Q1: What is Quaternary period? Give an account of the duration of Quaternary. Give an account on the societal relevance of Quaternary study.

Ans: Quaternary is the current and most recent of the three periods of the Cenozoic Era in the geologic time scale of the International Commission on Stratigraphy. It follows the Neogene Period and spans from 2.588 ± 0.005 million years ago to the present.

The Cenozoic Era includes Quaternary (above) and Tertiary (below). The Quaternary Period is the most recent geologic era spanning the last 2.6 My.

The Quaternary is divided into two epochs: the Pleistocene and the Holocene.

The Pleistocene includes the interval from 2.6 mya to 11,000 yr BP, and is characterized by more than 50 large-scale climatic oscillations from cold glacial intervals that persisted for up to 100 000 years, to warm interglacial intervals that lasted about 10 000 years, on average.

The Holocene is the current interglacial interval, when human civilizations arose.The Holocene Epoch spans only the last 10,000 years.

Societal relevance of Quaternary study.

The Quaternary Period, although only an instant in the 4.5 billion year expanse of geologic time, is disproportionately important because it is the interval during which humans evolved and because it includes the present. Events of the Quaternary are preserved in sediments, ice sheets, and landforms with a greater degree of completeness and temporal resolution than those of any earlier period of comparable length. Studies of these historical and environmental archives continue to provide the essential context that allows scientists to evaluate what is happening with Earth's climate today and to clarify our vulnerability to hazardous natural processes, for example earthquakes, tsunami, volcanic eruptions, floods, and landslides.

Most of the modern flora and fauna, including our own species, *Homo sapiens*, evolved during the Quaternary. The Quaternary has the most to tell us about the origins of modern environments, providing an opportunity to use past environments to explore future climate scenarios.

Q2: Briefly discuss the development of theories of the causes of glaciation.

Ans: 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.
- 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.
- 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.

Q3: State briefly the major characteristics of the Quaternary Period.
Ans:
General Characteristics
 Climatic Changes
 Ice Age
 Sea Level Changes
 Changes of Relief and Landscapes
 Vegetational Changes
 Paleontological Changes

Q4: What is called "Comilla Quartz Chalcedony Gravel Bed"? Give a short account of contribution of Md. Hussain Monsur on the development of the Quaternary stratigraphy of Bangladesh.
Ans: 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.

Bangladesh, one of the largest delta basin of the world, is covered for two third of her area by Quaternary sediments. The importance of Quaternary geology for this country need not be emphasized. Since the work of Morgan & McIntire (1959) limited number of studies have taken rigorous approach in solving the versatile problems of Quaternary geology of the land.

Dr. Md. Hussain Monsur has been carrying out research work on the Quaternary geology of Bangladesh for good number of years. He has published many papers on the above topic in national and international journals. He has been the primary initiator in formulating the IGCP project 347 and rightfully deserves major part of the credit for materializing the present seminar.

The ideas of our National geologists on the Quaternary geology of the Bengal basin echo the concepts of Morgan and McIntire who published a report about half a century ago. Now-a-days, the Quaternary researches are much more diversified. In that context, the initial concept on the Quaternary geology of the Bengal basin should be revised. This book is written with some new concepts, thoughts and ideas.

Recently, International Geological Correlation Programme (IGCP) of the Division of Earth Sciences of UNESCO combined with the International Union of Geological Sciences (IUGS) has accepted the project no. 347, entitled, **Quaternary Stratigraphic Correlation of the Ganges-Brahmaputra Sediments and of the Indian Subcontinent.** The approval of the project has intensified the speed of Quaternary researches not only in Bangladesh but also in India and Nepal. The programme is led by Professor G.S. Ghatak in India and Dr. Prokash Chandra Adhikary in Nepal. In this respect, I am very much grateful to Dr. Khandaker Mosharraf Hossain, His Excellency, the Minister for Energy and Mineral Resources of

Q5: Point out views of different authors on the development of Quaternary stratigraphy of Bangladesh.
Ans:

The Ganges-Brahmaputra delta in the north-eastern comer of Indian subcontinent is the largest delta with one of the thickest sedimentary sequence in the present world where the Tertiary Quaternary sedimentary column is more than 20 km thick.
 The Neogene stratigraphic units of the area are diachronic in nature (Imam and Shaw, 1985).

