

## CHAPTER TWO

### THE GEOLOGY OF ETHIOPIA AND THE HORN

#### 2.1. Introduction

**Geology** is an earth science that *studies: evolution of the earth, the materials of the earth, the structure of those materials, the processes acting upon them and organisms of our planet.*

#### 2.2. Origin of the Universe: The Big Bang Theory

Big Bang theory (BB) states the **universe is the result of the explosion of matter** which has extremely high density and temperature. Some 10 to 20 billion year ago, all matter in the known universe were once concentrated into a single point called **cosmic egg**.

The explosion destroyed the mass, and all the matter was thrown into space in all direction. The violence of the explosion was so great that matter of the cosmic egg was reduced to subatomic particles, **which soon reassembled to form only two elements hydrogen and helium**. The universe, shortly after explosion, comprised an expanding cloud of gases composed of nearly 75% of hydrogen, 24% is helium and 1% is the rest.

When a temperature of approximately **11 million degree Celsius was reached, thermonuclear fusion was spontaneously initiated, and stars were born**. The sun's first rays of thermonuclear light blazed across the galaxy 4.5 billion years ago. *The primal earth emerged from a spinning, turbulent cloud of gas, dust and planetoids* that surrounded the new star. The reason for the wide acceptance of this theory is that the universe and galaxies are still moving apart at a tremendous speed.

#### 2.3. The Theory of Continental Drift (CD)

The earth's continents were once bunched up together into a single huge continent called *Pangaea*. The large super continent was then split into smaller fragments. According to Alfred Wegener *Observations:*

- **Fit of the continents:** *The opposing coastlines of continents often fit together.*
- **Match of mountain belts, rock types:** *If the continents are reassembled as Pangaea, mountains in West Africa, North America, Greenland, and Western Europe match up.*
- **Distribution of fossils:** *Fossils form definite linked patterns if the continents are reassembled.*
- **Paleoclimates:** *rocks formed 200 million years ago in India, Australia, South America, and southern Africa all exhibited evidence of continental glaciations.*

## 2.4. The Geologic Processes: Endogenic and Exogenic Forces

Geology studies of how Earth's materials, structures, processes and organisms have changed over time. These processes are divided into two major groups: **internal and external processes**.

The internal processes (endogenic) include volcanic activity and all the **tectonic processes (folding, faulting, Orogenesis (mountain building), and epeirogenesis (slow rising and sinking of the landmass)**. These processes result in building of structural and volcanic features like **plateaus, rift valleys, Block Mountains, volcanic mountains**, etc.

The external (Exogenic) processes **are geomorphic processes**. They include **weathering, mass transfer, erosion and deposition**. They act upon the volcanic and structural landforms by modifying, roughening and lowering them down.

## 2.5. The Geological Time Scale and Age Dating Techniques

The geological history is divided into Eras. The Eras are given names that indicate the kind of life that existed in them. For instance, the Paleozoic Era (ancient life) is the **age of invertebrates**, the Mesozoic Era (the middle life) is the **age of reptiles** while the Cenozoic Era (recent life) is the **age of mammals**.

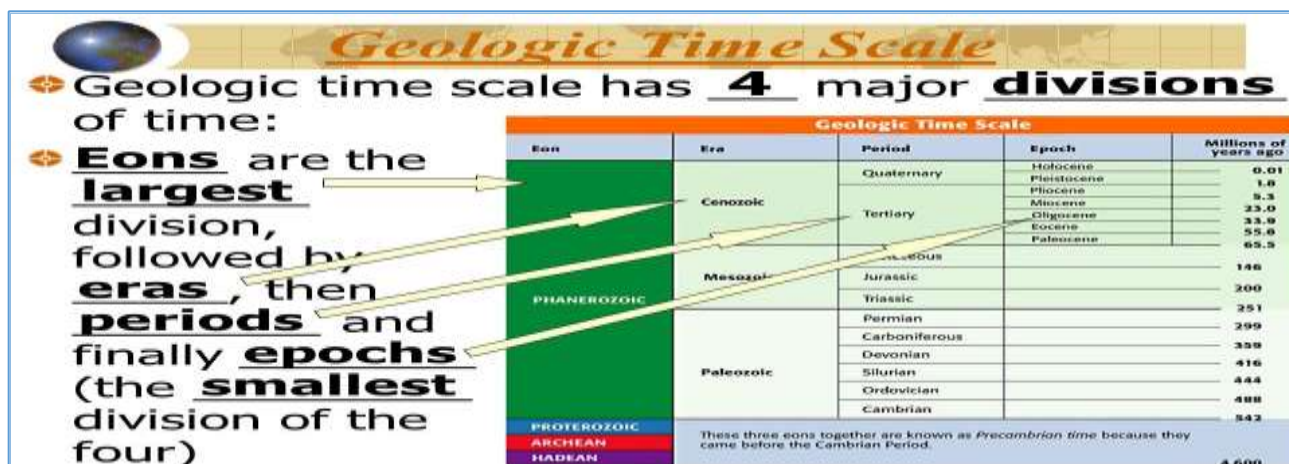
These geological time divisions basically differ from each other in such characteristics:

- Relative position of land and sea,
- The kind of climate and,
- Type of animal and plant life that developed.

The Earth is believed to have been formed approximately 4.6 billion years ago and the earliest forms of life were thought to have originated approximately 3.5 billion years ago. The span of time before life appeared was termed the **Precambrian Era**. To describe the geology and history of life on Earth, **scientists have developed the geological time scale**. The geological time scale measures time on a scale involving four main units:

1. An **epoch** is the smallest unit of time on the scale and encompasses a period of millions of years.
2. Epochs are clumped together into larger units called **periods**.
3. Periods are combined to make subdivisions called **Eras**.
4. An **eon** is the largest period of geological time.

The division of time units in the **geological time scale is usually based on the occurrence of significant geological events** (e.g. mass extinctions). As such, the **geological time categories do not usually consist of a uniform length of time.**



### 2.5.1. Age Dating Techniques

There are two techniques of knowing the age of rocks: Relative and absolute age dating.

#### A. Relative Dating

Relative dating **uses geological evidence** to assign comparative ages of fossils. **If any of the fossils are unique to one of the geologic time periods, then the rock was formed during that particular time period.** The second way is to use the **younger rocks are on top of older rocks.**

#### B. Absolute Dating (Radiometric Techniques)

Radioactive elements such as uranium (U) and thorium (Th) decay naturally to form different elements or isotopes of the same element. **Every radioactive element has its own half-life.**

At the end of the period constituting one half-life, half of the original quantity of radioactive element has decayed; after another half-life, half of what was left is halved again, leaving one fourth of the original, and so on. Two of the major techniques include:

**A. Carbon-14 Technique:** Upon the organism's death, carbon-14 begins to disintegrate at a **known rate**, and no further replacement of carbon from atmospheric carbon dioxide can take place. **Carbon-14 has half-life of 5730 years.**

**B. Potassium-Argon Technique:** Method of determining the time of origin of rocks by measuring the ratio of radioactive **argon** to radioactive **potassium** in the rock. This dating **method** is based upon the decay of radioactive **potassium-40** to radioactive **argon-40** in minerals and rocks.

## 2.6. Geological Processes and the Resulting Landforms of Ethiopia and the Horn

### 2.6.1. The Precambrian Era Geologic Processes (4.5 billion - 600 million years ago)

It covers 5/6th of the Earth's history. Knowledge of the events is limited because of its **remoteness in time** and the **absence of well-preserved fossils**.

The major geologic event of the Precambrian Era was **Orogenesis**. As a result, the land was subjected to intense folding. Therefore, in most parts of Ethiopia rocks belonging to this Era are found beneath all other rocks, forming the basement rocks. Since, they had been subjected to pressure and heat from overlying weight, earth movements (folding, orogenesis) and to intrusive igneous activity; the original rocks (both *sedimentary* and *igneous*) were altered into metamorphic rocks of varying stages of metamorphism. The Precambrian rocks are overlaid by recent rock formations.

