

***Wollo University***

***Kombolcha Institute Technology***



***Engineering Geology***

*GEol 3113*

## **Objectives**

- *To provide students with the basic knowledge of Geology*
- *To make students visualize the importance of geology to engineering activities*
- *To identify the geological materials uses as a construction materials*
- *To make students aware of the Geological structures, weathering and ground water, and how they affect civil works*
- *To understand the nature of geological information that is absolutely essential for the safe design and construction of engineering project*
- *To appreciate how geological site investigation is essential prior to construction in engineering project*
- *Knowing the methods to identify the suitability of the ground using direct and indirect method of Geological investigations*

# CHAPTER 1

## INTRODUCTION

### Definition of Geology and Engineering Geology

#### *What is geology?*

- Geology is the study of the Earth, it embraces knowledge of geological materials (**characteristically soils and rocks**) , **their constituents (mineralogy and crystallography)** ,and the processes that formed them and that currently transform them.
- **Engineering geology** is the application of the science of geology to the technology of ground engineering. The subject requires a comprehensive knowledge of geology, as well as an understanding of engineering properties and behaviour of the geological materials.
- The practice involves site investigation and site characterization specific to the needs of the engineering project. In outline, the investigation should cover the area of terrain that is affected by the project, and any adjacent terrain from which geological processes could affect the project.
- **Engineering geology** provides the link between geology and engineering through the formation of geological models which can be used to identify geological hazards and uncertainty, plan effective ground investigations, and define blocks of ground and geological structures in an engineering context to facilitate geotechnical risk assessment and design.

# THE SCIENCE OF GEOLOGY

❖ **Geology** is the study of the Earth, including the materials that it is made of, the physical and chemical changes that occur on its surface and in its interior, and the history of the planet and its life forms.

- What are the general structures of the earth ?
- How it was born or originated? explain the mysteries connected to our development and the nature of our planet
- What it is made of or composed of?
- What are the internal & external earth processes that gave rise to the existence of the earth?
- Where can the important natural resources (minerals, fuels, groundwater, Geothermal energy, etc) be found in the earth?

- ❖ The Earth's radius is about 6370 kilometers, nearly one and a half times the distance from New York to Los Angeles. If you could drive a magical vehicle from the center of the Earth to the surface at 100 kilometers per hour, the journey would take more than two and a half days.
- ❖ Most of the Earth is composed of rocks. Rocks, in turn, are composed of minerals. Although more than 3500 different minerals exist, fewer than a dozen are common.
- ❖ **Geologists** study the origins, properties, and compositions of both rocks and minerals.
- ❖ Geologists also explore the Earth for the resources needed in our technological world: fossil fuels such as coal, petroleum, and natural gas; mineral resources such as metals; sand and gravel; and fertilizers. Some search for water in reservoirs beneath Earth's surface.

## *INTERNAL PROCESSES*

- ❖ Processes that originate deep in the Earth's interior are called internal processes. These are the driving forces that raise mountains, cause earthquakes, and produce volcanic eruptions.
- Builders, engineers, and city planners might consult geologists, asking, “What is the probability that an earthquake or a volcanic eruption will damage our city?”
- The modern Earth is made up of a dense core of iron and nickel, a rocky mantle of lower density, and a crust of yet lower density. One hypothesis states that both a core and mantle existed in the earliest Earth.
- An alternative hypothesis states that the Earth was initially homogeneous. The primordial planet was heated by energy from the original gravitational coalescence, by radioactive decay, and by bombardment from outer space. This heat caused all or most of the Earth to melt, and dense materials settled to the center to form the core, while less dense rock floated toward the surface to form the mantle.

