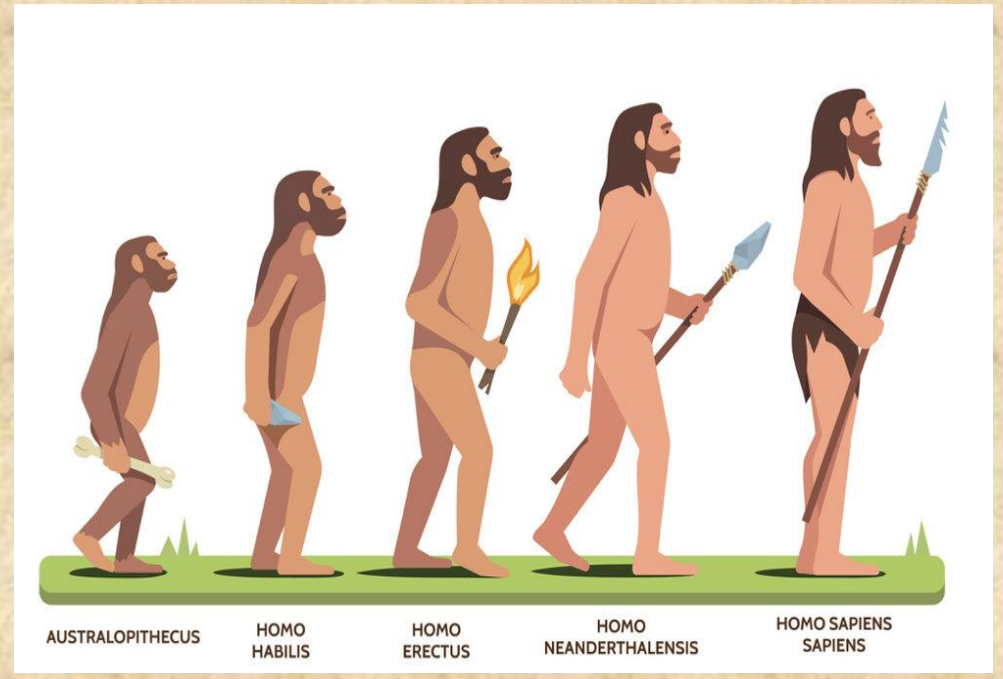
Quaternary Geology

Lecture 1

Dhiman Roy, PhD



quaternary

Course outline

- **Part-I**
  - Quaternary: Concept and Development
- **Part-II**
  - Quaternary Stratigraphy – Madhupur Area
  - Quaternary Stratigraphy – Lalmai Hills Area
  - Quaternary Stratigraphy – Barind Tract Area
  - Quaternary Stratigraphy – Chalanbil Area
  - Quaternary Stratigraphy – Dahagram-Panchagarh Area
  - Quaternary Stratigraphy – Jaintiapur-Bholagonj Area
  - Depositional Environment: Gravel Bed
  - Economic Importance of Quaternary

Course outline

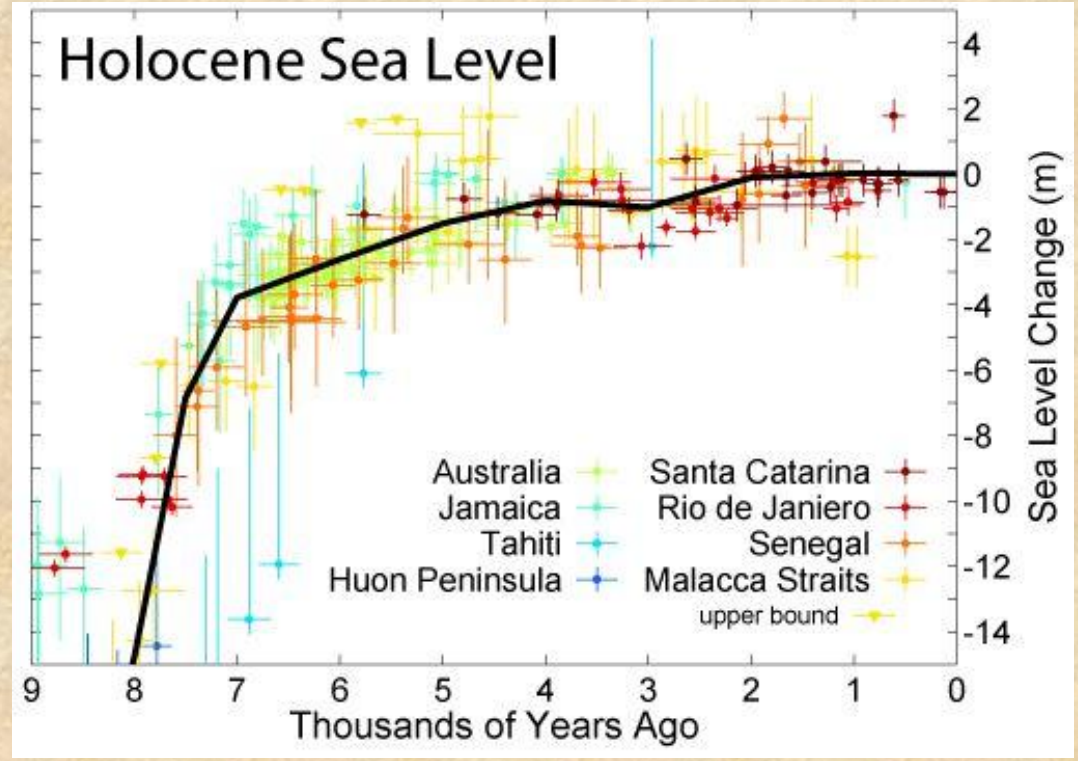
- **Part-III**
  - Paleosoil and Micromorphology
  - Paleomagnetism and Radiocarbon studies
  - Mineralogical and Sedimentological studies
  - Correlation of Quaternary deposits and Environment of deposition
  - Holocene Sea level and Marine transgression: Bay of Bengal
  - Neo-tectonics

