

# 1 ENGINEERING GEOLOGY AND ITS RELEVANCE TO ENGINEERING

## 1.1 Definition of Geology

Geology is the study of planet Earth, its rocky exterior, its history, and the processes that act upon it. The word geology comes from the Greek geo meaning earth and logia, which means the study of. Geologists seek to understand how the earth formed and evolved into what it is today.

Proper assessment of geologic hazards like floods, volcanoes, earthquakes, etc. is very important in engineering projects. Failure to characterize the geological site and geological setting can result in needless structural damage, environmental disasters, or loss of life. Proper consultation with engineering geologists or geological engineers would prevent such problems.

## 1.2 Branches of Geology

Geology is divided into two major groups- Physical and Historical geology. **Physical Geology** deals with the materials that constitute the Earth (soils and rocks), the structures and surface features of the Earth, and the processes that created these structures while **Historical Geology** deals with the history of the Earth.

Geology is further divided into a number of branches according to the subject matter that is covered or the industrial or commercial applications. Those that are of interest to engineers include:

**Petrology:** This involves study of rocks and their origin. It consists of *Petrography* which deals with the identification, description, and classification of rocks and *Petrogenesis* which is the study of origin of rocks.

**Mineralogy:** This involves the study of rock constituents or minerals.

**Crystallography:** This deals with the atomic structure of minerals and their external appearance.

**Geochemistry:** This involves the study of the chemistry of rocks.

**Geomorphology:** This is the study of landforms, their origin and development.

**Stratigraphy:** This is the study of layered rocks, mostly those of sedimentary origin.

**Structural Geology:** This involves the position of rock bodies, their deformation, and fracturing.

**Geophysics:** The application of principles of physics to the study of the Earth. It consists of

*Geomagnetic* (study of Earth's magnetic field), *Seismology* (study of earthquakes); and *Geodesy*: study of the form and size of the Earth. **Oceanography**: The study of oceans and basins.

**Paleontology**: The study of life of past geologic periods and evolution of plants and animals.

**Hydrogeology**: The study of underground and surface water.

### 1.3 Engineering Geology

Engineering geology involves the study of rock, soil, and water and the interaction among these three constituents, as well as their interactions with engineering materials and structures. The Association of Engineering Geologists (AEG) defines engineering geology as the application of geologic data, techniques, and principles to the study of naturally occurring rock, soil materials and subsurface fluids.

Engineering geology is mainly concerned with the application of geology to civil and mining engineering practice. It is the bridge between geology and engineering. It ensures that geological factors affecting the location, planning, design, construction and maintenance of engineering works and the development of groundwater resources are recognized, adequately interpreted and presented for use in engineering practice.

Engineering geology provides a means to appreciate and identify geologic features that could have short and long-term consequences to the overall performance of engineering structures and projects. It is also a study of how we are affected by geological phenomena, and how we can affect the environment and trigger geologic processes.

Currently, in the language of civil engineering there are two concepts: *engineering geology* and *geotechnics*. In practice, they are often used as alternatives. From the historical development, the essence of engineering geology lies in describing the geological environment in terms of needs of civil engineering and geotechnics involve using data of the geological environment in the civil engineering.

### 1.4 Relevance of Geology to Engineering

The knowledge of engineering geology is very important to an Engineer because he is often confronted with rock, soil and water and their interactions in the construction environment in these three ways: as resources (materials) such as aggregates, fills, water etc for his/her construction works; as foundations for his structures (finding stable foundation); and in

mitigating against geological hazards by identifying potential problems, and providing information to mitigate the problem.

The Engineer undertakes site investigation to know the environmental condition of the construction site. In undertaking the site investigation, the Engineer's knowledge of geology becomes useful. As an Engineer, your project must be carried out to match the natural conditions of the environment in which the construction will take place. Consideration must be given to such natural conditions like weather, soil type, wind etc. It is therefore of paramount importance for the Engineer to have a deeper understanding of the formations, properties and occurrence of soils and rocks, strengths of soils and rocks and the erosional and geological processes which subject them to continual change, because if the geology of the area is not properly ascertained, foundation problems may occur in structures such as dams, buildings, tunnels etc.

The detailed geological reports (geological maps and sections) which help in the planning, design and construction of structures are usually prepared before the commencement of any major engineering project. The Engineer must have the ability to assimilate knowledge from geological maps and be able to speak the same basic technical language as the professional geologists he consults to acquaint himself with all available information relating to the locality.

