Adama General Hospital & Medical College (AGHMC)
College of Health Sciences

Course Name: Geography of Ethiopia and the Horn (3 cr hrs)

Chapter 2: The Geology of Ethiopia and the Horn

May, 2022
Adama

Outline of the Presentation

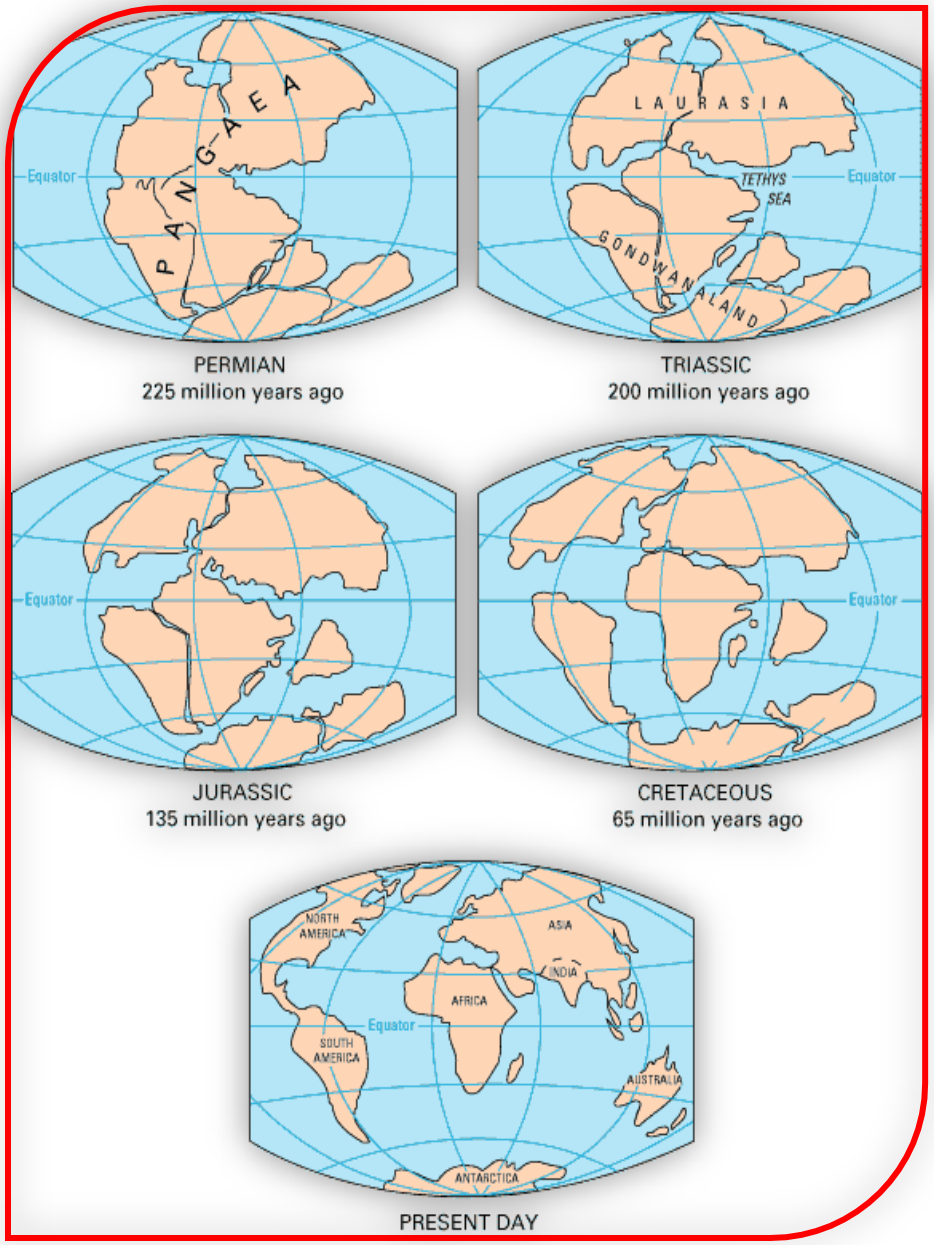
- Introduction: Geology and Continental drift theory
- The Geologic Processes: Endogenic and Exogenic Forces
- The Geological Time Scale and Age Dating Techniques
- Geological Processes and the Resulting Landforms of Ethiopia and the Horn
  - The Precambrian Era Geologic Processes
  - The Paleozoic Era Geologic Processes
  - The Mesozoic Era Geologic Processes
  - The Cenozoic Era Geologic Processes
- Rock and Mineral Resources of Ethiopia
  - Brief Facts and Current State of Main Minerals in Ethiopia
  - Mineral Potential Sites of Ethiopia