quaternary

Quaternary Concept and Development

Dhiman Roy, PhD

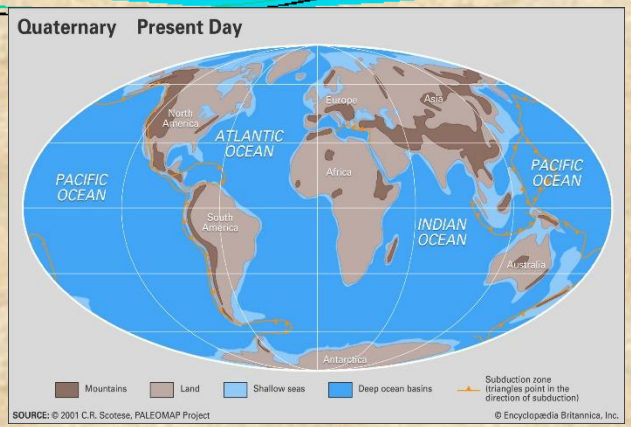
University of Barishal

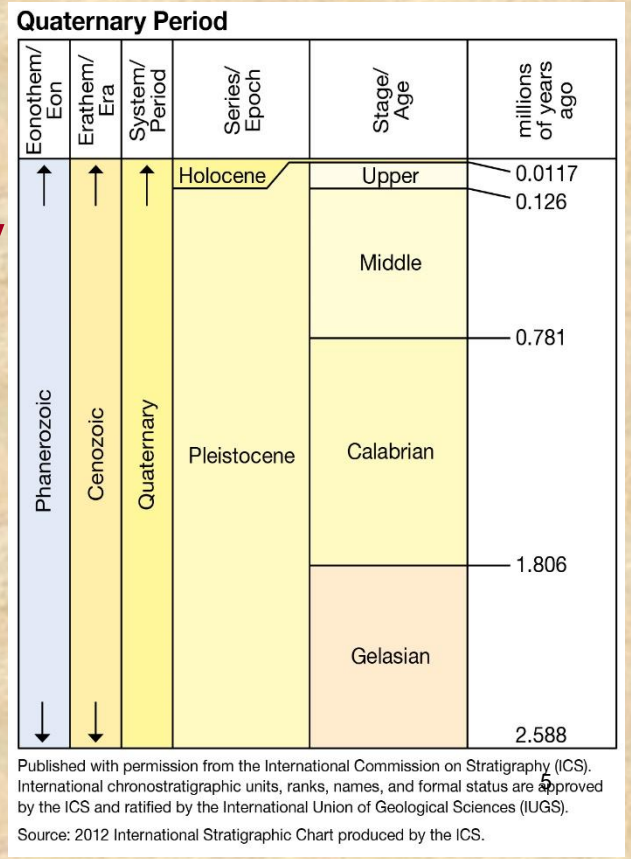


Talk outline

- Introduction
- General Characteristics
  - Climatic Changes
  - Ice Age
  - Sea Level Changes
  - Changes of Relief and Landscapes
  - Vegetational Changes
  - Paleontological Changes
- Development of Glacial Theory
- Subdivision of Quaternary
  - Alpine Model
  - Northern European Model
  - Classical Model-North America
- Plio-Pleistocene Boundary

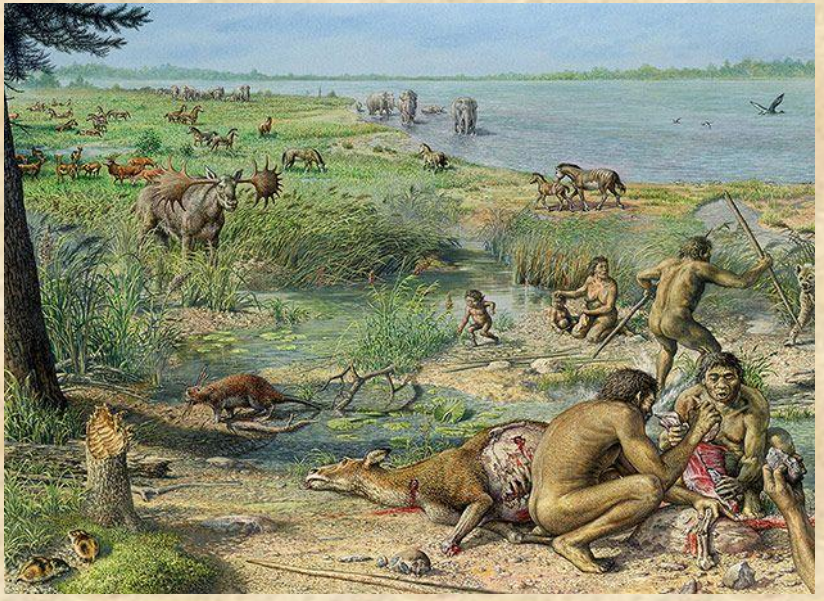
CONCEPT DEVELOPMENT

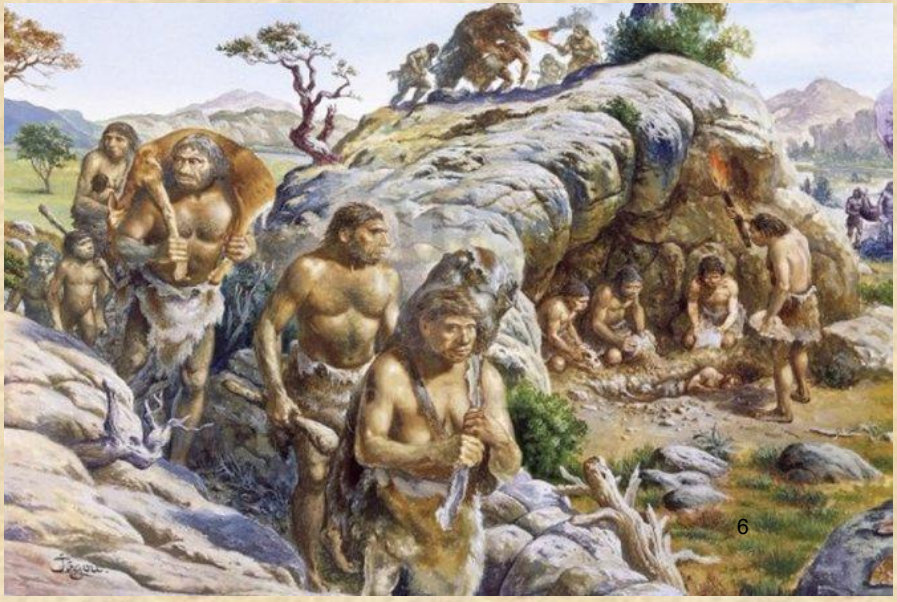




What is Quaternary?

- Quaternary is the latest Period in the Geological Time Scale.
- The Cenozoic Era includes Quaternary (above) and Tertiary (below).
- The Quaternary Period comprises Pleistocene and Holocene Epochs.
- The Holocene Epoch spans only the last 10,000 years.



