2.2. 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***.

Form 1 _ Science _ Exogenic and Endogenic Processes of Landscape Formations.mp4

The internal ***processes (endogenic)*** include

- ***Volcanic activity*** and ***all the tectonic processes*** (*folding, faulting*),

Incredible Krakatoa volcano eruptions at night _ anak krakatau 2018.mp4

- **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 (wasting),***
  - ***Erosion and***
  - ***Deposition***

- External processes, also known as **Exogenic Processes**, refer to those group of that ***originate and operate on the surface of the Earth***, modifying the ***structural features***, produced by ***internal processes.***

- They ***lower the land surface*** to that of the level of the sea by ***wearing down*** the ***higher places*** and ***filling in the low ones.***
- They are also called ***gradational Processes*** because they ***help level out the Earth's surface***.
- This group of processes derives their energy from ***external sources*** such as ***gravity*** or ***pressure gradient*** of the atmosphere or chemical and physical action from the ***weather system***.

- Even though the ***major task of these processes*** is to ***destroy the initial existing landforms***, they may ***produce transitional*** or ***secondary landforms*** while they denude the initial landforms produced by the internal processes.

- 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 brief geological history of Ethiopia and the Horn will be dealt chronologically starting from the ***oldest Era of the Earth's history to the recent***.

2.3. The Geological Time Scale and Age Dating Techniques

- The geological history is divided in to **Eras**. Each Era is divided into **periods**.
- 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***
- the ***Cenozoic Era*** (recent life) is the ***age of mammals***.

Geological time scale

- Is also known as ***Geo-chronology***.
- It is the time scale which indicates the sequential order of geological events.
- Geological time scale started with the ***age of the earth*** (**4.7** billion years).
- It is broken in to **four levels** of detail**: eons, eras, periods and epochs**.

- Eons are the **longest** intervals represented.
- There are four of them:

Hadean for which there is ***no rock recorded;***

Achaean (for **ancient**), which offers little evidence of life and surface conditions that were **not yet Earth** _like;

proterozoic (**early life**), in which conditions became Earth_ like for the most part and in which different life forms appear as fossils; and

Phanerozoic (**apparent life**) which has ***abundant signs of life*** and in which we live.

- **Hadean eon**- *Oldest part of* ***Precambrian Era***
- **Archean eon**- *Middle part of* ***Precambrian Era***
- **Praterozoic eon** - *(the suffix* ***zoic indicates life);*** *primitive fossils bacteria, algae and worms are formed. it is the youngest part of* ***Precambrian Era***

- 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***.
- Geological time is ***difficult to measure precisely***.

- The Earth is believed to have been formed approximately ***4.5 billion years*** ago and the earliest forms of life were thought to have originated approximately ***3.5 billion years ago***.

- The first major boundary is defined by what was believed at the time to be the first appearance of life on earth.

- 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. Chronologically, 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.***
- **The geological time scale, illustrated in Table 2.1, is built largely on the basis of life** and **evolution.**

Table 2.1: The Geological time scale

Era	Period	Began (in Million Years)	End (my)	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 age dating.

A. Relative Dating

- Relative dating uses ***geological evidence to assign comparative ages of fossils***.
- Hence, 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 2nd way is to use the "***What is on top of the older rocks***?"
- When you find layers of rocks in a cliff or hillside, **younger rocks are on top of older rocks**.
- But these two methods only give the relative age of rocks -***which one is younger*** and ***which is older.***

B. Absolute Dating Also known as ***Radiometric techniques.***

- This technique was developed with discovery of ***radioactivity*** in 1896.

- 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.*
- *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:*

Carbon 14 and **potassium-argon** methods

Carbon-14 Technique

- One of the most widely used and well-known absolute dating techniques is **carbon-14** (or **radiocarbon**) dating, which is ***used to date organic remains.***
- This is a radiometric technique since it is based on radioactive decay.
- ***Cosmic radiation entering the earth's atmosphere*** produces ***carbon-14***, and plants take in carbon-14 as they ***fix carbon dioxide.***
- ***Carbon-14*** moves up the food chain as ***animals eat plants*** and as ***predators eat other animals***.
- With **death**, the uptake of ***carbon-14 stops***.
- *Hence, 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.*
- It takes **5,730 years** for half the carbon-14 to change to nitrogen; this is the half-life of carbon-14.
- After another 5,730 years only one-quarter of the original carbon-14 will remain.
- After yet another 5,730 years only one-eighth will be left.
- By measuring the carbon-14 in organic material, scientists can determine the date of death of the ***organic matter*** in an artifact or ecofact.

- To understand **radiometric dating** it is important to understand what **isotopes** are