Introduction

- **Geology** is an Earth science that studies
  - the evolution of the earth
  - the materials of which it is made of, and
  - the processes acting upon them
- Geology studies how Earth's materials, structures, processes and organisms have changed over time.
- A great deal of geological understanding is obtained by inference, using clues from what can be seen and what can be measured such as:
  - rocks and landforms
  - geophysics (studying earthquake waves which can penetrate deep beneath the Earth's surface),
  - geochemistry (analysis of the detailed composition of rocks which can give clues as to their origin) and
  - geochronology (methods for finding the ages of rocks, usually from the radioactive elements they contain).

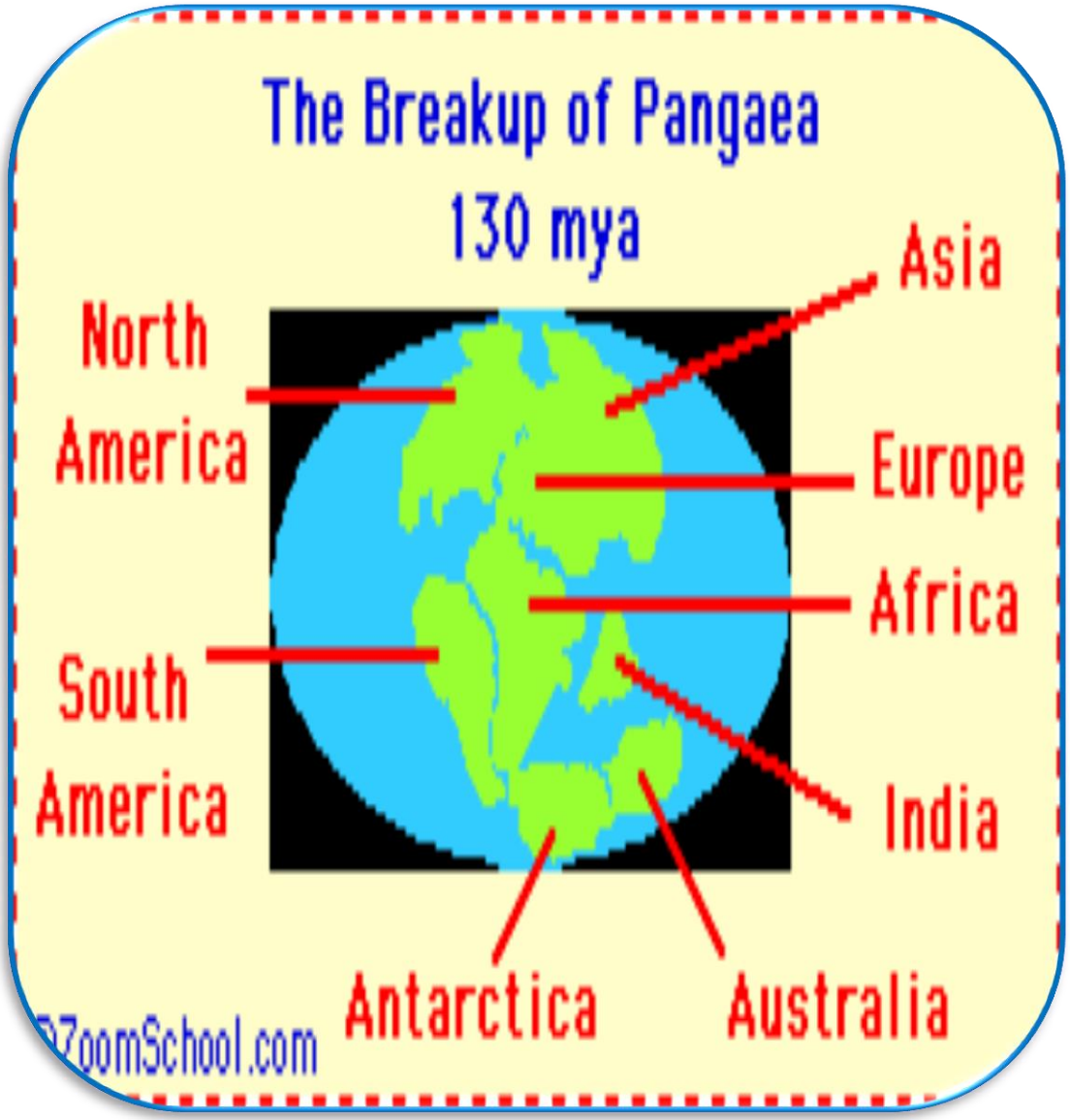
Continental Drift Theory

- Continental Drift Theory is developed by **Alfred Wegener**
- The theory primarily states that the earth's continents were once bunched up together into a single huge continent called ***Pangaea***.
- Proposed that about 200 million years ago, a super continent called Pangaea ("all Earth") slowly broke up & drifted apart forming 2 landmasses called Laurasia & Gondwanaland
- These 2 landmasses continued to break up & drift apart to their present positions



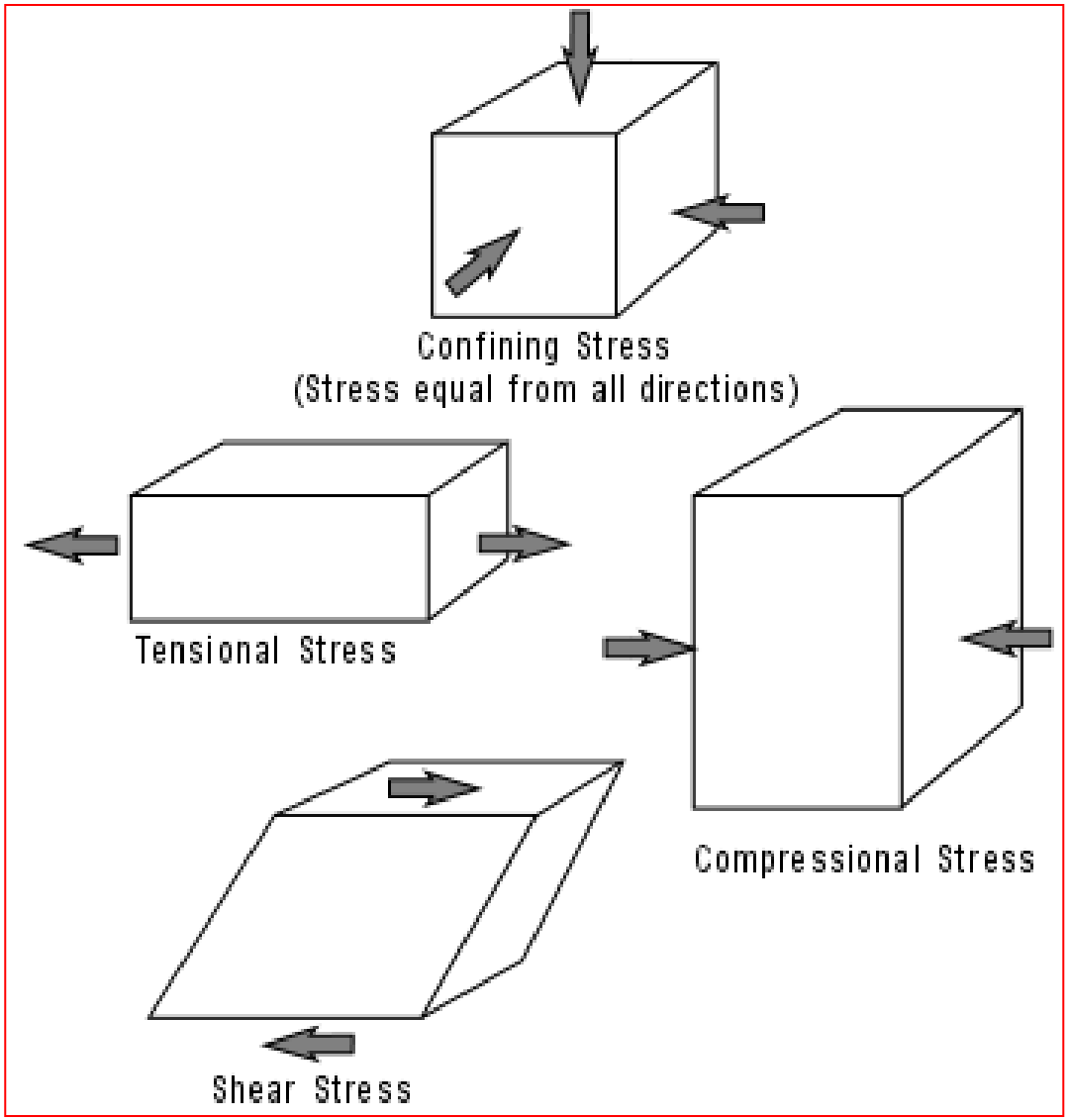
Wegener's principal observations were:

- ***Structural- Fit of the continents:*** coastlines of South America & Africa show that they could fix together
- ***Geological - Match of mountain belts and rocks:*** Europe & Africa & the Americas are geologically related
- ***Palaeontological- Distribution of fossils:*** identical fossils are found in rocks in South America & Africa
- ***Paleoclimates:*** glacial deposits



The Geologic Processes: Endogenic and Exogenic Forces

- Geologic processes are divided into two major groups:
  - i*nternal* 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.



- Three deforming forces:
  - compressional/convergent forces
    - when rocks (materials of the earth) move towards one another,
  - Tensional/divergent forces
    - movement of materials in opposite directions along the same line causing faulting
  - Shear/Transform forces
    - forces act parallel to one-another but in opposite directions

- 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.
- The landmass of Ethiopia, as elsewhere, is the result of the combined effect of endogenic and exogenic processes.

The Geological Time Scale and Age Dating Techniques

- The geological history is divided into Eras. Each Era is divided into periods
- The Eras are given names that indicate the kind of life that existed in them. For instance,
  - Precambrian Era is the span of time before life appeared
  - Paleozoic Era (ancient life) is the age of invertebrates,
  - Mesozoic Era (the middle life) is the age of reptiles
  - Cenozoic Era (recent life) is the age of mammals.
- These geological time divisions basically differ from each other in such characteristics as
  - the relative position of land and sea,
  - the kind of climate and
  - most important the kind of animal and plant life that developed and existed during that Era or period.