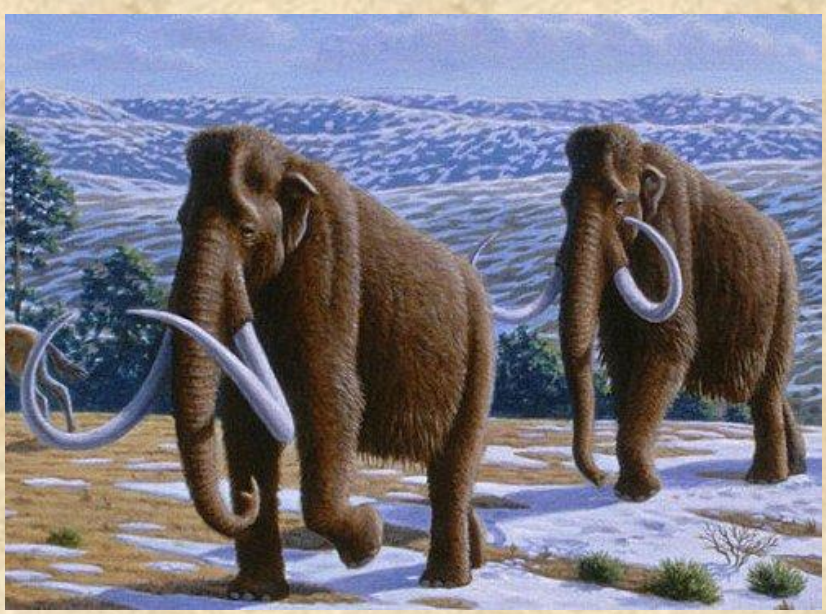


Cont'd……

- The whole of the Quaternary covers a small span of geological time, only 2.5ma.

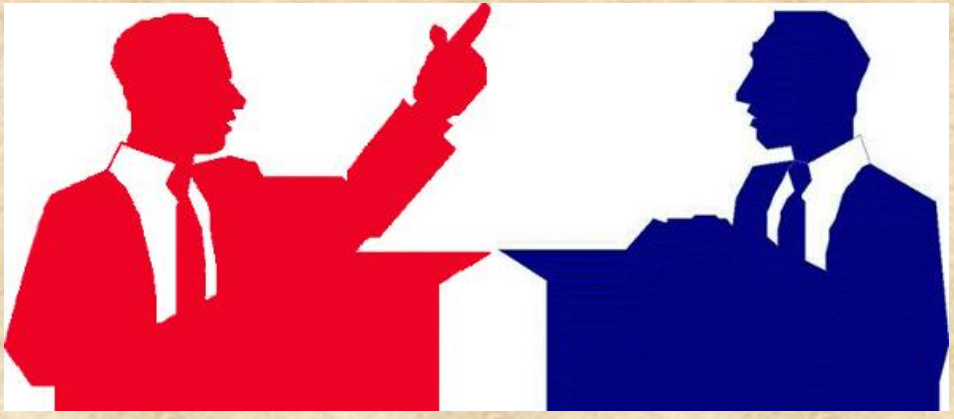
- On the other hand, Quaternary has not been separated in a traditional way.

- There was no major important universal orogenic movement that could make a sharp tectonic or stratigraphic boundary with the underlying Tertiary Period.



Cont'd……

- The next debate concerns the subdivision of the Quaternary into Pleistocene and Holocene Epochs.
- Edward Forbes (1815-1854) in his short life span worked on plant and animal life, and equated the Pleistocene with the Glacial Epoch.
- During the Pleistocene Epoch, cold phase (glacial) was alternat-ed with the warm phase (Interglacial).
- The warm phase of present day, or Interglacial, which started at about 10,000 years ago, is called Holocene.



quaternary

General Characteristics : Quaternary

- **General Characteristics**
  - **Climatic Changes**
  - **Ice Age**
  - **Sea Level Changes**
  - **Changes of Relief and Landscapes**
  - **Vegetational Changes**
  - **Paleontological Changes**

General Characteristics : Quaternary

General Characteristics : Climatic Changes

- Climatic change is unequivocally the dominating characteristics of the Quaternary.
- Global climate changes due to the variation of solar radiation received at the earth's surface.
- Global temperature changes periodically in some long-term, intermediate-term and short-term climatic cycles.
- The Quaternary climatic fluctuations followed a cyclic pattern.