Isotopes:
Atoms of the same element that contain a different number of neutrons

Isotopes C^{12} and C^{14}

6
C
12

Carbon^{12}

Protons = 6

neutrons = 6

6
C
14

Carbon^{14}

Protons = 6

neutrons = 8

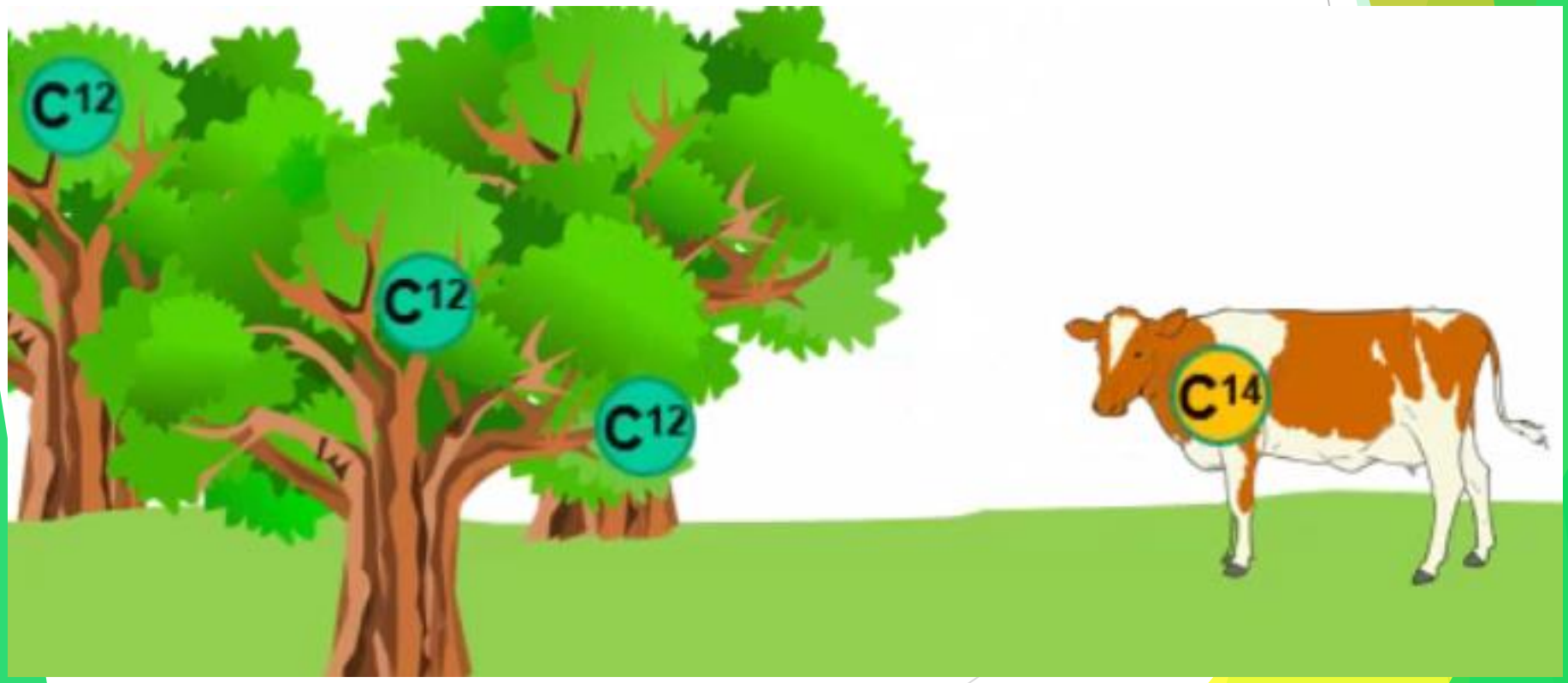
Carbon (C) taken in by autotrophs such as plants as they create glucose ($C_6H_{12}O_6$)

C^{12} and C^{14} transferred to animals in the form of glucose ($C_6H_{12}O_6$)

When living: Ratio of C^{14} and C^{12} similar to that of the atmosphere

When dead: C^{14} begins to decay (break down)

- Recently dead: Remains will still possess much C^{14}
- Long dead: Remains will possess much less C^{14}