Valuable time may be lost and necessary expenditure may subsequently be incurred, if the engineer carries out inadequate investigation either by neglect or because of lack of knowledge of the site, or of sources of information about the site. The knowledge of the ground conditions helps Engineer to produce design that can accommodate almost any ground conditions, thus preventing waste of time and resources and failure of engineering structures.

Engineering geology provides the knowledge of construction materials required by engineers for his projects, their composition, occurrence and other properties. Examples of such construction materials are granite, clays, limestone, and laterite. This enables him to use the materials properly.

The knowledge of the geological work of natural agencies such as water, wind, ice and earthquake helps in planning and carrying out major engineering works. For examples, the knowledge of erosion, transportation, and deposition helps greatly in solving the expensive problems of river control, coastal and harbour work and soil conservation.

The knowledge about groundwater in the subsurface rocks, its quantity and depth of occurrence is very important in engineering projects such as water supply for domestic and industrial consumption and other water-related engineering works like irrigation.

The knowledge of engineering geology is very essential in ensuring the stability of cuts and slopes in engineering projects such as construction of roads, canals, tunnels etc.

The stability of engineering structures is considerably increased if the geological features like faults, joints, folding, and solution channels etc. in the rock beds are properly located and suitably treated. This can only be possible, if the engineers have the knowledge of engineering geology

The knowledge of engineering geology is required in the classification of materials for excavation, embankment etc. Evaluation of landslide-prone areas and recognition of compressible soils are better carried out when the engineers have the knowledge of engineering geology.

## 2 STRUCTURE OF THE EARTH

### 2.1 The Earth and its relationship to the Sun and other Planets

#### 2.1.1 The solar system

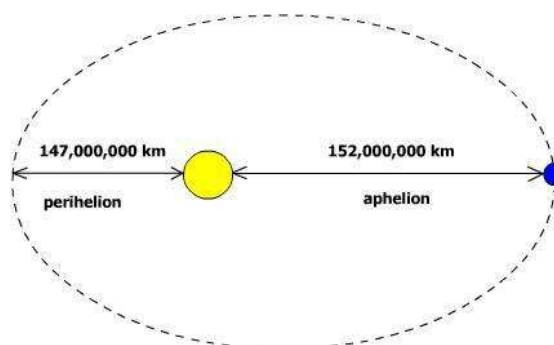
The solar system comprises the sun and the eight planets which are believed to have been developed from the condensation of gases and other lesser bodies. All the planets revolve round the sun in what is called **Elliptical Orbits**. Like the earth, they shine only by the reflected light of the sun. The sun has a surface temperature of  $6000^{\circ}\text{C}$  and increases to  $20\text{million}^{\circ}\text{C}$  in the interior. All over its surface are fiery gases that leap in whirls of glowing flames like a volcano in eruption. All the energy of the solar system is derived from the sun.

#### 2.1.2 The Planets

(a) **Mercury:** Amongst the nine planets, mercury is the smallest and the closest to the sun, only about  $57,900,000\text{km}$  away. It completes its orbit in a much shorter space of time than does the earth. A year in mercury is only 88days.

(b) **Venus:** Venus is twice the distance of mercury away from the sun. It is often considered as “Earth’s Twin” because of their close proximity in size, mass (weight) and density.

(c) **Earth:** This is the only planet that is highly conducive to life. Like any other planet, the earth has a natural satellite called the moon. The moon revolves eastward around the Earth once in every 27days. The Earth revolves round the sun in  $365\frac{1}{4}$  days. Rotation of the earth gives day and night while revolution round the sun gives seasons, because the earth’s distance from the sun changes during the year. Its closest position is called perihelion and its farthest position is called aphelion. At perihelion, the earth lies about 3 million miles ( $4.8$  million km) nearer to the sun than at aphelion (see Figure 2.1)



**Figure 2.1: Earth’s position from the sun (Perihelion and Aphelion)**

(d) **Mars:** The fourth planet from the sun is Mars which has dark patches on its surface and is believed by most professional astronomers to be the next planet after Earth to have the possibility of plant life.

(e) **Jupiter:** This is the largest planet in the solar system. Its surface is made up of many gases like hydrogen, helium, and methane. It is distinguished from other planets by its circular light and dark bands, and the twelve satellites that circle round it. Its surface is very cold, about  $-128^{\circ}\text{C}$ .

(f) **Saturn:** The next planet is the Saturn. It has three rings and nine satellites around it. In size, it is the second largest after Jupiter. It is so far from the sun that it takes  $29\frac{1}{2}$  years to complete its orbit.