The so-called Madhupur Clay or reddish-brown deposits which makes the beautiful scenery of the Lalmai hills, Madhupur and Barind tracts attracted the general attention of the geologists as early as nineteen fifty's when Morganand Mclntire(1956) published a report at the Louisiana State University, after their reconnaissance survey over the Bengal basin.
 Afterwards, Islam (1974), Alamand Khan (1980), Hassan (1986) studied the Madhupur Clay with the similar approach as was shown by Morgan and Mclntirein 1959.
 Bakr (1977) has introduced a new lithostratigaphic unit name ChandinaFormation for the Holocenedeposits exposed around the township of Chandinain Comilla district.
Much more detail investigations of the quaternary deposits exposed in the barind, Chalanbil, Panchagarh, Dahagram Angarpota, Madhupur, Lalmai, Jaintiapur, Areasandalsost. Martin's, Kutubdia, Maiskhali islands were carried out after nineteen ninety's (Akhterandhoque,1993; Monsur,1990; Monsurandhossain,1992; Monsurandpaepe,1992,1993,1994; Monsurandkamal,1994; Monsurandpaepe,1994; Monsur,1994; Monsur,1995; Morshed,1994; Saha,1994).

Q6: Briefly describe the quaternary stratigraphy of the chalanbil area. (Monsur,1993)

Ans: Quaternary Stratigraphy: Chalanbil Area

- The famous Chalanbil means a lake or marshy land in which water flows during the flood season.
- In fact during the rainy season (monsoon time) rivers are over loaded and the surplus water flows over the flood plain of the Chalanbil towards the mighty river Jamuna (Brahmaputra).
- The Chalanbil covers an area of about 500 sq.km. Roughly, the Chalanbil is extended from the village town Singra up to the village Naogaonand Chatmahorto Bastul.
- The environmental of change in Chalanbil area is quite prominent. Only about 200 years BP, the heart of the Chalanbil had never been dried up even during the peak of the dry season.
- As a result, it was a good site for gathering wild buffaloes during the dry (hot) season which created several pools and depressions.
- The wide area of Chalanbilis covered by Holocene fluvial deposits. The observation of different boreholes, pond and canal digging led to subdivide the deposits into the following units

I) the upper sticky silty-clay unit (Cl) which is called Chalanbil Silty-clay Formation (Monsur, 1993).

II) The Chalanbil Formation is underlain by the micaceous sand unit (C2) which is called Barind Formation.

- The Barind Formation is underlain by the Quartz-chalcedony Gravel layer (Comilla Gravel Bed) of DupiTila Formation of Pliocene age.

Table 3 : Stratigraphic Table for the Chalanbil area.

Chronostratigraphy: Series	Chronostratigraphy: Sub-Series	Formation	Member	Bed	Lithologic description	Thickness (m)
HOLOCENE	Sub-Atlantic	Chalanbil Silty-clay		Sand-silt-clay	Olive (5Y 5/3) to grey (5Y 5/1) silty clay to sand-silt-clay. Very sticky clay, containing Fe-concretions and plant roots.	1-5
					Unconformity	
	Sub-Boreal			Silty clay	Light yellowish brown (2.5Y 6/4) silty-clay, containing plant roots and Fe-concretions. The lower part is mottled.	3
					Unconformity	
Pleistocene	Lower	Barind	Gujorghat Sand		Pale yellowish brown (10R 6/2) silty-sand to sand. It is highly micaceous and cross bedded, contains Mn-spots. Micas are biotitic and highly oxidized. It contains some intraformational clay layers.	3
					Unconformity	
PLIOCENE		Dupi Tila			Quartz-chalcedony Gravel Bed	
					Oxidized sands with intraformational clay beds. It contins large silicified woods	

Q7: What is paleosol? Give the significance of paleosol in quaternary studies.

Ans: ➢Palaeosol are the soil horizons of the past.

➢Palaeosol represents stable stratigraphic key horizons and may reflect environmental climatic condition of the past which no longer exist today.

➢A palaeosol in stratigraphic horizon represents **a depositional** break (unconformity) in normal lithologic sequence.

Significance of paleosol:

The presence of palaeosol in **stratigraphic** horizon represents in one hand, a marker horizon **which can be** used as asynchronous level and on the other hand, it **can be** used as a geochronological tool for stratigraphic correlation of lithosequences of hundreds or thousands of kilometers apart.

In the Quaternary sequence of Bangladesh, palaeosol were used for the bases for stratigraphic subdivision.