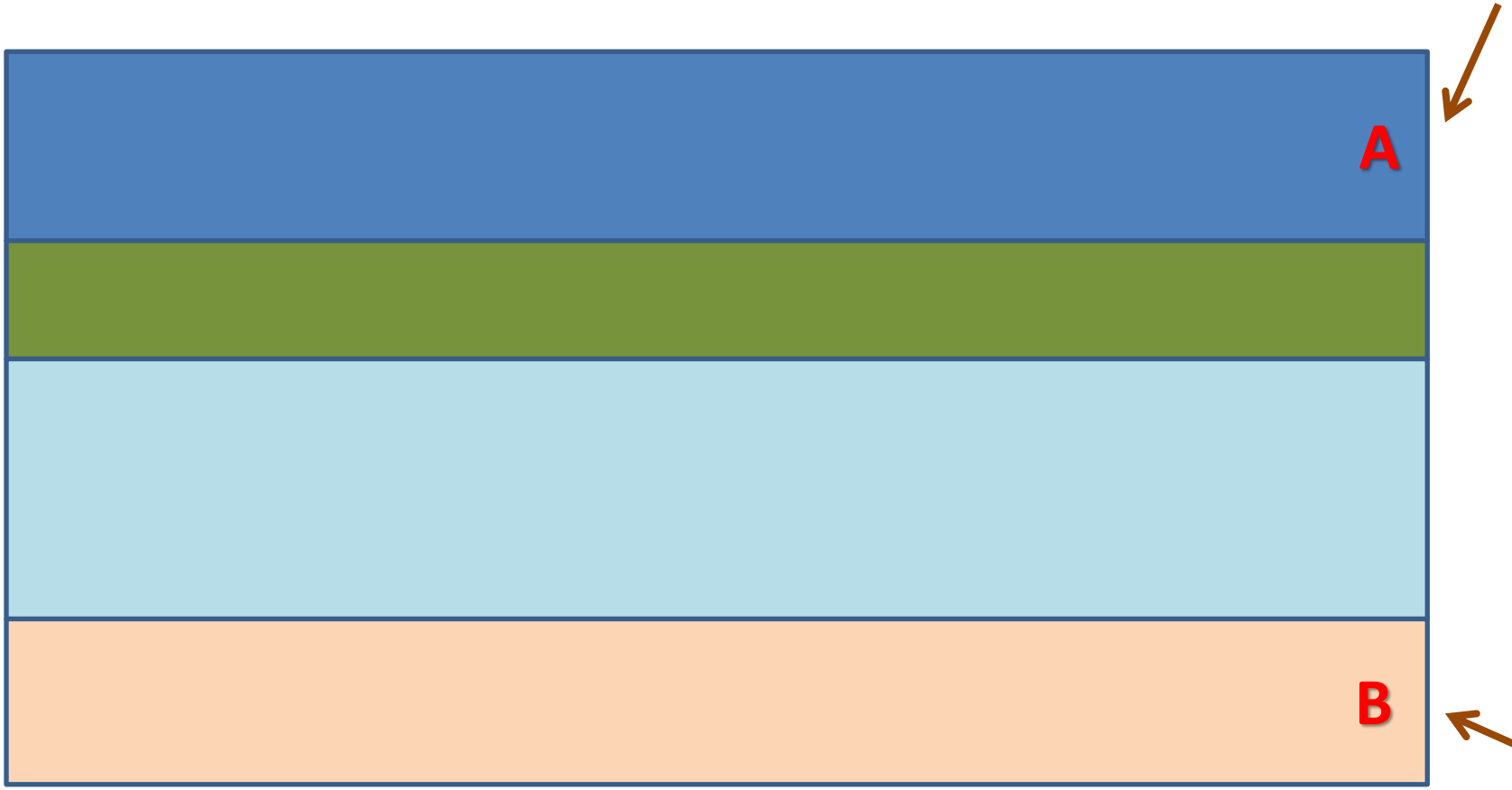
- The geological time scale measures time on a scale involving four main units:
  - An *epoch* is the smallest unit of time on the scale and encompasses a period of millions of years.
  - Chronologically, epochs are clumped together into larger units called *periods*.
  - Periods are combined to make subdivisions called *Eras*.
  - An *eon* is the largest period of geological time.
- As such, the geological time categories is usually based on the occurrence of significant geological events and do not usually consist of a uniform length of time.
- The geological time scale, illustrated in Table 2.1, is built largely on the basis of life and evolution (page 15).

Era	Period	Began	End	Major Events (million years ago)
Cenozoic	Quaternary	1.6	Present	Major glaciers in North America and Europe (1.5)
	Tertiary	70	1.6	Rocky Mountains (65), individual continents take shape.
Mesozoic	Cretaceous	146	70	Dinosaurs extinct (65), western interior seaway and marine reptiles (144 – 65)
	Jurassic	208	146	Pangaea (one land mass) begins to break up (200)
	Triassic	225	208	First mammals and dinosaurs
Paleozoic	Permian	290	225	Greatest extinction on Earth (245)
	Pennsylvanian	322	290	First reptiles
	Mississippian	362	322	Coal-forming forests
	Devonian	408	362	First land animals and first forests (408)
	Silurian	439	408	Life invades land
	Ordovician	510	439	First fish appeared
	Cambria	600	510	Great diversity of marine invertebrates
Precambrian	Proterozoic	2,500	600	Marine fossil invertebrates (600)
	Archean	4,500	2,500	Earliest fossils recorded (3,500), earliest rock formation (4,000)

Age Dating Techniques

- There are two techniques of knowing the age of rocks: relative and absolute dating or radiometric techniques
- **Relative dating**
  - uses geological evidence to assign comparative ages of fossils
  - We can use two ways to know the relative age of a rock:
    - one way is to look at any fossils the rock may contain.
    - 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 "What is on top of the older rocks?" younger rocks are on top of older rocks (layers)

- Law of superposition works in In rock that is not disturbed.
- But these two methods only give the relative age of rocks -which one is younger and which is older.
- The relative approach does not give exact ages



- **Absolute dating**
  - the regular rates of decay for unstable, radioactive elements were found to constitute virtual "clocks" within the earth's rocks.
  - 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.
  - Shorter half life means more accurate age
  - Two of the major techniques include:
    - *Carbon-14 Technique:*
      - Upon the organism's death, carbon-14 begins to disintegrate at a known rate. Carbon-14 has half-life of 5730 years.
    - *Potassium-Argon Technique:*
      - The decay is widely used for dating rocks.