Half-life

Half-life: time taken for 50% of the isotope to decay

Ex: Carbon^{14} = 5,730 years

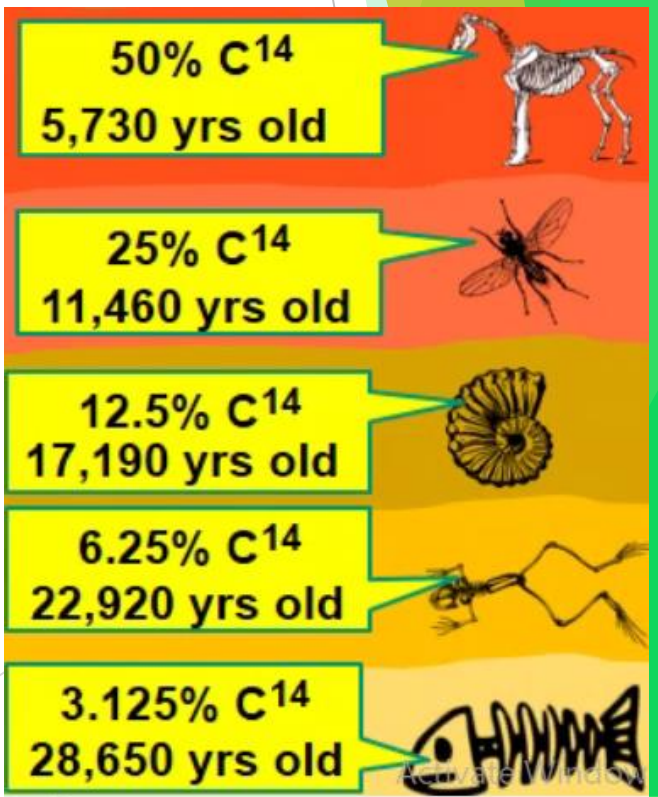
1 half life x 5730 yrs =

2 half lives x 5730 yrs

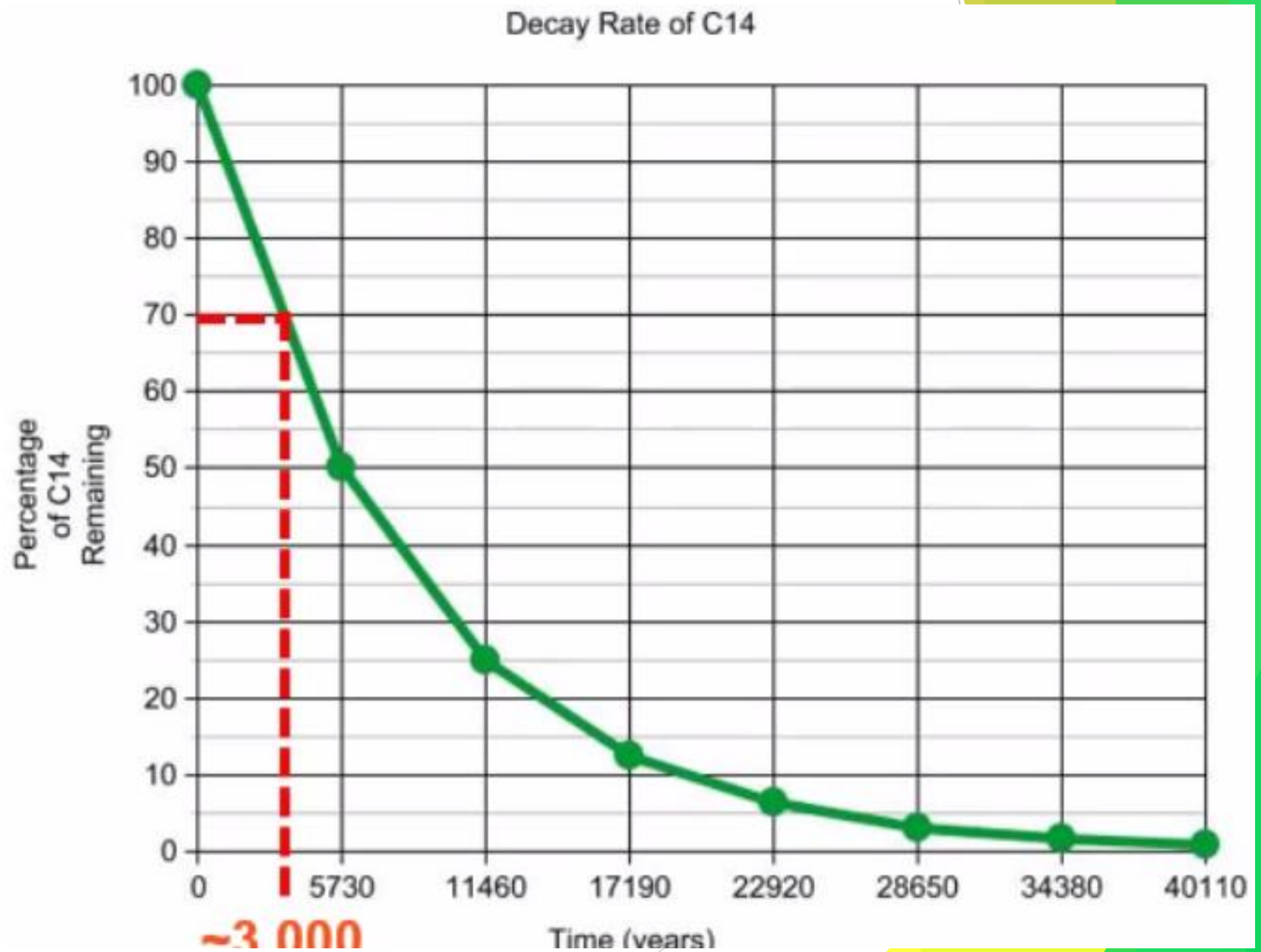
3 half lives x 5730 yrs

4 half lives x 5730 yrs

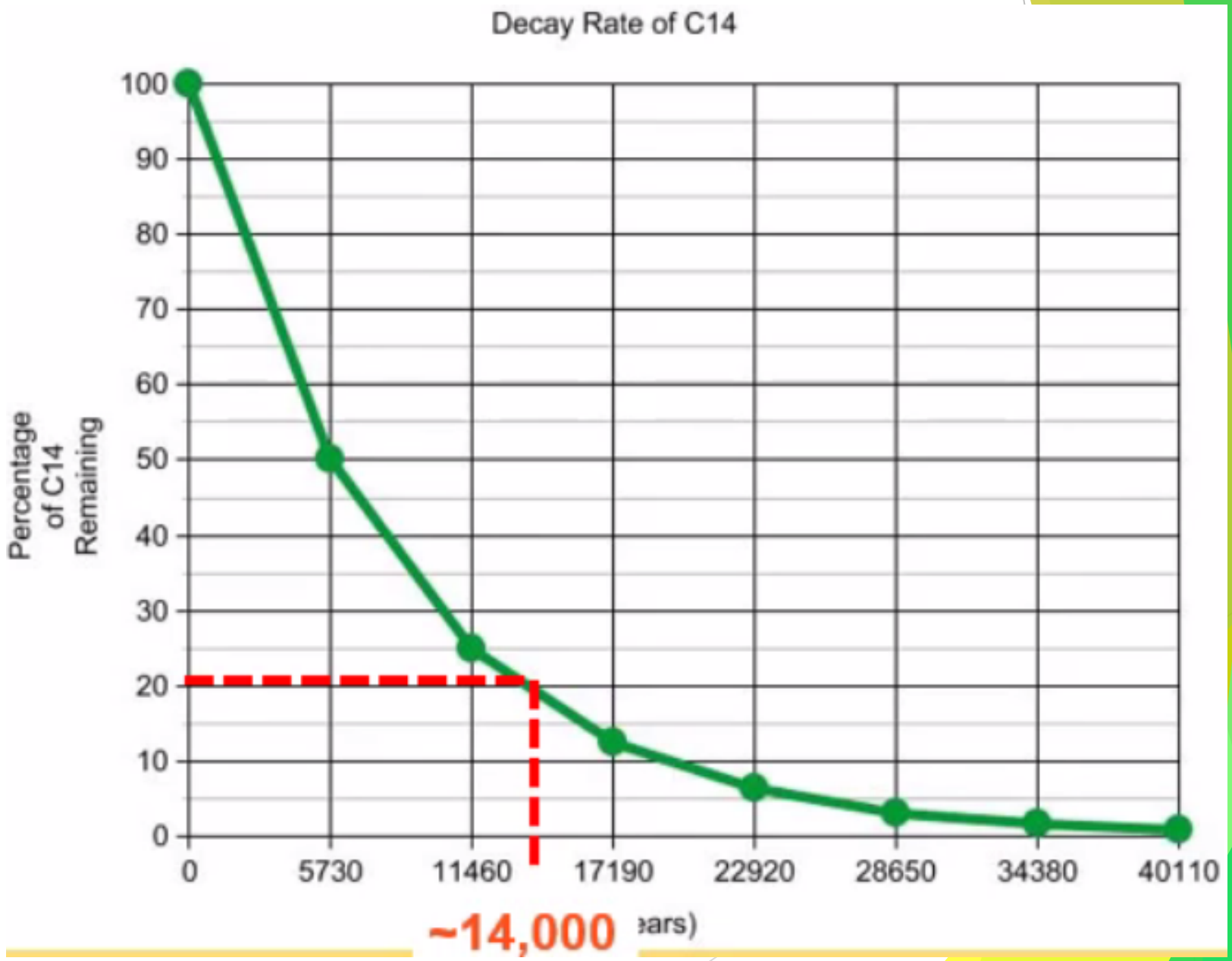
5 half lives x 5730 yrs



What if a fossil is found to have 70% of it's C^{14} remaining



What if a fossil is found to have 20% of it's C^{14} remaining?