## Geology and its Applied Fields

- ❖ **Applied Geology:** This branch of geology applies the principle of *pure Geology and other sciences to understand the nature of the earth and to extract the natural resources of Earth.*
- ❖ Some of the most common and important applied fields are:
  - **Economic Geology:** *Deals with economic minerals and rocks*
  - **Mining Geology:** *Deals the technique of extraction of the economic minerals and rocks*
  - **Hydrogeology:** *Deals with surface and underground water.*
  - **Engineering Geology:** *Applies the principle of geology to Engineering works*
  - **Rock mechanics:** *it deals exclusively with the study of behavior of rocks under loads (stress) imposed upon them.*

- ❖ **Geochemistry** is a study of the chemistry of rocks and the distribution of major and trace elements in rocks, This can lead to an understanding of how a particular rock has originated (petro genesis), and also, to a knowledge of the chemistry of the upper layers of the Earth. The distribution of rocks at the Earth's surface is found by making a geological survey and is recorded on geological maps. This information about rocks is superimposed on a topographic base map.
- ❖ Methods of **geophysics**, has been evolved for exploring the distribution of rocks of shallower levels
- ❖ The interpretation of rock layers as Earth history is called **stratigraphy**, and a study of the processes leading to the formation of sedimentary rocks is called sedimentology.

❖ **Engineering Geology** the discipline of applying geologic data, techniques, and principles to the study both of:

- a) Naturally occurring rock and soil materials, surface and sub-surface fluids and
- b) the interaction of introduced materials and processes with the geologic environment,

❖ The **philosophy** of engineering geology is based on three simple principles.

These are:

1. All engineering works are built in or on the ground.
2. The ground will always, react to the construction of the engineering work.
3. The reaction of the ground (its" engineering behavior")to the particular engineering work must be accommodated by the engineering work (Price,2009).

## Definition

### Engineering geology:

- is a branch of geology that applies geological principles of **rock**, **soil** and **groundwater**

to the appropriate :

- Location....
  - design.....
  - Construction....
- of a wide variety of engineering structures



The **assessment** and **design** of:

- ✓ **mitigative measures** for a wide variety of **natural** and **man-made** hazards.

Geologic Hazard: Landslide



Mitigative measures



## *Importance of Geology in Engineering works*

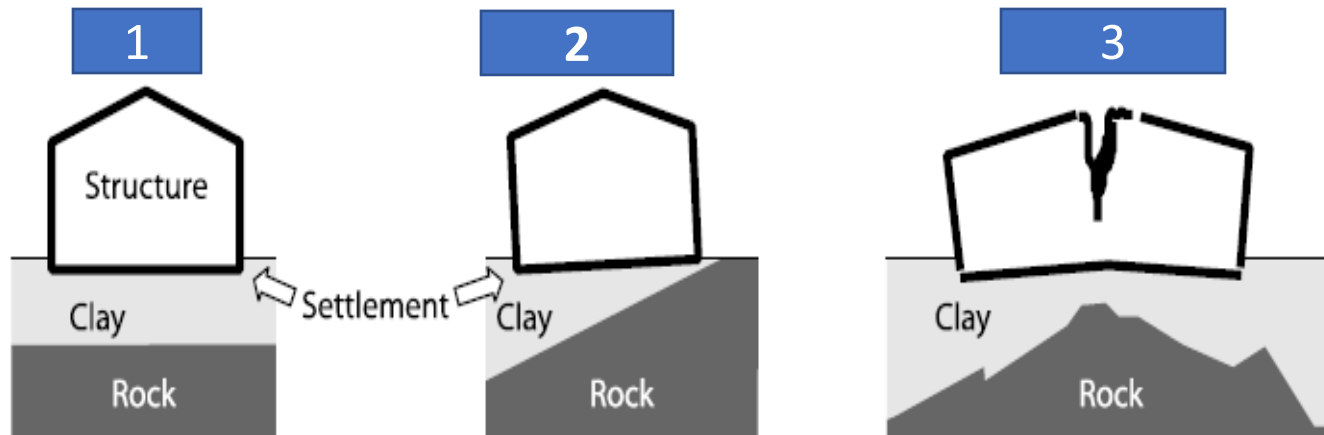


*Careful design of a structure itself is not all that is required for its safety.*



*In fact it is equally important to investigate and understand the nature and behavior of the foundation soil or rocks with its sub surface rock structure.*

Figure, below shows importance of distribution of earth materials relative to the position of structures



1. Compressible clay of uniform thickness overlying effectively incompressible rock; deformation of the clay and settlement of the structure in to the ground is uniform

2. Clay is not of uniform thickness. Settlement in this case is differential, being larger over the greatest thickness of clay. Building will tilt, and may crack.