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

- The Precambrian Era covers 5/6th of the Earth's history (majority).
- Due to its remoteness in time and the absence of well-preserved fossils, our knowledge of the events is limited.
- The major geologic event of the Precambrian Era was *Orogenesis* which was formed as a result of:
  - the land was subjected to intense folding.
  - then accompanied by intrusive igneous activity (when magma crystallizes beneath the earth's surface).
  - finally the result was the formation of huge mountain ranges.
- In most parts of Ethiopia rocks belonging to this Era are found beneath all other rocks, forming the basement rocks
- Because of pressure and heat from overlying weight as well as earth movements, the original rocks (both *sedimentary* and *igneous*) were altered into metamorphic rocks

- These processes have allowed mineralization and crystal formation and the rocks are also collectively described as *crystalline rocks*.
- The Precambrian rocks are overlaid by recent rock formations.
- However, surface rocks cover 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 southern Part: Guji, southern Omo, and parts of southern Bale and Borena.
  - In the eastern part: Eastern Hararghe.

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

- The major geological process of this Era was denudation (as a result of heavy erosion)
- The mountains were subjected to intense and prolonged denudation
- Finally reduced to a "peneplained" surface i.e condition of low relief or nearly to plain
- Undulating plain with some residual features (inselbergs) was formed
- Because of the limited deposition within Ethiopia, rocks belonging to this Era are rare in the country

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

- It was an Era of alternate sinking and rising of the landmass
- The land was tilted eastward as a result of tectonic forces – lower in the southeast and higher in the northwest.
- As the land sank, the sea coming from Indian ocean invaded it starting from Somalia and Ogaden and spreading northwestward
- As the sea spreading gets greater and greater, peneplained Precambrian rock surface was characterized by:
  - Deposition of sands, mud (shale), gypsum and later lime
  - Flourishing of marine life and decaying and precipitating of their remains
- Hence, Mesozoic rocks are considered to have the greatest potential for oil and gas deposits

- Compression by the overlying rocks and by cementing minerals, the sands and lime were compacted to form sandstone and limestone layers respectively.
- These are known as the Adigrat sand stone and Hintalo limestone layers.
- In the Horn of Africa and Ethiopia, the slow rise of the land and consequently the regression of the sea took place
- Then another process of deposition of clay, silt, sand conglomerate occurred as the sea receded (retreated) due to uplift of the landmass.
- Gypsum, shale and at last sands were laid over the Hintalo limestone.
- The uppermost layer is known as the Upper sandstone.

- 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 inter-bedded 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 due to:
  - the tilting of the landmass during the transgression and regression of the sea,
  - the direction of the invading and retreating sea.

- 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 thinner and younger (Upper Cretaceous) in the Southeast, while in the Northwest it is older and thicker.
- The transgressing sea and Mesozoic sediments nearly covered the whole of Ethiopia.
  - The northwestern limit was as far as central Tigray, and
  - western slopes of Western highlands.
- As surface rocks, these old marine sediments are extensively found in the
  - Southeast lowlands. Other exposures include
  - central Tigray, and
  - along the gorges of Abay and Wabishebelle rivers

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

- The most recent of the geologic era
- It has important effect in the present-day landmass of Ethiopia and the Horn of Africa
- The major geologic events and processes are:
  - Uplifting of the Arabo-Ethiopian landmass and outpouring of huge quantity of lava
  - Formation of the Rift Valley
  - Quaternary volcanism and deposition

Uplifting of the Arabo-Ethiopian landmass and outpouring of lava flood

- A continuation of the slow rise that began in the Upper Jurassic and Cretaceous periods then continued to the Paleocene and Oligocene epoch of the Tertiary period.
- The land was pushed up to a maximum height of 2,000 meters above sea level during the Eocene epoch.
- The whole of the Arabo-Ethiopian landmass was pushed up in blocks as one mass.
- The greatest uplift was in central Ethiopia which resulted in fracturing of the crust in many places
- Then huge quantity of lava came out through these fractures.
- The out pouring of this flood of basalt spread widely and extensively to form the Ethiopian plateau surface and also the floor of the present-day Rift Valley

- The mass of lava was so immense, that it formed a thick layer of volcanic rocks on the plateau, which mounted to more than 1,000 meters above sea level in the north Central Highlands.
- Where the lava comes out through vents, huge volcanic rocks were piled up to form many and huge Volcanic Mountains' towering the flat basaltic plateau.
- This volcanic material is known as Trappean lava or Trap Series lava.