- The relatively ***short half-life of carbon-14***, 5,730 years, makes dating reliable only up to nearly 50,000 years.
- Therefore, C14 is smaller that it can not measure more than around 40,000 years old fossils as you can see in the above graph.
- Hence, other methods or isotopes has to be examined.
- For example **Potassium-Arogon method**

Potassium-Argon Technique

- The decay is widely used for ***dating rocks***.
- Geologists are able to date entire rock samples in this way, because *potassium-40 is abundant in micas, feldspars, and hornblendes.*
- Leakage of argon is a problem if the rock has been exposed to temperatures above 125° C (257° F), because the age of the rock will then reflect the last episode of heating rather than the time of original rock formation.

- **Potassium-40** is a radioactive isotope of potassium that decays into argon-40.
- The half-life of potassium-40 is 1.25 billion years, far longer than that of carbon-14, allowing much older samples to be dated.

- Potassium is common in rocks and minerals, allowing many samples of geochronological or archeological interest to be dated.
- Argon, a noble gas, is not commonly incorporated into such samples except when produced *in situ* through radioactive decay. The date measured reveals the last time that the object was heated past the closure temperature at which the trapped argon can escape the lattice. K–Ar dating was used to calibrate the geomagnetic polarity time scale.

Potassium 40

19
K
40

Half life =

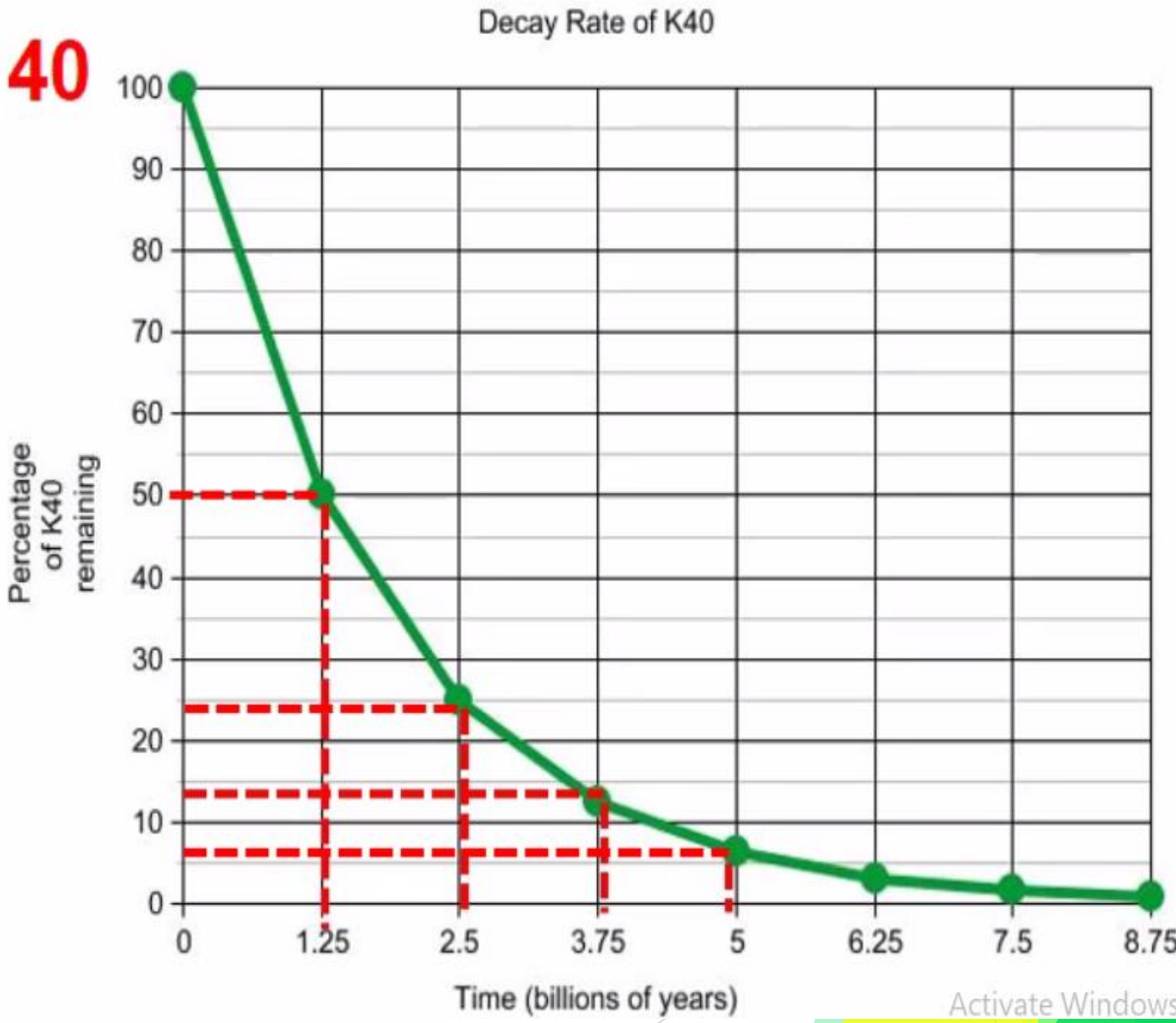
1.25 billion years

50% = 1 half life

25% = 2 half lives

12.5% = 3 half lives

6.25% = 4 half lives



- **Based on these aging methods scientists determine the age of earth and living and nonliving things within it as shown below.**

Evolution of Life on Earth	
Earth	4.5 billion years ago
Prokaryotes	3.5 billion years ago
Vertebrates (fish)	510 million years ago
Amphibians	340 million years ago
Reptiles	310 million years ago
Mammals & Dinosaurs	250 million years ago
Birds and flowering plants	175 million years ago
Humans	200,000 years ago

2.4. Geological Processes and the Resulting Landforms of Ethiopia and the Horn

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

- The Precambrian Era covers **5/6th** of the Earth's history.
- Due to its **remoteness** in **time** and the **absence** of ***well-preserved fossils***, our **knowledge** of the events is **limited**.
- Nevertheless, some general description of the main geologic processes can be made.

- The major geologic event of the Precambrian Era was ***Orogenesis***. As a result, the land was subjected to ***intense folding***.
- This was accompanied by ***intrusive igneous activity***.
- The result was the formation of **huge mountain** ranges.
- In between the ***orogenic periods*** and ***after the last orogenesis***, there were ***long periods of denudation***, which finally ***reduced these mountains to near-level*** (***peneplained***) rock surfaces.
- This "**levelled**" **surface** was later (***in the Mesozoic and Cenozoic Eras***) covered by ***younger rock formations.***

- 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***.