However, as surface rocks covering **25% of the land mass of the country**; they are found exposed in the following areas:

- In the northern part: Western lowlands, parts of **northern and central Tigray**.
- In the western Part: **Gambella, Benishangul-Gumuz (Metekel and Asossa)**, western Gojjam, western Wellega, Illuababora, and Abay gorge.
- In the eastern part: **Eastern Hararghe**.
- In the southern Part: **Guji, southern Omo**, and parts of southern *Bale and Borena*.

### 2.6.2. The Paleozoic Era Geologic Processes (600million - 225 million years ago)

The Paleozoic Era lasted for about 375 million years. The major geological process of this Era was **denudation**. Because of the limited deposition within Ethiopia, rocks belonging to this Era are rare in the country.

### 2.6.3. The Mesozoic Era Geologic Processes (225-70 million years ago)

This Mesozoic Era lasted for about 155 million years. It was an Era of alternate **slows sinking and rising (epeirogenesis) of the landmass**. This process affected the whole present-day Horn of Africa and Arabian landmass.

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The collapsing of the land began about 225 million years ago. As the land sank slowly the sea invaded it starting from Somalia and Ogaden and slowly spreading northwestward. This was in late Triassic. This phenomenon continued up to Jurassic period.

By the end of the Mesozoic Era, when the land emerged out of the sea, three major sedimentary formations were laid and formed upon the Precambrian rock surface. These were the **Adigrat or lower sandstone, Hintalo limestone and Upper Sandstone**. As transitional formations, gypsum and shale were interbedded above and below the Hintalo limestone. The **Mesozoic sedimentary rocks cover 25%** of the land mass of the country.

The age and thickness of the Sandstone layers vary in a Southeast - Northwest direction. The **Adigrat sandstone is older and thicker in the southeast and progressively decreases in age and thickness northwestward**. The **Upper sandstone, on the other hand, is thicker and younger (Upper Cretaceous) in the Southeast, while in the Northwest it is older and thinner**.

### 2.6.4. The Cenozoic Era Geologic Processes (70million years ago - Present)

It is the most recent of the geologic Eras. The tectonic and volcanic activities that took place in this Era have an important effect in the making of the present-day landmass of Ethiopia and the Horn of Africa. The land was subjected to two major geologic events and other geologic processes of lesser magnitude but still important. These geologic activities are:

- a. Uplifting of the Arabo-Ethiopian landmass and outpouring of huge quantity of lava.
- b. Formation of the Rift Valley.
- c. Quaternary volcanism and deposition.

#### a. Uplifting of the Arabo-Ethiopian landmass and outpouring of lava flood

The uplifting of the whole of the Arabo-Ethiopian landmass is a continuation of the slow rise that began in the Upper **Jurassic and Cretaceous periods**. This huge uplift continued to the **Paleocene and Oligocene epoch of the Tertiary** period. Where the uplifting was of greater magnitude, the land was pushed up to a maximum height of 2,000 meters above sea level.

#### b. The Formation of the Rift Valley

According to theory of plate tectonics the Rift Valley may be lying on the Earth's crust below which lateral movement of the crust in opposite directions producing *tensional forces* that caused

parallel fractures or faults. As the tension widened the fractures, the central part of the landmass collapsed to form an extensive structural depression known as the **Rift Valley**.

The **Red Sea and the Gulf of Aden** were connected as a result of the rifting and faulting of the land bridge that separated them. At the same period (Pliocene), the **Afar depression (including the Gulf of Zula)** was down-faulted allowing the Red sea water to penetrate far inside. Reversed tilting and volcanic activity, later (Pleistocene) blocked the connection and isolated the extension of the sea, allowing much of the water to evaporate. As a result, thick saline materials accumulated. During the same period, the area between the Danakil Depression and the Red Sea was uplifted to form the **Afar Block Mountains**.

### **The Spatial Extent of the Rift Valley**

Is part of the Great East African Rift system that extends from Palestine-Jordan to Malawi-Mozambique, with a distance of 7,200 KM (5,600 km is in Africa, and 1,700km is in Eritrea and Ethiopia. On land, the widest part of the Rift Valley is the Afar Triangle (200-300 km). The Red Sea, the Gulf of Aden, and the East African System meet and form the triangular depression of the Afar where **the Kobar Sink** lies about 125 meters below sea level.