➢Recognition and identification of palaeosols in the Madhupur and Barind Formations in the Madhupur and Barind areas and also in the Lalmai hills areas, were carried out by micro morphological studies (Monsur,1992).

Q8: Explain the reasons for appearance of reddish brown color of the madhupur and Barind formations.

Ans: Reason of Reddish Brown: Madhupur and Barind

➢The reddish brown colour of the Madhupur and Barind Formations is clearly related to the iron compounds.

➢The present author has tried to explain how these iron compounds were formed which ultimately caused the deep reddish brown to light yellowish brown colour of these deposits.

➢In this context, only the the petrographical observations with the aid of a polarizing microscope and the literature reviews are discussed (Monsur,1992; Hassan,1986). Iron in sediments can be divided into:

a) the iron present in primary minerals, the nature of which will depend on the type of parent materials undergoing weathering;
b) the iron present in secondary minerals and
c) free iron.

Q9: Briefly describe the micromorphological feature of paleosol of madhupur, barind and lalmai hills area.

Ans: Recognition and identification of palaeosols in the Madhupur and Barind Formations in the Madhupur and Barind areas and also in the Lalmai hills areas, were carried out by micro morphological studies (Monsur,1992).

➢Micro morphological descriptions of undisturbed soil samples has been given in the literature, illustrates the pedofeatures and micro structures of thin section of strongly impregnated palaeosols of the Madhupur Formation

➢One of the most distinctive aspects of some palaeosol is colour mottling reflecting localized changes in oxidation and reduction (Monsur,1990).

There is a distinct Boundary between the iron-depleted reduction zone (white spaces) and iron-rich oxidation zone (blackspaces).

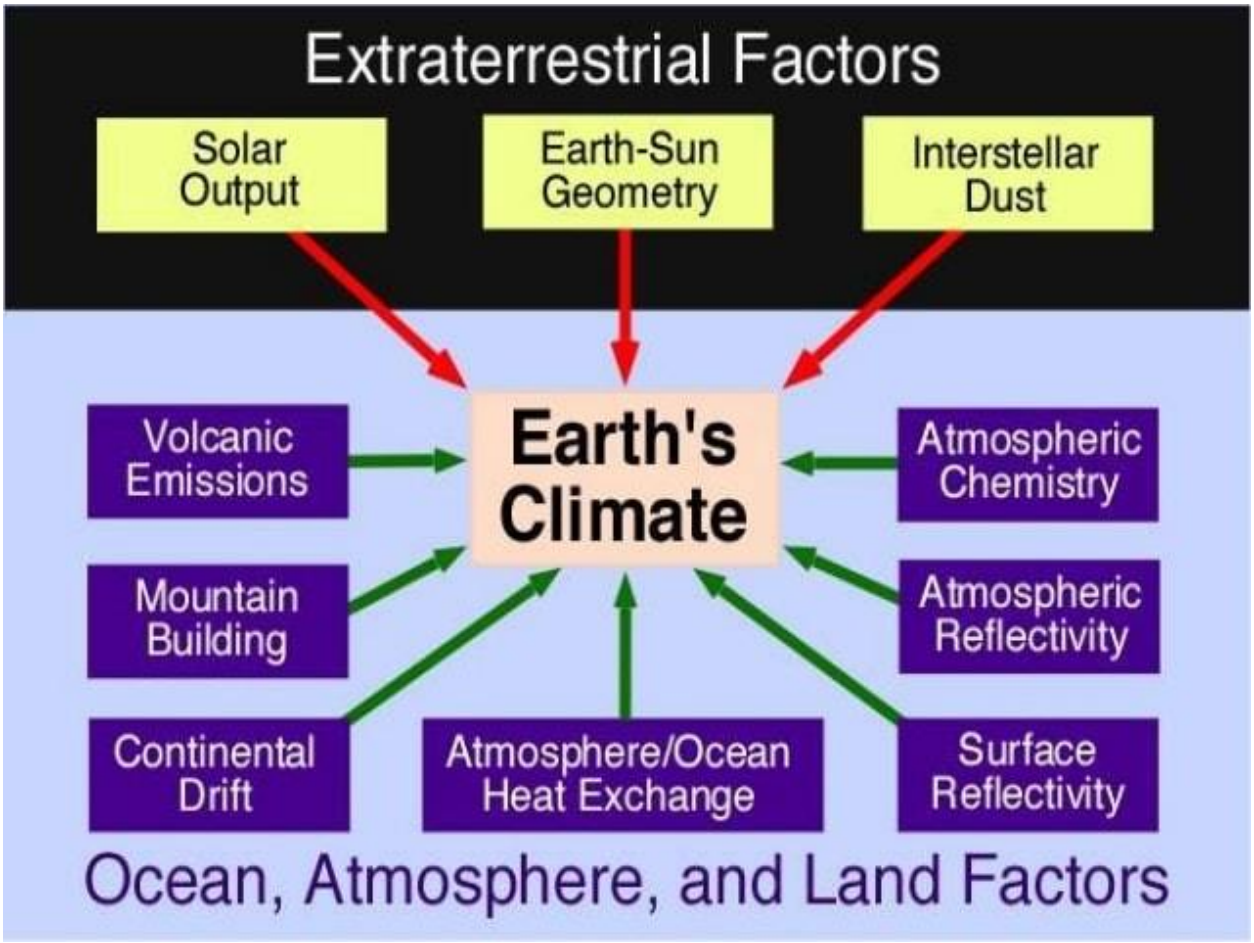
➢This kind of colour mottling is a common feature of the Madhupur and Barind Formations.