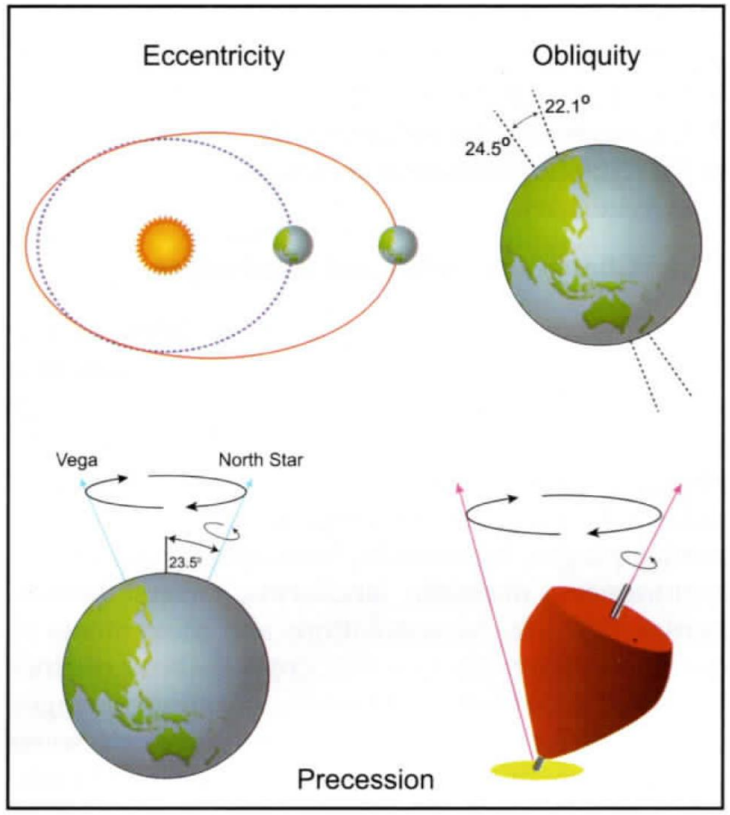
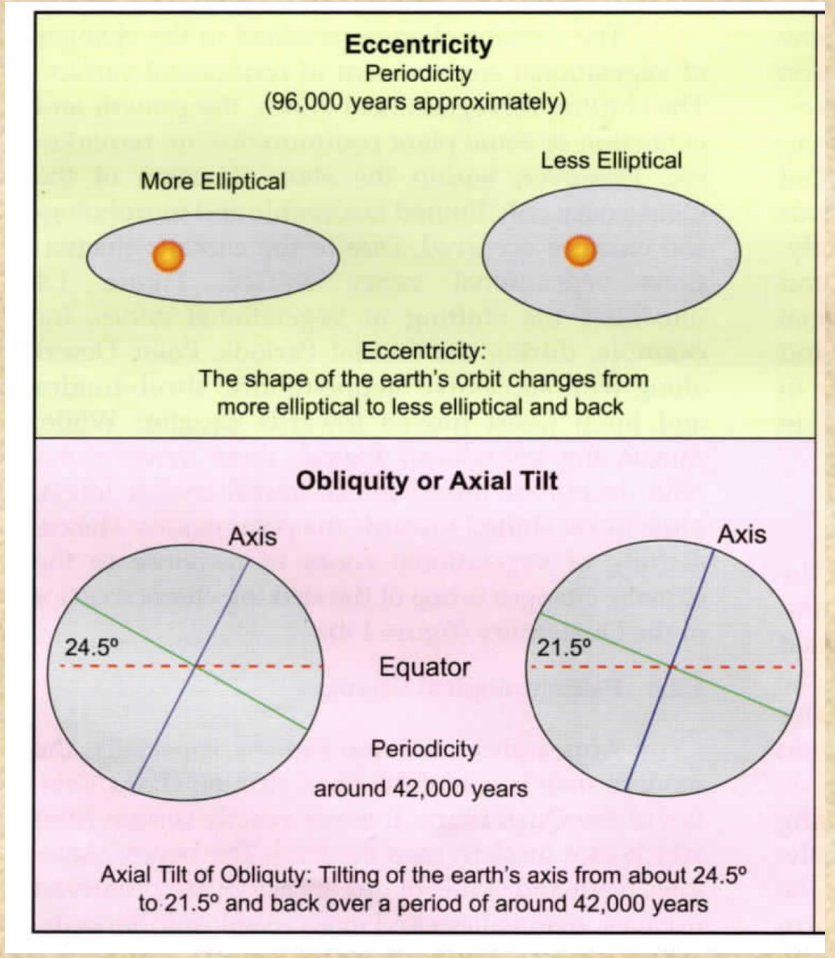


Figure 1.2 Milankovitch cycles.

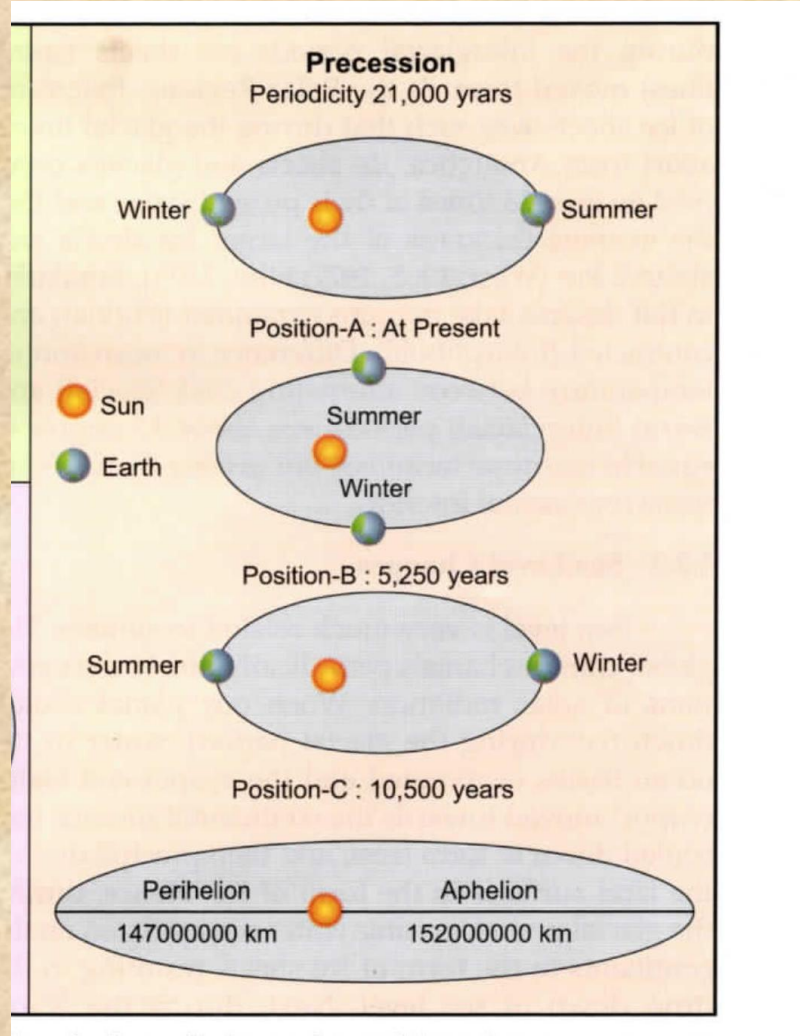
General Characteristics : Quaternary

- Approximately, over 96,000 years, the shape of earth's orbit changes from more elliptical to less elliptical and vice-versa.
- This phenomenon is called Eccentricity.
- It produces a change in the surface temperature of earth in a cycle of 96,000 years.
- The second variable is called 'Axial tilt or Obliquity'.
- The axis of the earth tilts from about 21.5 to 24.5 degrees and back over a period of around 42,000 years.