- Since these same processes have allowed **mineralization** and **crystal formation**, the rocks are also collectively described as ***crystalline rocks***.
- 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 Southern Part: Guji, southern Omo, and parts of southern Bale and Borena.

In the Eastern part: Eastern Hararghe.

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

- The Paleozoic Era lasted for about 375 million years.
- The major geological process of this Era was ***denudation***.
- The **gigantic mountains** that were formed by the **Precambrian orogeny** ***were subjected to intense and prolonged denudation*****.**

- At the end, the **once gigantic mountain ranges were reduced** to a ***"peneplained"*** surface. Undulating plain with some residual features (inselbergs) here and there was formed.
- The sediments were transported **southward** and **eastward** to form continental (in Africa) and marine deposits, respectively.
- Because of the ***limited deposition*** within ***Ethiopia,*** rocks belonging to this Era are ***rare*** in the country.

2.4.3. 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**.
- At the same time the land was ***tilted*** eastward and therefore ***lower*** in the ***southeast*** and ***higher*** in the ***northwest***.

- The ***subsidence/sinking*** 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*** period.
- This phenomenon continued up to ***Jurassic period***.
- As the ***shallow sea spread towards the land***, ***sands were deposited over the peneplained Precambrian rock surface***.
- As the ***depth of the sea increased***, ***mud (shale)***, ***gypsum*** and ***later lime*** were deposited.

- The latter is associated with the ***flourishing of marine life*** and ***decaying*** and ***precipitating*** of ***their remains***, as the ***sea stayed long***.
- Hence, ***Mesozoic rocks*** are considered to have the greatest potential for **oil** and **gas** deposits.
- Through time, 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.
- They are named after place names in ***Tigray*** where they might have been ***first identified***.

- In the ***Horn of Africa and Ethiopia***, the ***slow rise*** of the ***land*** and ***consequently*** the ***regression*** **of the** ***sea began*** in the ***Upper Jurassic***.
- It continued throughout the **Cretaceous period**.
- With the ***retreat of the sea***, ***another process of deposition*** ***occurred.***
- In the country sedimentation ended with the deposition of ***clay, silt, sand*** conglomerate brought in from the land ***as the sea receded*** 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.***
- 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.***
- Due to the tilting of the landmass during the transgression and regression of the sea, and due to the direction of the invading and retreating sea, 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.

- 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***.
- In most parts of Ethiopia, the Mesozoic rocks are **overlaid** by the **Cenozoic rocks**.
- 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.***

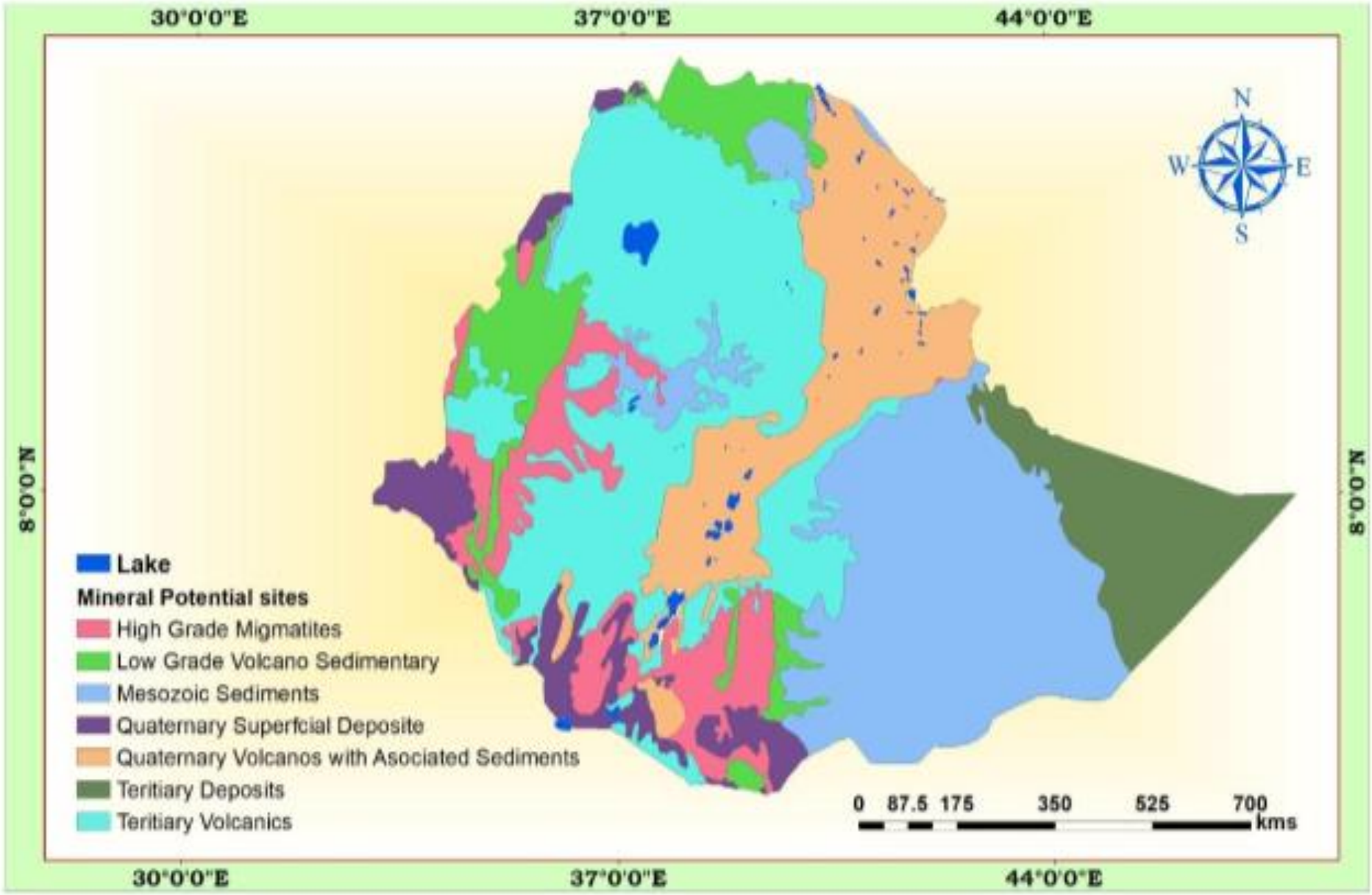


Figure 2.1. Geological map of Ethiopia *Source: CSA Shapefile, 2012*

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

- The Cenozoic Era 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 **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.