(g) **Uranus:** This is the seventh planet. It is about 50 times larger than the earth and 15 times as heavy. Unlike other planets, Uranus orbits around the sun in a clockwise direction from east to west with five satellites revolving round it.

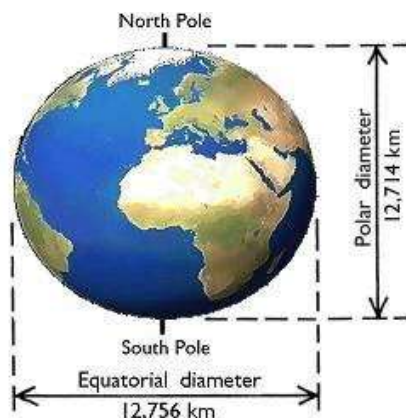
(h) **Neptune:** This planet closely resembles Uranus, except that it has only two known satellites and it is probably much colder.

(i) **Pluto:** This planet is smaller than the earth and the farthest from the sun. A year in Pluto is not less than 247 years on earth (now extinct). Pluto follows the first two rules: It is round, and it orbits the sun. It does not, however, follow the third rule. It has not yet cleared the neighborhood of its orbit in space. Because it does not follow this rule, Pluto is no longer considered a planet. On August 24, 2006 at the International Astronomy Union (IAU) General Assembly the ninth planet was scrubbed only 76 years after its discovery.

## 2.2 Structure of the Earth

### 2.2.1 The Earth

From years of accumulated knowledge, experience and observations in different parts of the world, we know that the earth is round. Its spherical shape is an established fact, proved and accepted by all. The olden days' belief that the earth is flat as table has now been totally disapproved. The earth is not in a perfect spherical shape. It is flattened at the poles. Its diameter is 7,900 miles (12,700 km) from pole to pole. It is 7,920 miles (12,750 km) around at the equator (see Figure 2.2). The earth is the densest of all planets.



**Figure 2.2: Shape of the Earth**

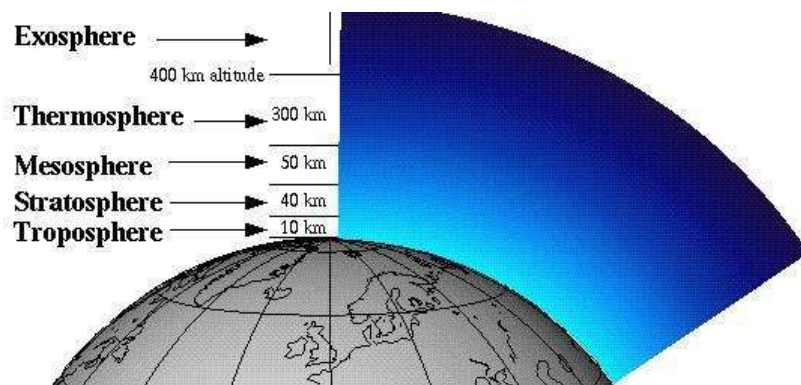
The earth can be physically described as a ball of rock (solid ground) called Lithosphere and wrapped in an envelope of air called Atmosphere. Part of the lithosphere is immersed by

oceans and seas called Hydrosphere. To these physical zones, it is convenient to add a biological zone (Biosphere).

### 2.2.1.1 The Atmosphere

This is a layer of gases and vapour which envelopes the earth. It is essentially a mixture of nitrogen and oxygen with smaller quantities of water vapour, carbon dioxide, and inert gases such as argon. The blanket is made up of 21 percent oxygen, 78 percent nitrogen and 1 percent other gases. It also contains dust and water vapour. The atmosphere shields the planet from deadly radiation and meteors. It acts as blanket to keep Earth's temperature stable. Geologically and geographically, it is important as the medium of climate and weather, of wind, cloud, rain and snow.

The atmosphere is divided into five layers, which are troposphere; stratosphere; mesosphere; thermosphere; and exosphere (see Figure 2.3). It is thickest near the surface and thins out with height until it eventually merges with space.