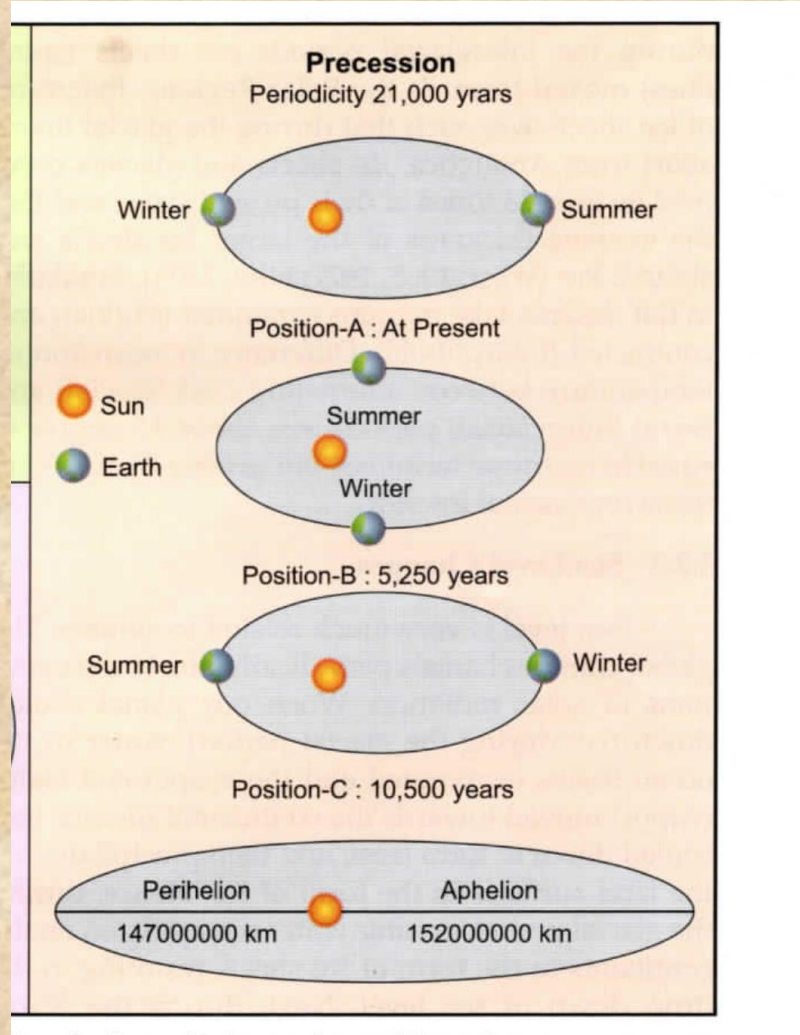
General Characteristics : Quaternary

- This is the angle between equatorial plane and orbital plane.
- The third variable is called Precession of the equinoxes. Precession is a change in the orientation of the rotational axis of a rotating body.
- The rotational motion of the axis of a spinning body, such as, the wobbling of a spinning top, caused by torque applied to the body along its axis of rotation.



General Characteristics : Quaternary

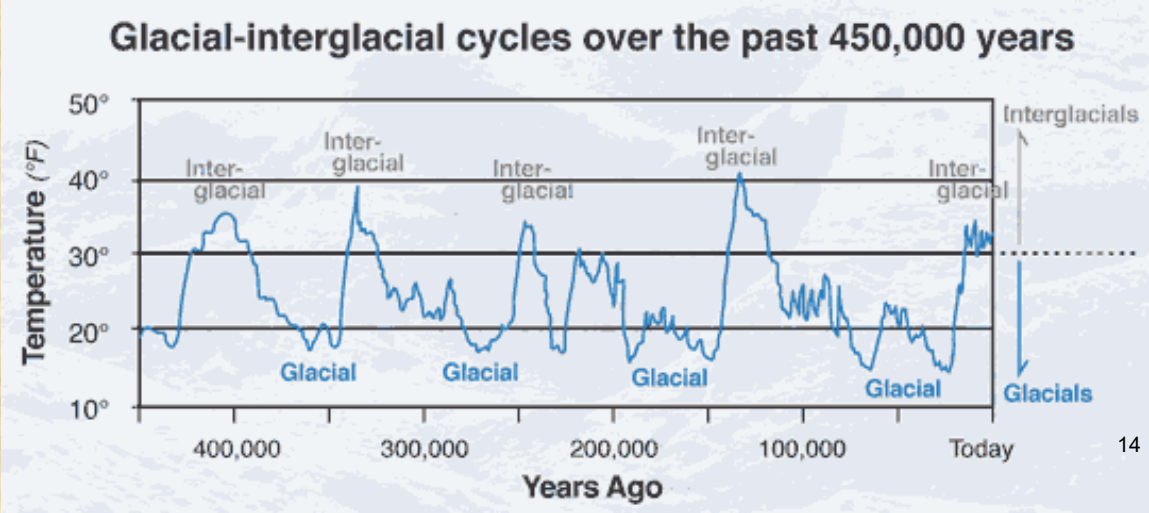
- The time when the earth is nearest to the sun is called Perihelion.
- At present, the Northern Hemisphere winter occurs in perihelion, while the summer occurs at the furthest point on the orbit and is called aphelion.
- To shift the position from perihelion to aphelion, it takes about 10500 years and further back to perihelion to complete the cycle it takes about 21000 years



General Characteristics : Quaternary

General Characteristics : Ice Age: Glacial and Interglacial Periods

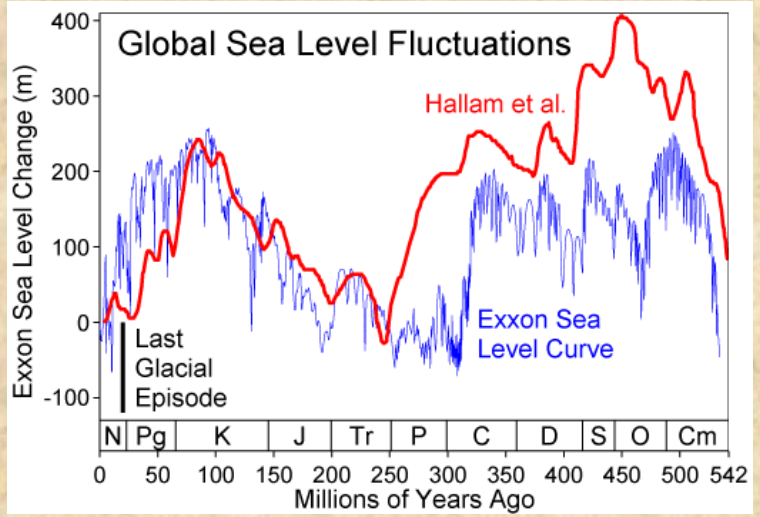
- Glacial and Interglacial Periods (phases) are the major characteristics of the Quaternary.
- An ice age is a period of long-term reduction in the temperature of the earth's surface and its atmosphere, resulting in the appearance or expansion of continental and polar ice sheets as well as mountain glaciers.
- Within a long-term ice age, individual pulses of cold climate are termed glacial periods (or alternatively glacial or glaciations or colloquially as ice age) and intermittent warm periods are called interglacial.