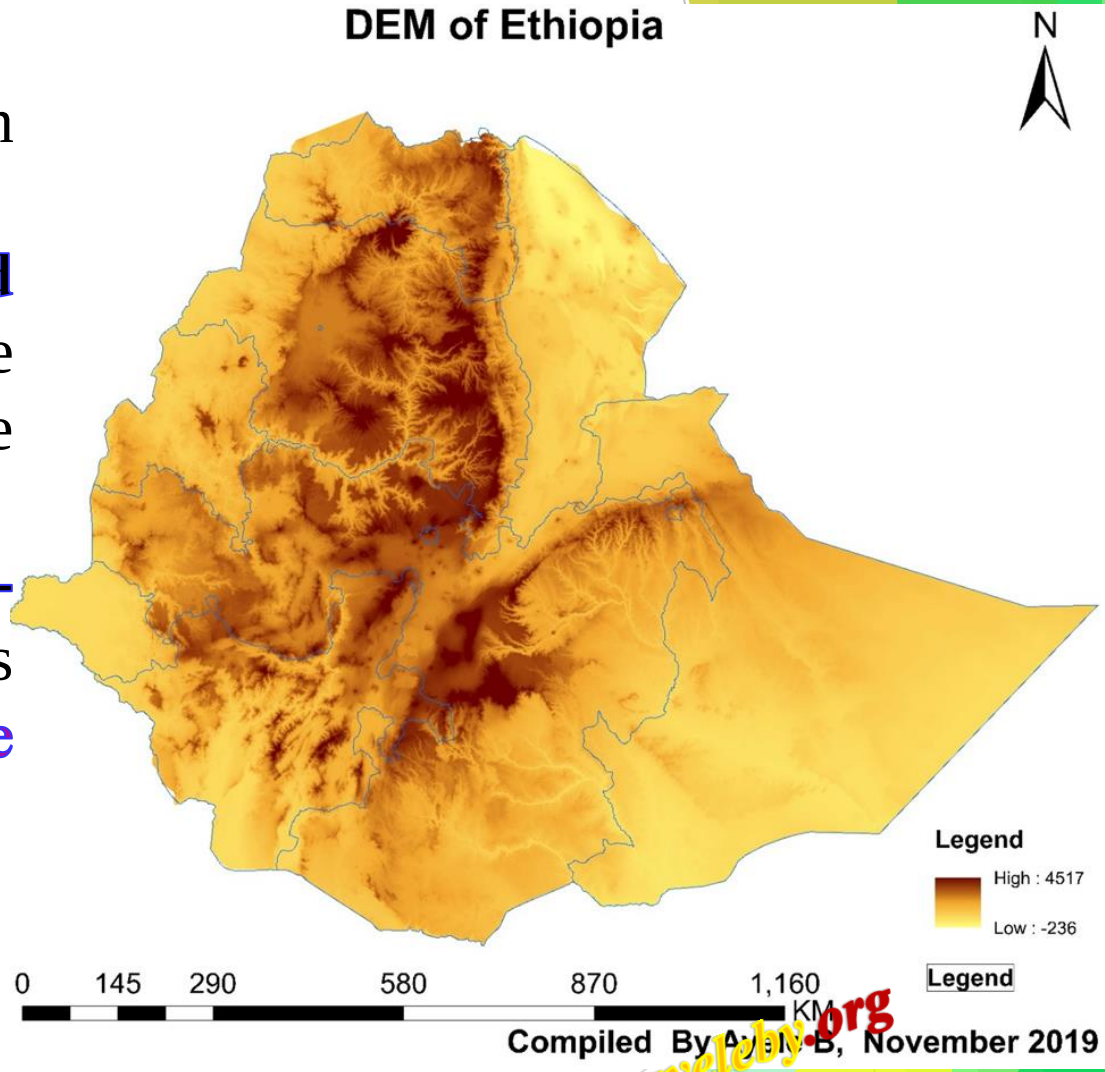
c. Quaternary volcanism and **deposition**.

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*** m.a.s.l.

- This occurred during the ***Eocene epoch***.
- This uplifting was of an ***epeirogenic*** character.
- It was **unparalleled** anywhere else except in the Alpine orogenic belts of the Andes.
- The whole of the **Arabo-Ethiopian landmass** was **pushed up** in **blocks** as one mass.
- The **greatest uplift** was in ***central Ethiopia***. This