The formation of the Gulf of Aden and the separation of the Arabian Peninsula from the Horn of Africa also took place during the Tertiary period. The Rift Valley region of Ethiopian is the most *unstable* part of the country. The formation of the Rift Valley has the following structural (physiographic) effects:

- It divides the Ethiopian Plateau into two.
- It separates the Arabian landmass from African landmass.
- It causes the formation of the Dead Sea, Red Sea and the Gulf of Aden troughs.
- It creates basins and fault depressions on which the Rift Valley lakes are formed.

Faulting and graben formation are not only limited to the Rift Valley, whereas, the formation of Lake Tana had been another significant feature.

### **c. Quaternary Volcanic Eruptions and Depositions**

Quaternary Volcanic is a continuation of the tectonic and volcanic processes that earlier affected the Rift Valley formation. It occurred in the form of renewed rifting/faulting and more volcanism.

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This activity was generally limited to the floor of the Rift Valley and the region south of Lake Tana, where the lava covers an area of more than 3,000km<sup>2</sup>.

Aden volcanic and recent faulting are more extensively developed in the Afar region. Because of their recent occurrence, the Aden volcanic have relatively well-preserved and visible morphological features. The basic volcanic features of the Aden series include the following:

- Numerous and freshly preserved volcanic cones, many of which have explosive craters.  
Eg. Dubi, Erta Ale, Afrera etc. Of these, Erta Ale is the most active volcano in Ethiopia.
- Volcanic hills and mountains, some of which are semi-dormant (Fantale, Boseti-Gouda near Adama, Aletu north of Lake Ziway, Chebbi north of Lake Hawassa etc.).
- Extensive lava fields and lava sheets some of which are very recent.
- Lava ridges.
- Thermal springs, fumaroles etc.

### Quaternary Deposition

During the Quaternary period of the Cenozoic Era, the Earth experienced a marked climatic change, where warmer and dry periods were alternating with cooler and wet periods. This was the time of the 'Pluvial Rains in Africa'. The heavy Pluvial Rains eroded the Ethiopian plateau and the eroded materials were deposited in the Rift Valley lakes.

The excessive rain resulted in an excessive surface flow. They carried a lot of water and sediments. Lake and marshy areas became numerous and deep. Many were enlarged and covered much area and even merged together. For example, **Ziway-Langano- Shalla; Hawasa-Shallo; Chamo-Abaya**; and Lake Abe and the nearby smaller lakes and marsh basins formed huge lakes.

After the 'Pluvial Rains', the Earth's climate became warmer and drier. Thus, it increased the rate of evaporation that diminished the sizes of the lakes. Today, **there are lacustrine deposits of continental origin around many of the Ethiopian lakes**, river valleys and lowlands. Based on manner of deposition and agents these **deposits are divided as:**

- *Lacustrine deposits:* Deposits on former lakebeds, and swampy depressions.
- *Fluvial deposits:* Deposits on the banks of rivers, flood plains both in plateau, foothills etc.

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- *Glacio-fluvial deposits and erosional features:* These are occurred on high mountains, such as Bale and Kaka Mountains.
- *Aeolian deposits:* Are windblown deposits.
- *Coastal and marine deposits:* Deposits on sea invaded and sea-covered places.

The quaternary deposits are mainly found in the Rift Valley (Afar and Lakes Region), Baro lowlands, southern Borena, and parts of northwestern low lands. Generally, the **Cenozoic rocks cover 50% of the land mass of the country**. These include Highland Tertiary volcanics (basalts), Tertiary as well as Quaternary volcanics, and sediments of the rift valley.

### 2.7. Rock and Mineral Resources of Ethiopia

The occurrence of metallic minerals in Ethiopia is associated with the Precambrian rocks. With varied concentration and extent, a great variety of such minerals occur in the basement rocks. Even though the exploitation and search of mineral (metal, salt and gold) deposits in Ethiopia has been taking place since long years before, presently mineral production from Ethiopia has been negligible by World standards.

Geological surveys proved that Ethiopia has abundant mineral resources of metals and precious **metals, coal, and industrial minerals**.