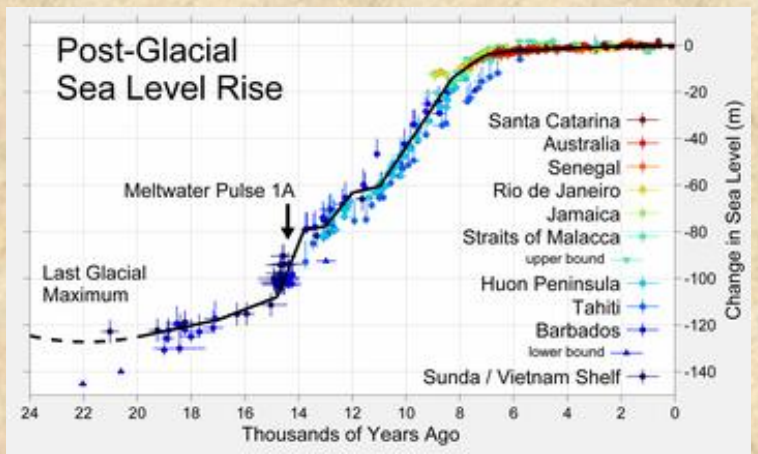


General Characteristics : Quaternary

General Characteristics : Sea Level Changes

- Sea level is very much related to climate.
- The global climate changes occur periodically due to the variations of solar radiation.
- When our planet cool down (i.e. during the glacial period), water in the ocean basins evaporated and the evaporated water (vapor) moved towards the continental interior that cool down to form frost; and then precipitated on the land surfaces in the form of ice.
- Hence, during the glacial period, oceanic water accumulated on the continents in the form of ice sheets resulting in the drop down of sea level.





General Characteristics : Quaternary

- **General Characteristics :** Sea Level Changes

- Next, during the warm period, i.e. during the interglacial period, ice sheets on the continental surfaces melt down and meltwater again returned to the ocean basin. As a result, sea level rose up.

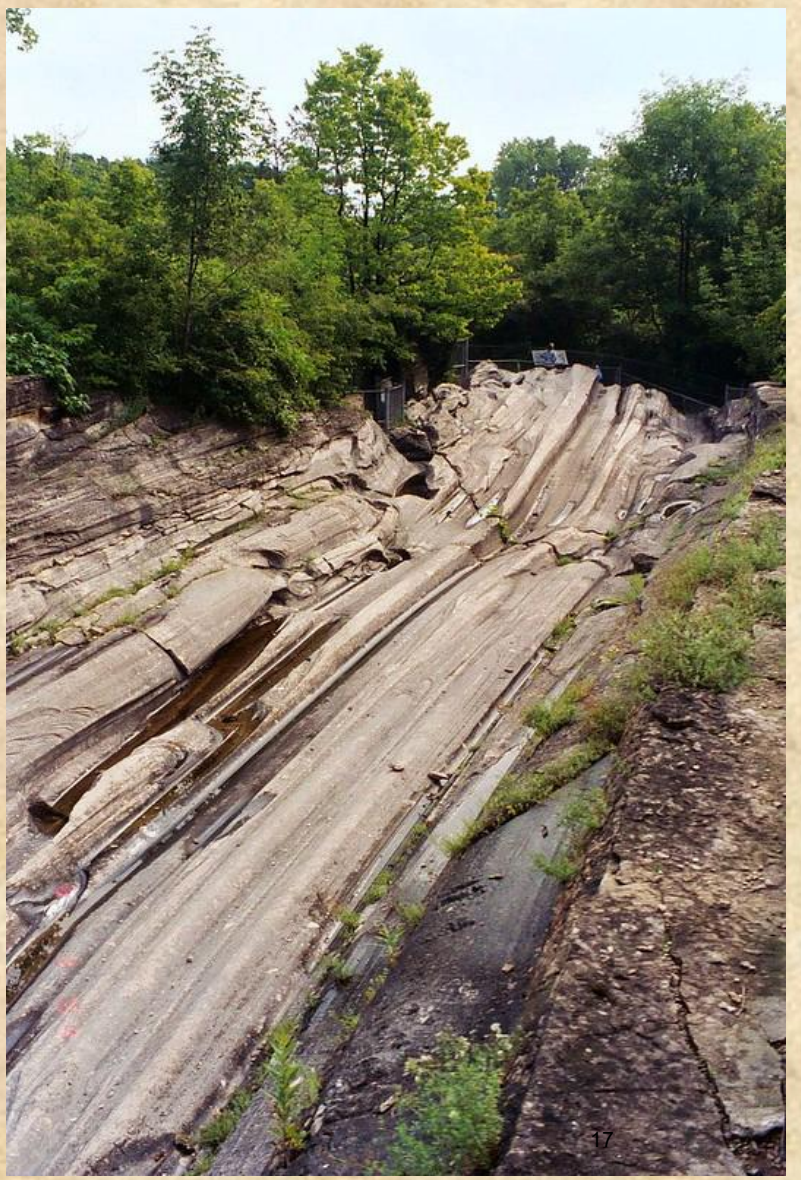
- Therefore, eustatic sea level changes (changes of water volume in the ocean basin) due to the climatic fluctuation is another characteristic of the Quaternary.

General Characteristics : Quaternary

- **General Characteristics :**
  Changes of Relief and Landscapes

- One of the striking characteristics of the Quaternary is glacial and post-glacial landforms resulted by the occurrence of ice sheets and melt water.

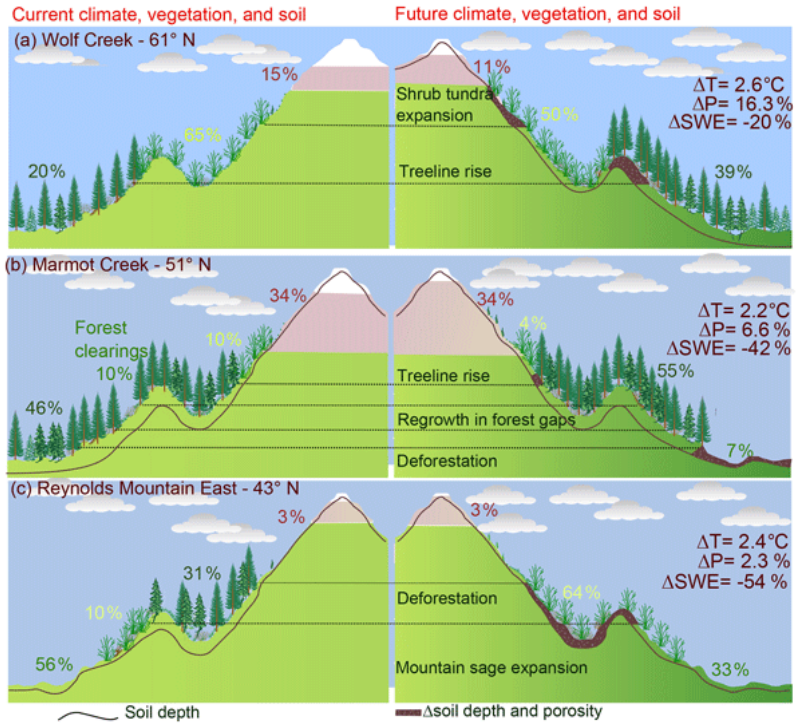
- The resulting erosional landforms include striations, glacial horns, aretes, trim lines, U-shaped valleys, hanging valleys, cirques, erratics, striations, pingos, hummocks, truncated spurs,, morainic landforms, eskers, kames, kettles, tills, etc.