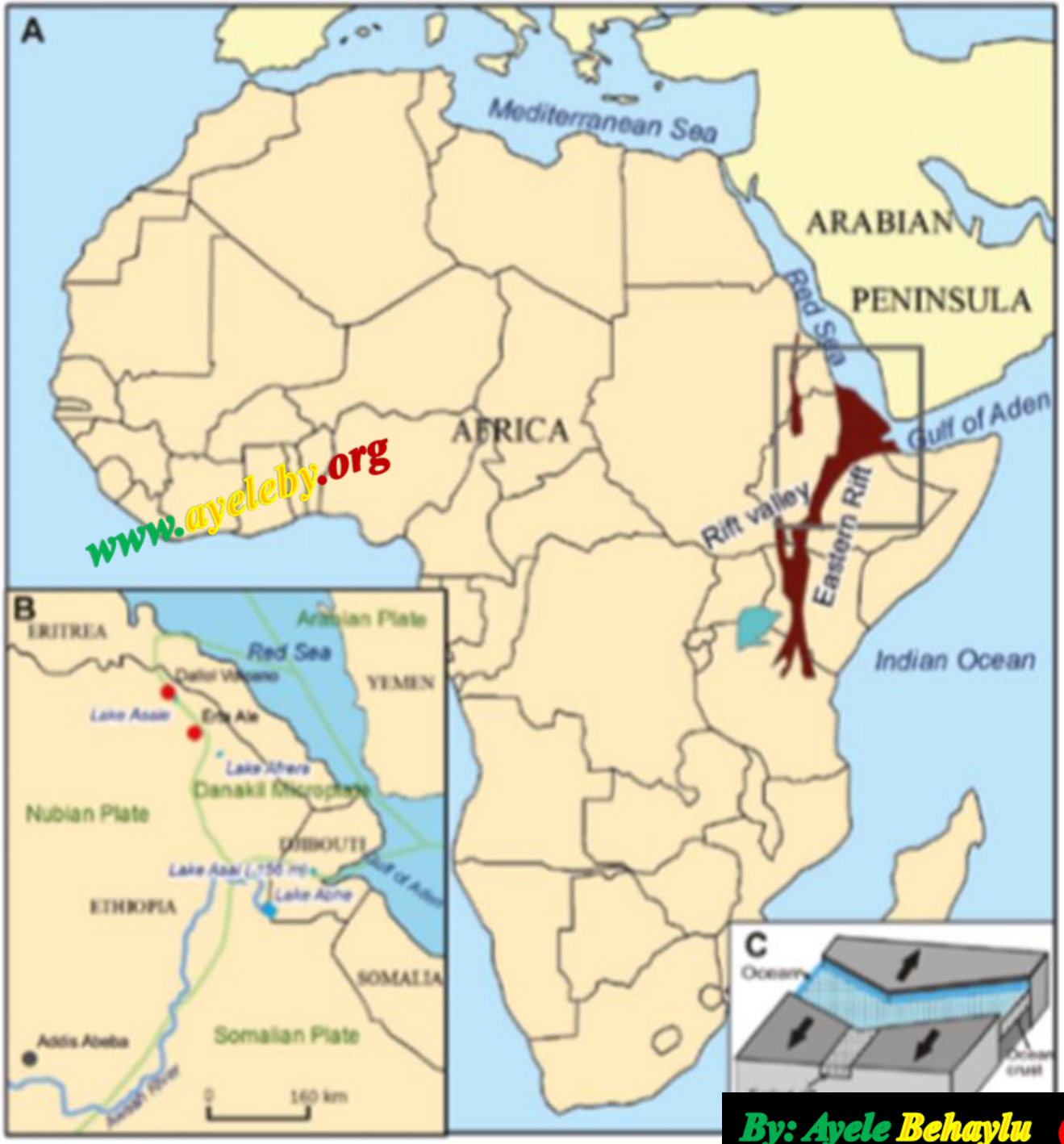
- This **immense tectonic force** also **fractured** the crust at many places.
- ***Huge quantity of lava*** **came out** through these **fractures**.
- The out pouring of this flood of basalt spread widely and extensively and covered a large part of the Mesozoic sedimentary layer to form the **Ethiopian plateau surface** and also the **floor of the present-day Rift Valley.**

- At that time the **Rift Valley** was **not yet formed**.
- 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**.
- Where it is not dissected by erosion, the Ethiopian plateau had flat and nearly horizontal surface.
- This is an expression of the peneplained Precambrian surfaces, the smothering effect of the Mesozoic deposition, and the spreading of the Trap series lava over the Mesozoic sediments

b) The Formation of the Rift Valley

- The formation of the **Rift Valley** is said to be related with the ***theory of plate tectonics***.
- According to the theory, 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 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*** (*see figure below*).



By: Ayele Behaylu (Assistant Professor)

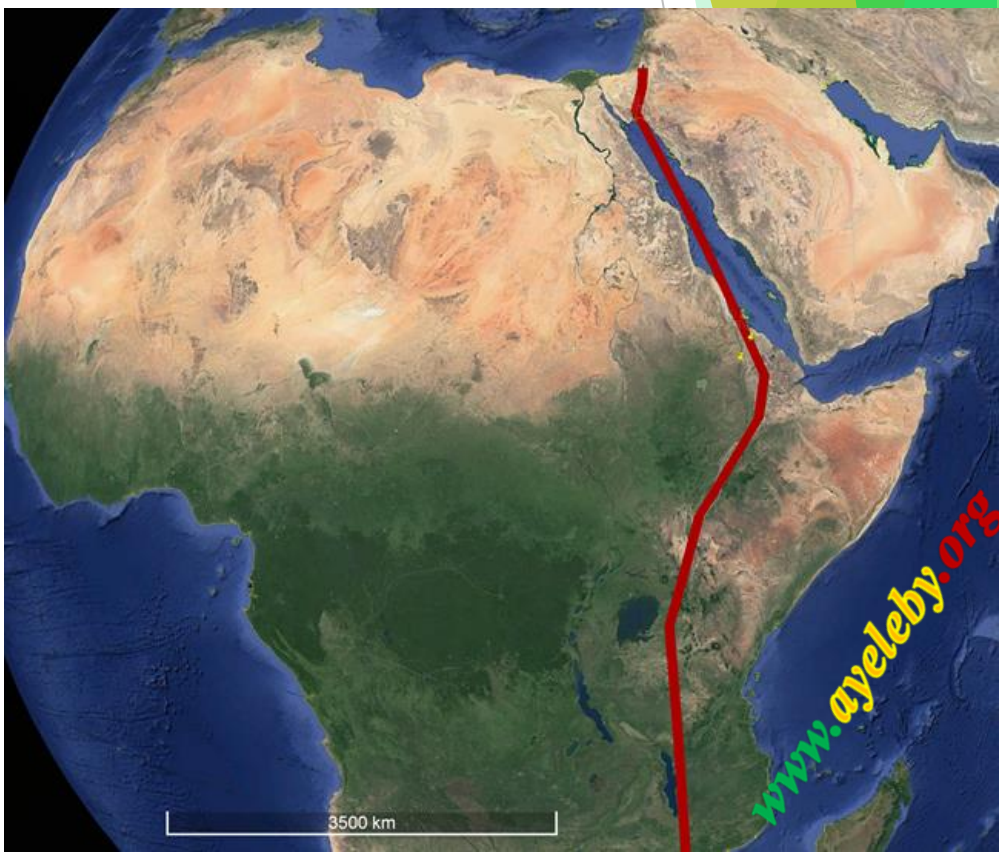
- The major faulting movement probably began in the *late Oligocene* and *Miocene Epochs of the* ***Cenozoic Era***.
- This **rifted the Red Sea trough**, which began to be **flooded** from the **north**.
- But the **major rifting**, affecting the whole *African Rift System*, including that of *Ethiopia* and the *Gulf of Aden* took place in the **Miocene Epoch.**
- **Rifting** and **faulting**, however, ***continued*** all the time throughout the ***Pliocene*** and even the ***Pleistocene Epochs***.