Micro morphological studies of the Madhupur and Barind Formations indicated that the upper part of the Formations represent a strongly impregnated soil with vughs, vesicles, chamber and channel microstructures having amorphous and cryptocrystalline pedofeature.

It is quite clear that the deposits had undergone pedogenic processes. All the pedofeatures indicated that these are *in situ* developed soil and do not represent a transported or re-deposited soil materials

Q10: What are the natural causes of climate change?

Ans:

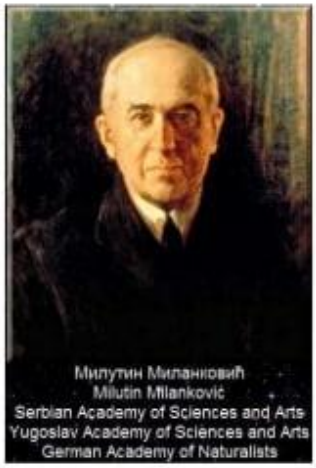


Possible causes of climate change

Ice ages in geological time (glacial/interglacial cycles) (1,000s–10,000s years)	Milankovitch cycles — changes in the amount and distribution of solar energy received at the Earth's surface caused by natural variations in its orbit around the sun and the tilt of the Earth's axis.
Historical changes (Little Ice Age/Medieval Warm Period) (several hundreds of years)	Variations in solar output and volcanic activity. The output of the sun naturally varies as sunspots grow and shrink, thereby changing the amount of solar energy received by the Earth. Volcanic dust, ash and sulphur dioxide have a short-term cooling effect.
Global warming (several decades since 1970)	Anthropogenic (human) greenhouse gas emissions (carbon dioxide, methane) trap outgoing radiation in the atmosphere, thereby creating a warming effect.
El Niño Southern Oscillation (years)	Variations in Pacific Ocean currents cause short-term changes in climate around the world.