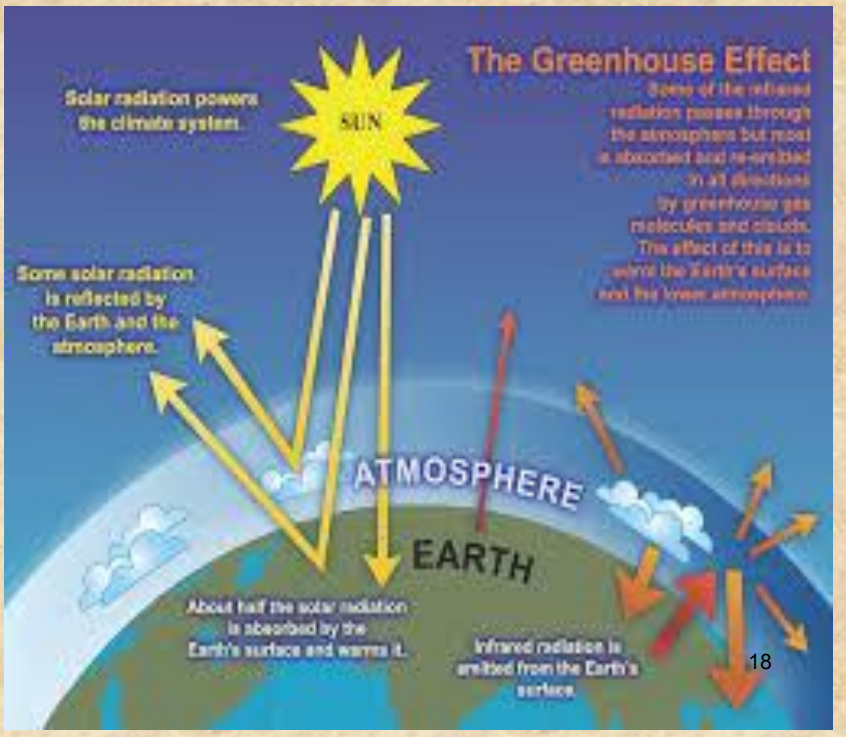


General Characteristics : Quaternary

General Characteristics : Vegetational Changes

- The climatic changes resulted in the changes of vegetational environment in continental surface.
- The shifting of vegetational zones, the growth and extinction of some plant communities are remarkable.

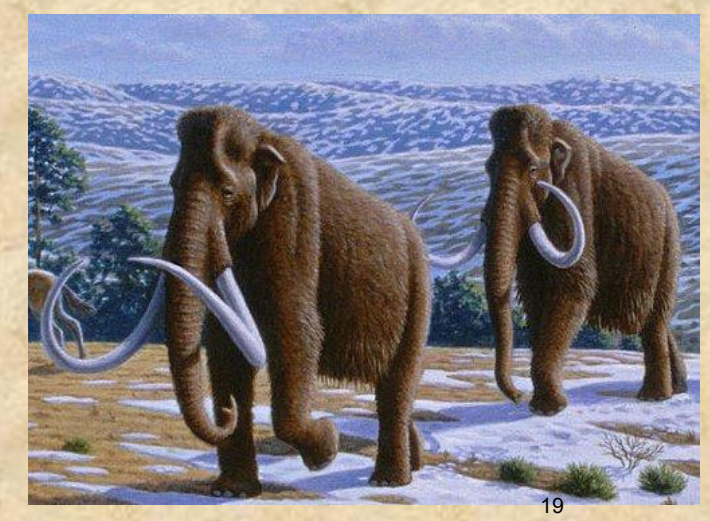




General Characteristics : Quaternary

General Characteristics : Paleontological Changes

- Appearance of Homo sapiens, especially, the modern man is one of the most striking characteristics of the Quaternary. It is not exactly certain from which race modern man evolved.
- The bones, skeletons, teeth and skulls of our ancestors are preserved in caves, river valleys and in some volcanic deposits.
- The East African Rift and Olduvai Gorge (Tanzania) in Africa, and the Siwalik Hills in the Himalayas were the best sites for our ancestors.
- The oldest bones and skeleton remains of our ancestors are found in East Africa.



Development of Glacial Theory

- Initially, the Quaternary Period was thought to be the Period of glaciation, because the people were astonished to observe the evidences of glaciations and glacial deposits in those places, especially in the Alpine regions, that never witnessed permanent glaciations at the present time.

- The evidence of glaciation was first observed at the end of eighteenth century when James Hutton (1726-1797), a Scottish farmer and naturalist (he is known as the founder of modem geology), identified erratic blocks in the Jura mountainous region in France in 1795.

Development of Glacial Theory

- A Scottish geologist Charles Lyell in 1839 introduced the term 'Pleistocene'.
- The term Pleistocene is derived from two Greek words, *pleistos* (meaning 'most') and *kainos* (meaning 'new' or 'recent').
- Hence, Pleistocene means 'Most Recent'.
- Lyell introduced this term to describe the strata exposed in Sicily (type section, southern Italy) that had at least 70% of their molluscan fauna still living today.
- Edward Forbes (1946) redefined the Pleistocene as the same age of glacial epochs.

Development of Glacial Theory

- Lyell noticed that between the layers of rock or within the same layer, there was a distinct change between fossils of marine mollusks of warm water species and fossils which were like modern cold water species.

- Forbes in 1846, suggested the post-glacial time as Recent. In 1885, International Geological Congress (IGQ accepted the term Holocene (meaning wholly recent).

- In 1869, Paul Gervais, a French paleontologist, introduced a term Holocene (wholly recent) for the last 10,000 years. The Holocene is indeed the 'Age of Man.