3. Differential settlement may produced and results effectively breaking the back of the building

## *Tasks of Engineering geologist*

- Professional in geology is responsible to accomplish the following tasks in relation to Civil engineering works and hydraulic structure.
- ✂ What rocks and soils are present, including the sequence of strata, and thicknesses of superficial deposits and the presence of igneous intrusions like dikes and sill
- ✂ The frequency and orientation of joints in the different bodies of rock and the location of any faults and joints ( spacing and aperture )
- ✂ The presence and extent of any weathering of the rocks, and particularly any soluble rocks such as limestone; and gypsum
- ✂ The ground water conditions, including the position of the water table, and whether the ground water contains harmful material in solution, such as sulphates, which may affect cement with which it comes in contact with the foundation materials.

 The suitability of local rocks and soils, especially those to be excavated, *as construction materials. Most civil engineering projects involve some excavation of the soils and rocks. In some cases the excavated rocks may be used as construction material.*

- ❖ The feasibility, planning and design of the construction and costing, and the safety of project may depend critically on the geological condition where the construction take place.
- ❖ This can be accomplished only if sufficient information is obtained about each alternative to support a reasonably close cost estimate to be able to prepare such an estimate implies a general project layout, including what to be built, on and from what kinds or rocks and soils.
- ❑ Geologic data are very important to achieve accuracy in our tasks

❖ *The geologic study will be directed towards finding sites for project features that:*

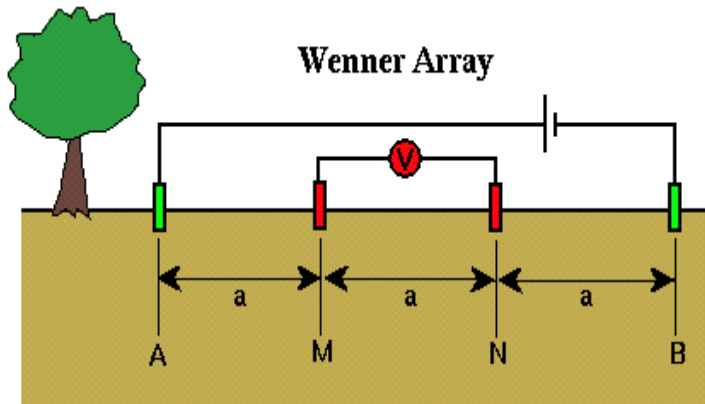
- Avoid Hazards of landslide and faults at each site
- Provide an approximate understanding of the range of the rock types, their attributes, and their spatial relationships.
- Foresee problems that might arise during construction
- Incorporate appropriate measures in the preliminary design.
- Geologic investigation will be conducted to provide an understanding of the potential modes of failure of the rock in relation to its composition and, especially, its structure.
- In general, engineering geology provides basic geological data for the safe construction and remediation of engineering structures .

## Use of Different Geophysical Methods

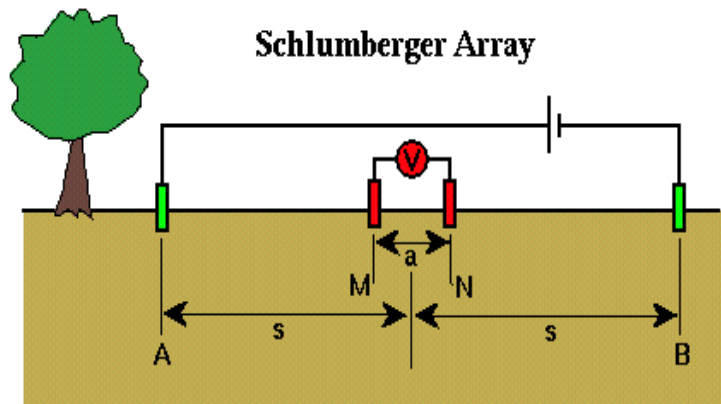
- ❖ *Exploration geophysics* plays a major role in the area of mineral and petroleum exploration, groundwater exploration and engineering construction in which its primary aim is to add extra dimension to geologic information.
- ❖ *Geophysics involves* application principles of several physical sciences related to measurements of rock properties such as density, velocity, susceptibility and resistivity and drawing a deduction about the rock types and their geologic configurations.
- ✓ *The geophysical techniques* most widely used for exploration works are seismic, electrical, gravity, magnetic and electromagnetic methods. For our purpose we try to see only the Electrical resistivity and seismic methods
- ✓ In the *resistivity method*, an electric current is introduced in to the ground by means of two current electrodes and the potential difference between two potential electrodes is measured.
- ✓ It is preferable to measure the potential drop or apparent resistance directly in ohms rather than observe both current and voltage. The ohms value is converted to apparent resistivity by use of a factor that depends on the particular electrode configuration in use