#### Gold

Gold has been mined in Ethiopia for quite long time, mainly from Benishangul-Gumuz (Metekel) and Adola. Operating mines produce gold from primary sources: (Dermi-dama, Sakoro and Lega-dembi. Mechanized alluvial working of gold field from Adola.

Secondary gold deposits are common in: (Adola, Murmur Basin, Shakiso, Awata Basin, Dawa Basin, Ghenale Basin, Ujama Basin, Makanisa, Akobo River basin, Wondo, Negele-Yabelo area, Sherkole, Mengi-Tumat-Shangul areas, and the drainage of the Didessa and Birbir.

#### Platinum

The Yubdo area in Wellega, is the only active Ethiopian Platinum mine and reported occurrences area are from Delatti in Wellega, and the valley of Demi-Denissa and Bone Rivers as well as Tullu Mountain area in Sidama.

## **Tantalum**

Significant deposit of tantalum and niobium is found in southern Ethiopia. It occurs in Adola area where Kenticha Tantalum mine with resources of more than 17,000 metric tons of world class ore reserve is found. The sedimentary and volcanic rock activities are also resourceful. Extensive lignite deposits in Ethiopia are found in Nedjo (Wellega), and in small amounts in Chilga (Gonder).

## **Gemstones**

Gemstones, including amethyst, aquamarine, emerald, garnet, opal, peridot, sapphire, and tourmaline occur in many parts of Ethiopia, mainly in Amhara and Oromia Regional States. Quality Opal was first discovered by local people in Wadla and Dalanta woredas of North Wollo, Amhara Region.

## **Potash**

The potash reserve in the Danakil (Dallol Depression) of the Afar region is believed to be significant.

## **Gypsum and Anhydrite**

Very large deposits are known to occur in sedimentary formations of the Red Sea coastal area, Danakil Depression, Ogaden, Shewa, Gojjam, Tigray, and Hararghe.

## **Clay**

Ethiopia is endowed with industrial clay material. Alluvial clay deposits for bricks and tile, pottery and pipe industry occur in Adola, Abay gorge, and the Rift Valley lakes region. Ceramic clay for the production of glasses, plates, bricks is found at Ambo and Adola.

## **Marble**

Crystalline limestone is widespread in the basement rocks of Ethiopia. Marble has been quarried in west of Mekelle and south of Adwa in Tigray. In the east in Galetti, Soka, Ramis, Rochelle, Kumi and other valleys of Chercher Mountain in West Hararghe. In the northwestern also in Gonder, the Dabus river and river basins in Benishangul-Gumuz and Gojjam.

## Construction stones

Basalt, granite, limestone and sandstone are important building stones. For the surfacing of roads and compaction, basalt, scoria and other volcanic rocks are extensively used. Mesozoic limestone is an important raw material for cement and chalk production. The earlier cement works at Dire Dawa and the recent ones at Muger Valley, Abay gorge (Dejen), Tigray (Messebo) are using similar raw materials from these rock formations.

### 2.7.1. Mineral Potential Sites of Ethiopia

According to the Ethiopian geological survey, the geologic formations that host most mineral potentials of Ethiopia includes three major greenstone belts:

These are:

1. **The Western and South-western-greenstone belt:** They contain various minerals: primary gold occurrences (Dul,Tulu-Kape,Oda-Godere, Akobo,Baruda,Bekuji-Motish and Kalaj); Yubdo Platinum, Base metals of Azali Akendeyu, Abetselo and Kata; Fakushu Molybdenite and the iron deposits of Bikilal, Chago, Gordana and Korre, Benshagul-Gumuz- Marble, Akobo and Asosa placer gold deposits and etc.
2. **The Southern greenstone belt:** It is **known as the Adola belt**, which comprises the primary gold deposits and occurrences of Lega-dembi, Sakaro, Wellena, Kumudu, Megado-Serdo, Dawa Digati, Moyale and Ababa River;the columbo-tantalite of kenticha and Meleka, and the Adola nickel deposit and other industrial minerals.
3. **The Northern greenstone belt (Tigray):** This belt comprises of the primary gold occurrences of Terakemti, Adi-Zeresenay, and Nirague. The base metals of Terer, Tsehafiemba and other parts of Tigray, Placer gold occurrences of Tigray.