Classical Model: Quaternary Subdivision

- There are some models for the classification of the Quaternary.
- These models were established following the antiquated method based on inadequate data.
- Some models did not follow the *Law of Superposition* for stratigraphic classification.
- Those were based on geomorphologic positions and the concept of terrace system.
- The emphasis was given to climatic changes that should not be used in stratigraphic classification.
- The Alpine Model
- Northern European Model
- Classical Model of Central North America

Classical Model: Quaternary Subdivision

The Alpine Model:

- Initially, the Quaternary Period was presumed to be a single event of cold phase.
- It was thought that during the Period, our planet cooled down and ice accumulated on two poles and mountain tops.
- The ice caps on the mountainous regions extended down to the foot hills or even extended over the outwash plains and to the continental interiors.
- Penck and Bruckner (1909) who subdivided the Quaternary Period into four events of glaciation.
- Each glacial event (Glacial Period) alternated with an event of warm period (Interglaciation).

Classical Model: Quaternary Subdivision

The Alpine Model:

- In 1909, Albrecht Penck and Eduard Bruckner (photo 1.1) published their classic work in German Language.
- The name of the book is DIE ALPEN IM E1SZEITALTER (The Alpine Glaciation).
- These four glaciations were named after four rivers: Wurm, Riss, Mindel and Gunz, flowing in the Bavarian region (table 1.1).
- After a long time, two more glaciations discovered and added to the original scheme of Penck and Bruckner.

Classical Model: Quaternary Subdivision

- **The Alpine Model**

Table 1.1 Penck and Bruckner's (1909) scheme of Glaciation in the Alpine region.

Name of Glacial/ Interglacial Period	Erosional Feature
Wurm Glaciation	Low Terrace
Riss-Wurm Interglacial	Erosion
Riss Glaciation	High Terrace
Mindel-Riss Interglacial	Erosion
Mindel Glaciation	Younger Cover Gravel
Gunz-Mindel Interglacial	Erosion
Gunz Glaciation	Older Cover Gravel

Classical Model: Quaternary Subdivision

Northern European Model

The Northern European Classical Model is being largely used in Western Europe for long time with some modifications. This classical model, based on the subdivision of the Scandinavian Ice Sheet, extended beyond the North German Plain.

Table 1.2 The classical Sequence of Glaciations and Interglaciations In northern Europe.

Name of Glaciation/Interglaciation		Cold Period	Warm Period
Weichselian Glaciation		Glacial	
Eemian Interglaciation			Interglacial
Saale Glaciation	Warthe	Glacial	
	Drenthe		
Holsteinian Interglaciation			Interglacial
Elsterian Glaciation		Glacial	
Cromerian Interglaciation			Interglacial

Classical Model: Quaternary Subdivision

Classical Model: Central North America

Canada and the northernmost parts of America were glaciated during the Quaternary Period. The classical model of Central North America (table 1.4) was based on till sheets (rock stratigraphic units), landforms (morphostratigraphy) and paleosols (soil stratigraphic units).

Table 1.4 Classical Model of Central North America (after Bowen, 1978).

Stage	Glacial/Interglacial Period	Type Locality
Wisconsin	Glacial	State of Wisconsin
Sangamon	Interglacial	Sangamon County and Illinois. Presence of soil between Wisconsin loess and Illinoian till deposits.
Illinoian	Glacial	State of Illinois. All deposits between the Yarmouth and Sangamon soils.
Yarmouth	Interglacial	Yourmouth, Des Moines County and Iowa. Soil separating Kansas and Illinoian glacial deposits.
Kansan	Glacial	Upper till at Afton Junction Pit, Union County, Iowa.
Aftonian	Interglacial	Gravels at Afton Junction Pit, Union County, Iowa
Nebraskan	Glacial	Lower till at Afton Junction Pit, Union County, Iowa.

PLIOCENE - PLEISTOCENE BOUNDARY

- It has been discussed that the major characteristic of the Quaternary is the climatic fluctuations.
- The cooling of global climate resulted in the accumulation of ice sheets in and around two poles.
- Further cooling accelerated the movement or extension of ice sheets towards the equator and their accumulation on mountain tops.
- The terminal moraines of the first glaciation in the frigid zone are much older than those of the same Glaciation in the temperate zone.
- Hence, the time of inception of a single Glacial Period varies from latitude to latitude.
- In addition, the tropical regions were not glaciated except for the high mountains.

PLIOCENE - PLEISTOCENE BOUNDARY

Recommendation for Pliocene-Pleistocene Boundary:

- Some important recommendations were adopted by the General Assembly of the18th Geological Congress held in London in 1948.
- The following recommendations were suggested by the temporary Commission on the Pliocene-Pleistocene Boundary (Zagwijn,1974):

  i. The Type Area should be selected prior to the fixation of Pliocene-Pleistocene Boundary and the Boundary should be drawn following the stratigraphic principles.
  ii. the Commission suggested that the Pliocene-Pleistocene Boundary should be based on the evolutionary changes in marine faunas.

PLIOCENE - PLEISTOCENE BOUNDARY

Recommendation for Pliocene-Pleistocene Boundary:

iii. To eliminate the existing ambiguities, the Commission recommended that the Lower Pleistocene should be included as its basal member in the type area, the Calabrian Formation (marine) together with its terrestrial equivalent the Villafranchian (thisproposal was rejected by a Sub-committee of INQUA, after a field Conference on the Boundary, held in Punjab and Kashmir in 1979)

iv. The Commission noted that the PliocenePleistocene Boundary should be place at the horizon of the first indications of climatic deterioration in the Italian Neogene (this proposal was rejected by a Subcommittee of INQUA, after a field conference on the Boundary, held in Punjab and Kashmir in1979).

PLIOCENE - PLEISTOCENE BOUNDARY

Pliocene-Pleistocene Boundary: Bengal Basin

- The reddish-brown clastic deposits exposed in the Lalmai Hills, Madhupur and Barind tracts are called Madhupur Clay Formation.
- The lower member of the Madhupur Formation is represented by bidirectional (herringbone type) cross-bedded, highly micaceous sand (deposits). At the bottom of this sand, quartz-chalcedony gravel bed is present.
- This quartz-chalcedony gravel bed, named as Cumilla Gravel Bed, represents a marker horizon in the Bengal basin. The Plio-Pleistocene boundary has been placed at the top of this Quartz-chalcedony Gravel Bed.
- This Bed is well exposed in the Ranirbanglow section of Lalmai hills. This Bed can also be seen in the Rupban Mura hill-slope section. In the Bengal Basin, it has been assumed that the Pleistocene started around 1.6 million years ago.