**Figure 2.3: The Atmosphere**

### Troposphere

The troposphere is the lowest layer of Earth's atmosphere. The troposphere starts at Earth's surface and goes up to a height of 7 to 20 km (4 to 12 miles, or 23,000 to 65,000 feet) above sea level. Most of the mass (about 75-80%) of the atmosphere is in the troposphere. Almost all weather occurs within this layer. Air is warmest at the bottom of the troposphere near ground level and gets colder higher up. Air pressure and the density of the air are also less at high altitudes. Nearly all of the water vapour and dust particles in the atmosphere are in the troposphere. That is why most clouds are found in this lowest layer. The bottom of the troposphere, right next to the surface of Earth, is called the "boundary layer". The

troposphere is heated from below. Sunlight warms the ground or ocean, which in turn radiates the heat into the air right above it. This warm air tends to rise and keeps the air in the troposphere "stirred up". The temperature there is around  $-55^{\circ}\text{C}$  ( $-64^{\circ}\text{F}$ ). The boundary between the stratosphere and the troposphere below is called the tropopause.

### **Stratosphere**

The stratosphere is the second layer, as we move upward from Earth's surface of the atmosphere. The top of the stratosphere occurs at 50 km (31 miles) altitude. The altitude of the bottom of the stratosphere varies with latitude and with the seasons, occurring between about 8 and 16 km (5 and 10 miles). The bottom of the stratosphere is around 16 km (10 miles) above Earth's surface near the equator, around 10 km (6 miles) at mid-latitudes, and around 8 km (5 miles) near the poles. It is slightly lower in winter at mid and high latitudes, and slightly higher in the summer. The boundary between the stratosphere and the mesosphere above is called the stratopause. Ozone, an unusual type of oxygen molecule that is relatively abundant in the stratosphere, heats this layer as it absorbs energy from incoming ultraviolet radiation from the Sun. Temperatures rise as we move upward through the stratosphere. This is exactly the opposite of the behaviour in the troposphere in which we live, where temperatures drop with increasing altitude. The stratosphere is very dry; air there contains little water vapour. Because of this, few clouds are found in this layer; almost all clouds occur in the lower, more humid troposphere.

### **Mesosphere**

The mesosphere starts at 50 km (31 miles) above Earth's surface and goes up to 85 km (53 miles) high. As you get higher up in the mesosphere, the temperature gets colder. The top of the mesosphere is the coldest part of Earth's atmosphere. The temperature there is around  $-90^{\circ}\text{C}$  ( $-130^{\circ}\text{F}$ ). The boundary between the mesosphere and the thermosphere is called mesopause. Scientists know less about the mesosphere than other layers of the atmosphere. This is because weather balloons and jet planes cannot fly high enough to reach the mesosphere. Also, the orbits of satellites are above the mesosphere. Most meteors from space burn up in this layer. A special type of clouds, called "noctilucent clouds", sometimes forms in the mesosphere near the North and South Poles. These clouds are strange because they form much, much higher up than any other type of cloud.

### **Thermosphere**

The thermosphere is directly above the mesosphere and below the exosphere. It extends from about 90 km (56 miles) to between 500 and 1,000 km (311 to 621 miles) above our planet. Temperatures climb sharply in the lower thermosphere (below 200 to 300 km altitude), then level off and hold fairly steady with increasing altitude above that height. Solar activity strongly influences temperature in the thermosphere. The thermosphere is typically about 200°C (360°F) hotter in the daytime than at night, and roughly 500°C (900°F) hotter when the Sun is very active than at other times. Temperatures in the upper thermosphere can range from about 500°C (932°F) to 2,000°C (3,632°F) or higher. The boundary between the thermosphere and the exosphere is called the thermopause. Although the thermosphere is considered part of Earth's atmosphere, the air density is so low in this layer that most of the thermosphere is what we normally think of as outer space. The space shuttle and the International Space Station orbit Earth within the thermosphere.

### **Exosphere**

This is the outermost layer of the earth's atmosphere, lying above the thermosphere and extending thousands of kilometres into space, from which molecules having sufficient velocity can escape earth's gravitation. It starts at the altitude of about 500 km and extends to about 10000 km.

#### **2.2.1.2 The hydrosphere**

This is the zone which includes all the natural waters of the outer earth, that is, oceans, seas, lakes and rivers. Three-quarters of the earth surface is covered with water called hydrosphere. Earth is the only planet known to have liquid water. The oceans, lakes and rivers are filled with plants and animals. The hydrosphere provides food, fertilizers and industrial materials. The oceans produce salt and many other important chemicals.

