust** at the surface each with its own characteristics

The earth is unique among the planets in its chemical composition, abundant surface water and oxygen-rich atmosphere. The earth passed through a major period of internal differentiation early in its history, which led to the formation of the atmosphere and the oceans. Earth's surface features have continued to change throughout the last 4 billion years. The earliest plants were responsible for the development of free oxygen in the atmosphere, which, in turn, made it possible for oxygen-breathing animals to survive.

ACTIVITY

Investigate the geologic history of some particular part of your country. (A good starting point might be a visit to the government's mines and geological surveys offices at the District Headquarters of the region of interest.) Was the area ever an ocean basin, a desert or subject to volcanic activity? How long ago was it first inhabited by humans?

REFERENCES.

1. Earth Materials and Processes By Open University press, London (1988).
2. Environmental Geology By Carla W. Montgomery (1989).