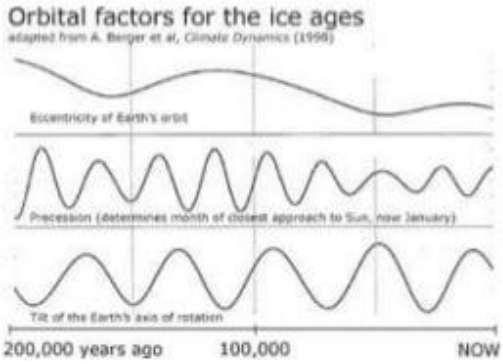
The Causes

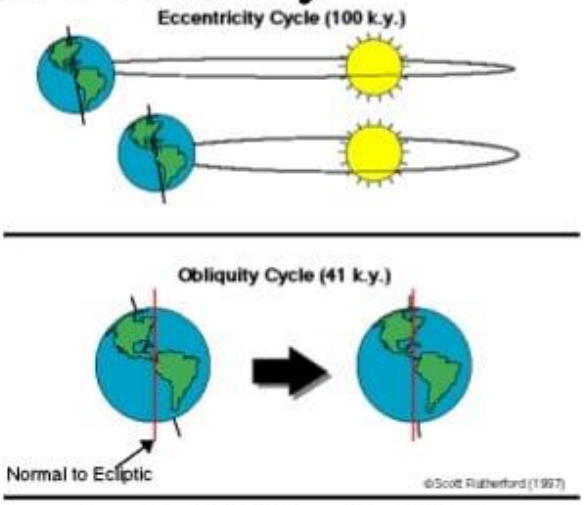
1. Earth-Sun Geometry



- The Serbian astrophysicist Milutin Milankovitch is best known for developing one of the most significant theories relating Earth motions and long-term climate change.
- Milankovitch dedicated his career to developing a mathematical theory of climate based on the seasonal and latitudinal variations of solar radiation received by the Earth.
- Now known as the Milankovitch Theory, it states that as the Earth travels through space around the sun, cyclical variations in three elements of Earth-sun geometry combine to produce variations in the amount of solar energy that reaches Earth:
  - Variations in the Earth's orbital eccentricity—the shape of the orbit around the sun.
  - Changes in obliquity—changes in the angle that Earth's axis makes with the plane of Earth's orbit.
  - Precession—the change in the direction of the Earth's axis of rotation, i.e., the axis of rotation behaves like the spin axis of a top that is winding down; hence it traces a circle on the celestial sphere over a period of time.
- Together, the periods of these orbital motions have become known as Milankovitch cycles.

The Causes
1. Earth-Sun Geometry





2. Volcanic eruptions

Scientists are quite certain that over a period of several million years, increased volcanism can create enough dust and soot to block out sunlight and produce climatic change.

mechanism

For instance at the end of the Cretaceous period and beginning of the Tertiary (known as the KT boundary) there was increased volcanic activity, with huge volcanic eruptions spewing forth floods of lava. The Deccan traps in India are an example of K-T boundary ruptures in the Earth's surface, which may have lead to the extinction of dinosaurs.

512,000 cubic km = the 1980 eruption of Mount St. Helens produced 1 cubic km of volcanic material. 60-65 Myr BP

Q11: Briefly describe the mineralogical composition of Madhupur and Barind formations (

Ans: Iron in sediments can bedivided into:
a) the iron present in primary minerals, the nature of which will depend on the type of parent materials undergoing weathering;
b) the iron present in secondary minerals and
c) free iron.

➢The primary iron-containing minerals are usually associated with igneous rocks, such as, ferromagnesian silicates (pyroxene, olivine and amphibole) biotite micas and the iron ores, comprising hematite, ilmenite and magnetite.

The sediments of the Madhupur and Barind Formations contain a lot of ferromagnesian minerals (quite fresh in the lower part of these Formations) derived from the Himalayan mountain ranges.

➢These sediments under gone intensive weathering processes and released Fe ions in a free state.

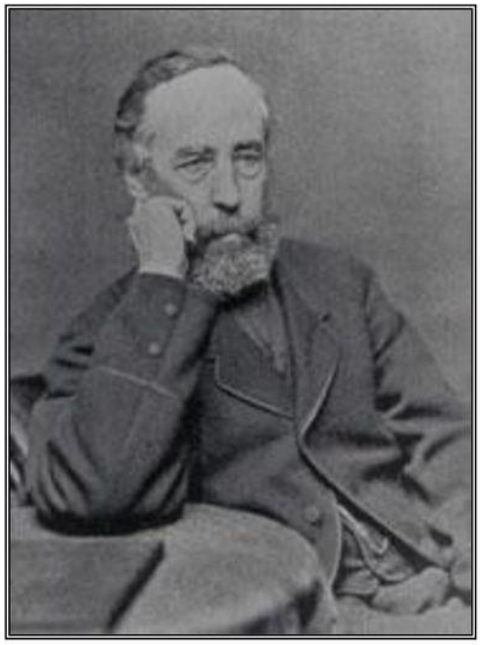
➢In the Madhupur and Barind areas these iron compounds are distributed throughout the sections in the form of nodules or in association with clays.

A lot of papers explains the formation of iron compounds in red beds. Among the iron oxides the authigenic hematite(aFe203), goethite (aFeOOH), Lepidochrocite (gFeOOH) andhydrated-ferric-oxidesgel (Fe(OH)3.H20) areimportant.

➢The colours of the upper, middle and lower Members of theMadhupur Formation are, respectively, moderate reddish brown(10R 4/6), light brown (5YR 5/6) and pale yellowish brown(10YR 6/2).