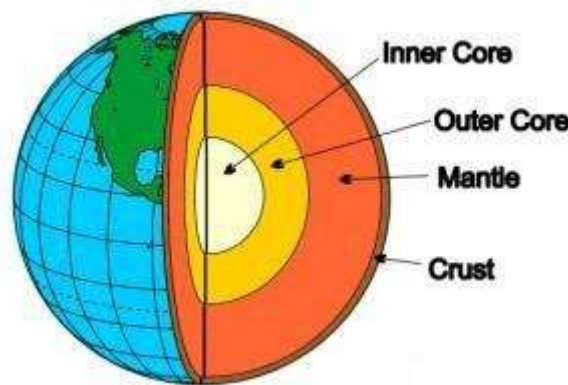
#### **2.2.1.3 The Biosphere**

The biosphere, the sphere of life, is probably a less familiar conception. But think of great forests and prairies with their countless swarms of animals and insects. Think of the tangles of sea weed; of the wide spread banks of molluscs, of reefs, of coral and shoals of fishes. Add to these, the inconceivable numbers of bacteria and other microscopic plants and animals; myriads of these minute organisms are present in every cubic inch of air and water and soil.

Taken altogether, the diverse forms of life constitute an intricate and ever-changing network, clothing the surface with a tapestry that is nearly continuous. Given high snows and desert sands fail to interrupt it completely, and lava fields fresh from craters of volcanoes are quickly invaded by the pressure of life outside. Such is the sphere of life, and both geologically and geographically, it is of no less importance than the physical zones. Amongst its many products are coal and oil, most of the oxygen of the air we breathe and limestone in great abundance.

### 2.2.2 Structure of the Earth

The Earth is made up of several concentric layers shown in Figure 2.3. The outer layer is the Earth's Crust which is also known as the Lithosphere. Earth's interior is made up of three main layers, which are the crust, the mantle, and the core. Each of these layers may be divided into smaller layers by their specific properties.



**Figure 2.3: Structure of the Earth**

#### 2.2.2.1 The earth's crust

The lithosphere (also called the crust) is the outer solid shell of the earth, similar to the shell of an egg. Like an eggshell, the crust is thin compared to the thickness of the mantle and core. The crust ranges in thickness from as little as 4 miles (6 km) thick beneath the oceans to more than 50 miles (80 km) thick under continental mountains.

It is made of rocks in great variety, and where it forms land masses its uppermost layer is commonly a blanket of soil or other loose deposits, such as desert sands. The principal elements which made up the outer crust are approximately as shown in Table 2.1.

The lithosphere is composed of a dozen or more plates that move relative to one another as they ride atop hotter, more mobile materials. The plates move at average speeds of a few inches per year. A tectonic plate is a massive, irregular slab of solid rock. Tectonic plates

have drifted around on the surface of the Earth throughout geologic time, breaking apart, crunching together, and/or sliding past or under one another. Plates are divided into two types, oceanic and continental plates, based on their physical properties. The earth's crust comprises of two distinct parts as highlighted below

(a) The upper part: This part consists of **GRANITE ROCKS** and forms the continents. Its main mineral constituents are Silica and Alumina. The two minerals are collectively called **SIAL**.

(b) The lower part: The lower part is a continuous zone of denser **BASALTIC ROCKS** forming the ocean floors, comprising mainly Silica, Iron and Magnesium. It is therefore called **SIMA**.

The **SIAL** and **SIMA** together form the earth's crust. The upper part (SIAL) is lighter than the lower part (SIMA). The continents which make up the upper part can then be said to be floating on a sea of denser SIMA.

**Table 2.1: Principal elements of the outer crust**

Elements	Symbols	% By Weight	% By Volume
Oxygen	O	46.6	93.8%
Silicon	Si	27.7	0.9%
Aluminium	Al	8.1	0.5%
Iron	Fe	5.0	0.4%
Magnesium	Mg	2.1	0.3%
Calcium	Ca	3.6	1.0%
Sodium	Na	2.8	1.3%
Potassium	K	2.6	1.8%

#### 2.2.2.2 The mantle

The mantle is directly beneath the crust, similar to the white of an egg. It is a pliable layer of rock that is denser than the crust because it contains more iron and manganese. Immediately beneath the crust (lithosphere) is the mantle. It is about 2990km (1800miles) thick. It composed mainly of very dense rocks rich in olivine. Note that the boundary surface between the crust and the mantle is known as the **Mohorovic Discontinuity**.

#### 2.2.2.2 The Core

The core of the Earth is similar to the yolk of an egg. It is composed of an iron-nickel alloy and is nearly twice as dense as the mantle. The outer core is a thick liquid, approximately 1,800 miles deep with a thickness of 1,400 miles. The inner core is solid, due to the intense pressure at this depth. As Earth rotates, the liquid outer core slowly flows, creating Earth's