- ✓ The electrodes normally are arranged along a straight line, the potential electrodes being placed inside the current electrodes and all four are disposed symmetrically with respect to the centre of the configuration.
- ✓ The configurations of the symmetric type that are used most frequently are those introduced by Wenner and Schlumberger. Other configurations include the dipole–dipole and the pole–dipole arrays.
- ✓ In the Wenner configuration, the distances between all four electrodes are equal, whereas the distances between the potential electrodes and the center of the array in the Schlumberger configuration are less than those between the current and potential electrodes.

**Fig.** *The expressions used to compute the apparent resistivity, for the Wenner and Schlumberger are;*



$$\rho_a = 2\pi a \frac{\Delta V}{i}$$



$$\rho_a = \frac{\pi(s^2 - a^2/4)}{a} \frac{\Delta V}{i}$$

## 1.2 The Earth and its Interior

- ❖ It How do we determine the structure and composition of earth's interior?
  - Is not possible to get a direct evidence of the interior the earth.
  - The deepest part of the earth that can be directly accessed so far is **13 kilometer**.
  - **Structural deformation and erosion rarely exposes** rocks formed more than **20-25km** below the surface.
  - So, **indirect methods have been used** to study the **interior structure and composition of the earth**. These indirect evidences come largely from the studies of;
    - A) the physical properties of the planet itself- **density**
    - B) the way it transmits **seismic waves**
    - C) volcanic eruptions (**xenoliths**)
    - D) from comparison with **meteorites**
    - E) Nature of **magnetic fields** (from outer core)

- ❖ **Density Evidence:** The average density of the earth is determined to be **5.52 g/cc**, while surfacial rocks have an average density of **2.7 g/cc**, which is less than half of the value for the **entire earth**.
- This indicates that the interior of the earth should be composed of materials, which are heavier than the surfacial materials.
  - Based on this simple evidence, the earth was modeled to be composed of three layers of different density: **from the** surface to about 40 km depth with an average density of 2.7 g/cc; from 40 km to about 3000 km depth with an average density of 6 to 7 g/cc; and from 3000km to the center with an average density of 9 to 10 g/cc.
  - If these different densities are manipulated the average density of the earth will fall at 5.52 g/cc which is the density already determined astronomically.

- ❑ **Meteoritic Evidence** The meteorites are of three types representing three different layers of the disintegrated planet.
- *The **Stony Meteorites***- which are composed of silicates similar to the rocks on the surface of the earth and are inferred to represent the surface of the asteroids;
  - *The **Iron Meteorites***- which are composed of **iron-nickel alloys and are different from any type of material on the earth's surface** and are assumed to represent the interior of the asteroids.
  - *The **Stony-Iron meteorites*** - which are composed of both **silicates and iron nickel alloys** representing the intermediate part of the asteroids.
  - The presence of these three different types of meteorites indicates that the **inner planets are made of different layers of materials.**

- Since ,it is already known that all the planets are formed at the same time from the same material, it can be inferred that the planet earth is also made up of three different layers, which are represented by the three different meteorites.
- The stony meteorites represent the surface of the earth, the iron-nickel meteorites represent the central part of the earth, and the stony-iron meteorites represent the intermediary part of the earth.
- This confirms the model given based on the mathematical computation of the density evidence.
- ❖ **Volcanic Evidence:** Apart from the meteorites there are some materials known as xenoliths that directly come from the depth of the earth enclosed with in magmas, which are not contaminated by surfacial rocks.
- The composition of the **xenoliths** represents the composition of the materials at that depth and it is found out to be heavy silicates of magnesium and iron.