Plate tectonics theory and formation of the Rift Valley

- Modifies the continental drift theory
- This theory describes the Earth as a restless planet with plates drifting across the surface
- Accordingly, there are three major types of plate movements:
  - Spreading or pulling away from each other (Divergent)
  - Collision or crashing head-on (Convergent)
  - Sliding past each other (Transform)
- Accepted by most earth scientists today as modern, most satisfactory explanation of:
  - internal forces shaping Earth's surface
  - crustal movements (folding & faulting) & volcanic activity
  - formation of major landforms
  - occurrence of some major natural hazards like earthquakes & tsunami

- The formation of the Rift Valley is connected with the theory of plate tectonics.
- According to the theory, the Rift Valley is formed when:
  - lateral movement of the crust in opposite directions producing *tensional forces* that caused parallel fractures or faults on the sides of the up-arched swell.
  - 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
- Again 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, however blocked the connection and isolated the extension of the sea, allowing much of the water to evaporate.
- As a result, thick saline materials accumulated

The Spatial Extent of the Rift Valley

- The Ethiopian Rift Valley is part of the Great East African Rift system
- Extends from Palestine-Jordan in the north to Malawi-Mozambique in the south for a distance of about 7,200 kilometers. Of these,
  - 5,600 kilometers is in Africa, and
  - 1,700 kilometers 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 Rift Valley region of Ethiopian is the most *unstable* part of the country.
- There are numerous hot springs, fumorales, active volcanoes, geysers, and frequent earthquakes.

- 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.
- For example, similar tectonics activities have occurred in the Lake Tana Basin.
- However, the formation of Lake Tana had been emphasized by volcanic activity so that lava flow in the southeast had dammed part of the rim to deepen the basin.
- Faulting in other places had a structural control along some part of the river courses.

Quaternary Volcanic Eruptions

- Took place after the formation of the Rift Valley which occurred in the Pliocene-Pleistocene Epochs.
- 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^2.
- Aden volcanics and recent faulting are more extensively developed in the Afar region.
- The basic volcanic features of the Aden series include the following:
  - Numerous and freshly preserved volcanic cones, many of which have explosive craters. Some of these are active 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
- It was the time of the last ‘’Ice Age’’ in the middle and high latitude areas
- 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; rivers were many and large.
- 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.
- According to the place and manner of deposition and depositing agents these deposits are divided as follow.
  - *Lacustrine deposits:* Deposits on former lakebeds, and swampy depressions.
  - *Fluvial deposits:* Deposits on the banks of rivers, flood plains both in plateau, foothills etc.
  - *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,
  - 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

Rock and Mineral Resources of Ethiopia

- The occurrence of metallic minerals in Ethiopia is associated with the Precambrian rocks.
- Although not in sufficient concentration and extent, a great variety of such minerals occur in the basement rocks.
- These rocks contain most of the metallic deposits known at present.
- The exploitation and search for mineral deposits in Ethiopia has been taking place for the past 2,000 years
- Such has been the case of gold production and utilization, the mining and working of iron
- However, presently mineral production from Ethiopia has been negligible by World standards.
- The mineral potential sites of Ethiopia includes three major greenstone belts
  - The Western and South-western-greenstone belt
  - The Southern greenstone belt
  - The Northern greenstone belt (Tigray)


THANK YOU!

Group assignment

- Organize yourself into groups in which one group should contain six students
- Give the list of the group members in A4 size paper and identify the group leader/representative
- Group leader is responsible for managing the activities and he/she should outline details of weekly activities
- I need report from the group leader after three weeks
- You should read and understand the last two chapters of the course

- After some three weeks, I will inform you the specific activities you should do
- You should come together in group at least twice in a week and discuss about the chapters
- In one week you should stay together for a minimum of two hours should be allocated will be given.
- Absence from group discussion schedule results in ‘Incomplete’ grade in this course, unless unexpected social, administrative, religious and health problems
- So group leader should manage all the activities in responsible manner