➢Similarly,the colours of the three Member of the Barind Froamtion from top to bottom are respectively, strong brown(7.5YR4/6), brownish yellow(10YR6/8) and yellowish brown(10YR5/8).

➢The colour of authigenic hematite and goethite are respectively 2.5 YR and/or redder, and 1O YR. The abundance of these two minerals is probably responsible for the colour variation of these Formations.

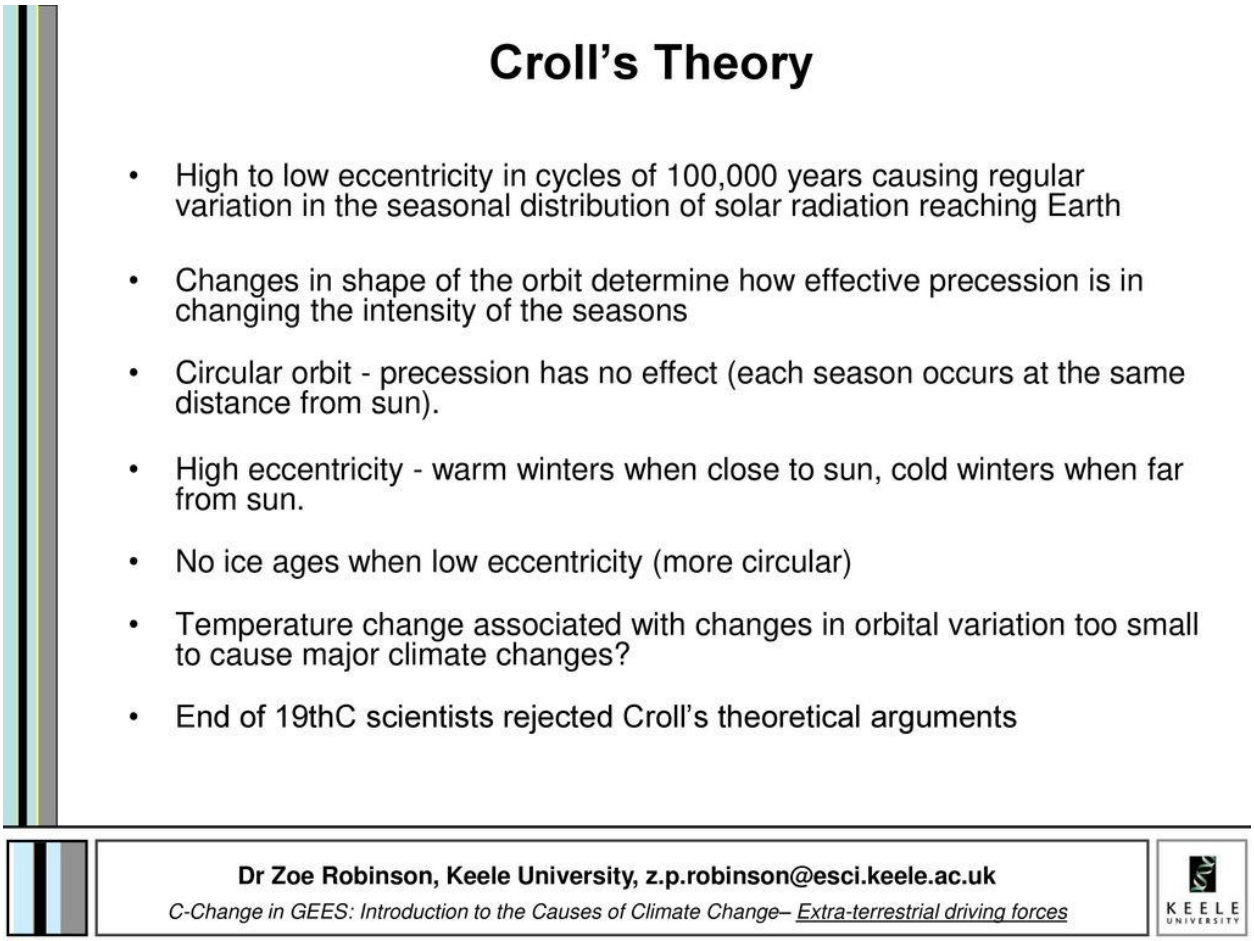


James Croll

wikimedia commons (Luis Alberto)

Development of the Orbital Theory

- Croll (1867) concluded that major ice ages linked with cycles of orbital eccentricity.
- Croll's theory combines precession and eccentricity
- Eccentricity affects intensity of radiation received during the seasons
- Believed a decrease in sunlight during winter favoured accumulation of snow – increase area of snow – increase albedo and reflection of solar radiation (Positive Feedback)



What is sea level and sea level changes?