- ❖ *Earthquake (Seismic Waves) Evidence:* Earthquake waves commonly called seismic waves pass through the earth's interior and then emerge at the surface where they can be recorded by wave sensitive devices called Seismographs at seismograph stations.
- ✓ *Body Waves-* which are traveling through the interior body of the earth having relatively higher velocity and lower amplitude than the surface waves.
- They are not destructive but are very important to understand the nature of the interior of the earth because their velocity is dependent on the nature of the materials through which they are traveling.

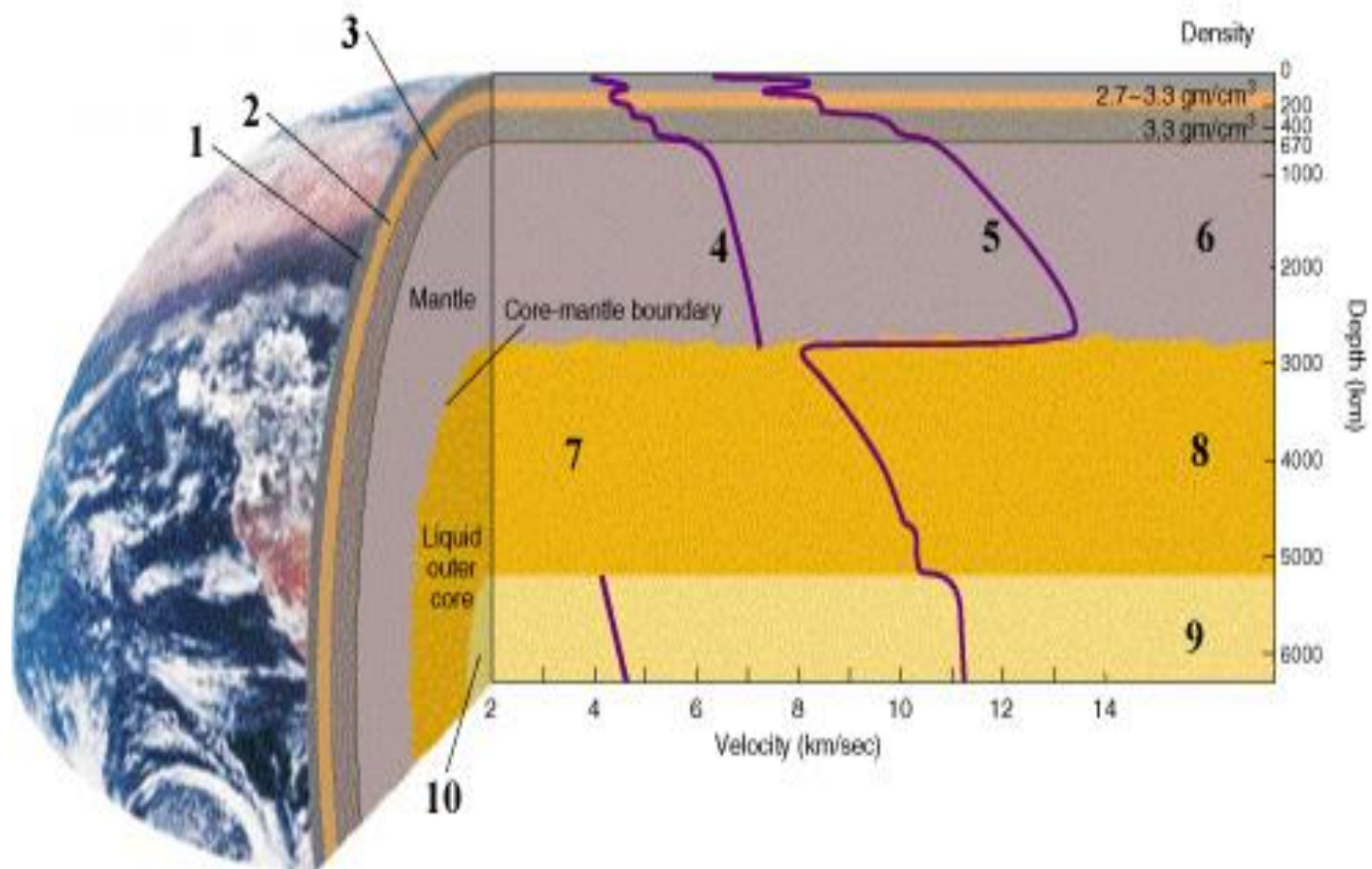
➤ There are two types of the Body waves:

❖ The Primary waves; Called (P) waves and longitudinal waves.