- 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

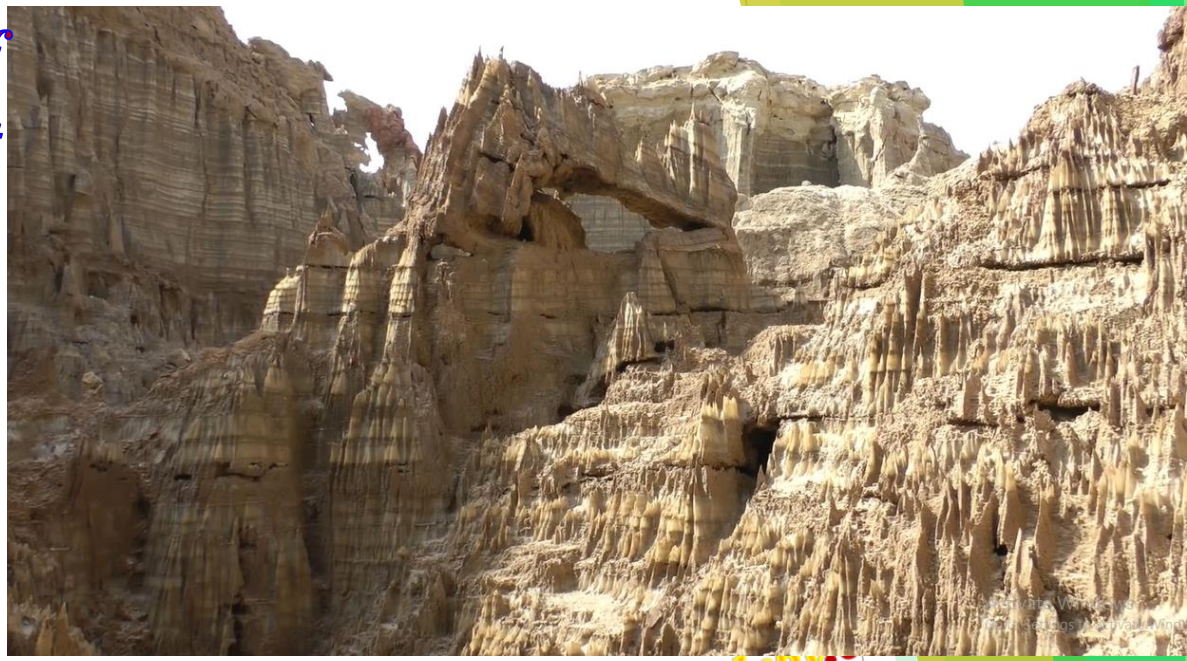
- The ***Ethiopian Rift Valley*** is part of the ***Great East African Rift system*** that extends from ***Palestine-Jordan*** in the ***north*** to ***Malawi-Mozambique*** in the ***south***, for a distance of about ***7,200*** kilometers.

- Of these, **5,600** km is **in Africa**, and **1,700** km in ***Eritrea*** and ***Ethiopia***.
- **On land**, the **widest part** of the **Rift Valley** is the **Afar Triangle** (**200-300 km**).



By: Ayele Behaylu (Assistant Professor)

- The ***Red Sea***, the ***Gulf of Aden***, and ***the East African rift 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.**
- There are ***numerous hot springs***, ***fumaroles***, ***active volcanoes***, ***geysers***, and ***frequent earthquakes***.

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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 accentuated 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.

c) Quaternary volcanism and deposition

They are **recent volcanic activities** that took place ***after the formation of the Rift Valley***.

- This occurred in the ***Pliocene-Pleistocene Epochs.***
- This 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***.
- 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 3,000km2**.

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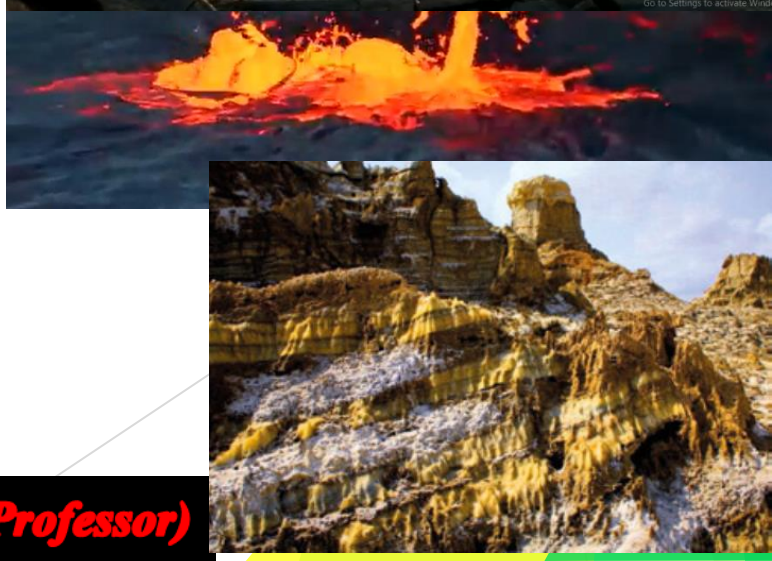
- *Aden volcanics* and *recent faulting* are more extensively developed in the *Afar region*.
- The area is *shattered by numerous faults* and *subjected* to *extensive scoriaceous basalt eruptions*.
- The latter phenomenon is also widely manifested in the ***main Ethiopian Rift***, especially in its ***northern section***.
- Some of the eruptions have occurred in the last ***few hundred years***.
- Because of their ***recent occurrence***, the ***Aden volcanics*** 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.
- 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.



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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 last "***Ice Age***" in the ***middle*** and ***high latitude areas*** and 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***; **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:

a. **Lacustrine deposits**: Deposits on former lakebeds, and swampy depressions.
b. **Fluvial deposits:** Deposits on the ***banks of rivers***, ***flood plains*** both in plateau, foothills etc.
c. **Glacio-fluvial deposits** and **erosional features**: These are occurred on **high mountains**, such as Bale and Kaka Mountains.
d. **Aeolian deposits:** Are **windblown** deposits.
e. **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 landmass of the country***.
- These include:
  - **Highland Tertiary volcanics** (basalts),
  - **Tertiary** as well as **Quaternary volcanics**, and
  - **Sediments of the rift valley**.