Ans: The level of the surface of the sea especially at its mean position midway between mean high and low water.

The reference point used as a standard for determining terrestrial and atmospheric elevation or ocean depths is called the mean **sea level**

Sea level is the base level for measuring elevation and depth on Earth. Hence, sea-level rise is a **climate change phenomenon through which the ocean water volume increases**, mostly as a consequence of ice-sheets and glaciers melting and water thermal expansion.

Sea level change refers to how the height of the ocean rises or falls relative to the land at a particular location

Why did civilization emerge only during the Holocene?

Ans:
Several independent trajectories of subsistence intensification, often leading to agriculture, began during the Holocene. No plant-rich intensifications are known from the Pleistocene, even from the late Pleistocene when human populations were otherwise quite sophisticated. Recent data from ice and ocean-core climate proxies show that last glacial climates were extremely hostile to agriculture—dry, low in atmospheric CO_2, and extremely variable on quite short time scales. We hypothesize that agriculture was impossible under last-glacial conditions.

Almost all trajectories of subsistence intensification in the Holocene are progressive, and eventually agriculture became the dominant strategy in all but marginal environments. We hypothesize that, in the Holocene, agriculture was, in the long run, compulsory.

The Holocene is indeed the 'Age of Man. Holocene has also seen the **great development of human knowledge and technology**,
The Holocene corresponds with **the rapid proliferation, growth and impacts of the human species worldwide**, including all of its written history, technological revolutions, development of major civilizations, and overall significant transition towards urban living in the present.

Q: Briefly describe the quaternary stratigraphy of the Barind track.

Ans:
 The Barindarea falls in the central part of north Bengal and covers an area of about 7680 sq.km.
 The area comprises about six north-south elongated isolated exposures of reddish brown deposits.
 Previously, the reddish-brown deposits exposed in the Barindarea were also called Madhupur Clay (Morgan and Mclntire, 1959), Alamand Khan (1980), Islam (1974).
 The Barind and Madhupur area are quite apart from each other and there is no lithologic continuity.
 Hence, the Quaternary deposits exposed in the Barind area are considered separately since Barind tract is a different geomorphic unit.
 However, the Quaternary deposits exposed in the Barind area are subdivided into two broad units:
 i) **Barind Clay and Sand Formation** (Monsurand Paepe,1992), represented by deep reddish-brown, highly oxidized and weathered clay silty-clay and sand with ferruginous concretions, calcareous nodules, plant roots, pipe stems and manganese spots; and
 ii) **RohonpurSilty-clay Formation,** represented by yellowish grey, silty-clay to clay with organic matter and plant roots.

 The Barind Formation has further been subdivided into three Members (lowersubunits) and one Bed (uppersubunit) based on the presence of two palaeosol horizons.

 The Members are called **Gujorghat Sand Member** (LowerMember, **R2-3), NacholeSilty-clay Member** (middleMember, **R2-2)** and **Sherpur Clay Member** (upper Member, M2-1).

 The upper Bed of this Formation is called **GouripurSand-silt-clay Bed.**
 Similarly, the Rohonpur Formation has also been subdivided into five subunits based on the presence of four palaeosol horizons (H).
 The presence of buried soil horizons represent the Boundary Strato type.

Views of different authors for origin of madhupur tract

Most of the authors including Fergusson (1863), Hirst (1916), Morgan & McIntire (1959), Rizvi (1975), Khandoker (1987&1989), Huq et al. (1991), Coates et al. (1988, 1990 &1991), A1am (1988 & 1995) and Kamal (1998, 2005) believed that the Madhupur, Barind and Lalmai tracts represent tectonically uplifted surface. Some researchers including Monsur (1995) opined that the La1mai hills and the small portion of Madhupur (locality) represent tectonically uplifted blocks but the entire Barind and the major portion of the Madhupur tracts are originated by erossional processes rather than structural. Morgan & McIntire (1959) considered the red deposits exposed in the Madhupur, Lalmai hills and Barind areas as the 'Pleistocene terrace' but could not establish conclusively the existence of multiple terrace system 111 the Bengal plain

Briefly describe the Holocene sea level changes of the eastern coast of the bay of bengal

Ans: Book page 58-60