- They have high velocity.
- Their velocity is determined by the *compressibility* ( $K$ ), *rigidity* ( $\mu$ ), and *density* ( $\rho$ ) of the materials through which it is traveling.
- The P-waves can travel through solid, liquid, and gaseous media.

❖ The Secondary waves ;Called (S) waves and transversal waves.

- They have **low velocity**.
- Their velocity is determined by the **rigidity** ( $\mu$ ), and **density** ( $\rho$ ) of the materials through which it is traveling.
- The S-waves can travel only through solid media because fluids have zero rigidity.



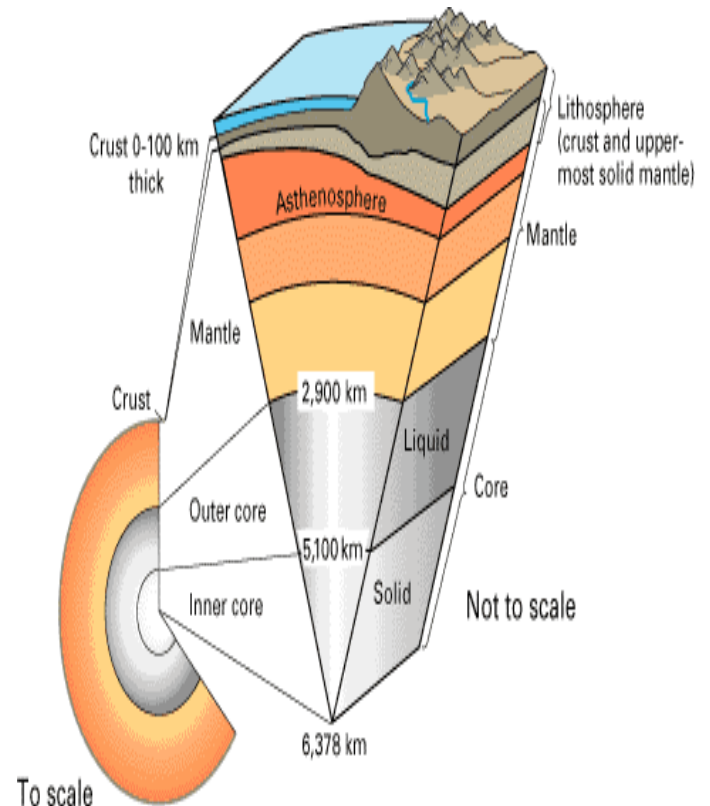
**CRUST** ; (7-70km thick) It contains minerals with Oxygen, silicon, aluminum, iron, calcium, sodium, potassium, magnesium,

**MANTLE** ; (about 2800km thick) Contains iron ,and magnesium silicate minerals

- it extends from 50km to 2900km in to the inner earth ( Gutenberg discontinuity)
- Its density ranges from 3.4 to 5.5 g/cm<sup>3</sup>
- constitute 82% by volume and 68% by mass of the earth

**Core** ; (about 3500km thick); The central mass extended from 2900km up to the centre

- Mostly made up of iron with some nickel
- Average density is 10.79 g/cm<sup>3</sup>
- Constitute 16% by volume and 32% by mass of earth



□ The interior of the earth is recognized according to **composition** as: *Crust, Mantle & Core*

❖ **Crust:** outer layer extended from solid surface down to the first major discontinuity (Mohorovic discontinuities)

- Made up of light materials(silicate rocks)
- It is of two types: continental and oceanic crust
- The density ranges from 2.7 (continental) to 3 (oceanic crust)
- ✓ All engineering works built in or on the upper crust and crustal rock material serve as a construction materials .

### a. Continental Crust

- ♦ thick as much as 70km
- ♦ composed of light weight rocks
- ♦ the oldest rock of the crust
- ♦ average density is  $2.7 \text{ gm/cm}^3$

### b. Oceanic Crust

- ♦ is thinner about 8km
- ♦ is dark dense volcanic rocks
- ♦ younger and relatively undeformed
- ♦ average density is  $3 \text{ g/cm}^3$