UNIT 7 CENOZOIC ERA WITH SPECIAL REFERENCE TO QUATERNARY PERIOD

Contents

Learning Objectives

Once you have studied this unit, you should be able to:

- Know the chronology and position of Cenozoic Era in Geological Time Scale;
- Understand different periods of Cenozoic Era;
- Study various glaciation and inter glaciation phases; and
- Discuss the causes of Pleistocene climatic change

7.0 INTRODUCTION

The Cenozoic Era is also known as Caenozoic or Cainozoic. Cenozoic literally means 'new life' after the Greek roots '*kainos*' meaning 'new' and '*zoico*' meaning 'animal life'. The Cenozoic Era is of substantial interest for anthropologists since the evolution and diversification of fossil primates, including humans, took place during this era. Besides primates, a significant portion of the evolution and radiation of various groups of mammals also happened during the Cenozoic. It is for this reason that sometimes the Cenozoic is also termed as the 'Age of Mammals' who were the dominant animal life of earth during the Cenozoic Era. The era began about 65 million years ago and continues into the present. The existing locations of the continents and the distribution of current flora and fauna acquired its present-day configuration during this time period.

The era began at the end of Cretaceous, the last phase of the Mesozoic. The end of Cretaceous was marked by large-scale extinctions, when the non-avian dinosaurs, along with several other types of fauna, were completely wiped out. Several types of ecological niches vacated by the reptilian extinction were gradually occupied and exploited by the mammals, which flourished, diversified and came to dominate Earth's faunal life.

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During early part of the Cenozoic, Earth was largely populated by small fauna, which also included small mammals. However, over a period of time the mammals diversified and radiated taking advantage of the absence of dinosaurs who had dominated the earth during the Mesozoic Era. The mammals occupied almost all the ecological niches, which were earlier the domain of the dinosaurs. Over time, a few of the mammals greatly increased in size and grew much larger than even some of the largest mammals of today, such as whales and as elephants. Of all the twenty orders of the class mammalian, of special interest for an anthropologist are the primates, which also evolved, diversified and radiated along with other mammals during the Cenozoic Era.

7.1 POSITION OF CENOZOIC IN THE GEOLOGIC TIME SCALE

The Cenozoic Era is the most recent of the three major subdivisions of animal history. The other two are the *Mesozoic* and *Palaeozoic* Eras. Before we discuss the Cenozoic, it would be useful to understand, in brief, the various divisions of the earth's geologic history and the position of Cenozoic in it. The history of the Earth is divided into parts based on certain geologic or faunal/floral events. The generally accepted divisions are eon, era, period, epoch, and age, as progressively smaller units of geological time. The major divisions of time are termed eons. In succession these are: *Hadean*, the *Archean*, the *Proterozoic* and the *Phanerozoic*. The first three of these can be collectively called as the Precambrian super eons. Eons are further divided into *eras*. The eras are in turn divisible into periods, epochs and ages. The various divisions of geologic time, along with their ages, and the position of Cenozoic in it are depicted in Table 1.

7.2 CHRONOLOGY OF CENOZOIC ERA

From an anthropological perspective, Cenozoic Era is very important because, the entire primate evolution and subsequently the human evolution occurred during this Era. Besides primates, the evolution and radiation of mammals, birds and most flowering plants and grasses took place during this phase of Earth's history. The Cenozoic is divided into three periods, namely the Palaeogene, the Neogene and the Quaternary, and seven epochs, viz. Palaeocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene and Holocene. The Cenozoic is sometimes called the 'Age of Mammals', because the largest land animals,the mammals appeared on earth during that time. The Palaeogene is subdivided into three epochs: the Palaeocene, the Eocene and the Oligocene. The Neogene is subdivided into two epochs: the Miocene and Pliocene. The Quaternary is divisible into two epochs: the Pleistocene and the Holocene.

a) Palaeocene Epoch

The Palaeocene is the first epoch of the Cenozoic, which began at about 66 million year before present (myr). It begins at the end of Cretaceous when large-scale extinctions of life occurred. *Dinosaurs* on land, large swimming *reptiles* in seas, nektonic *ammonites* and most microscopic planktons died out at the end of Cretaceous leaving many ecological niches vacant for evolution and radiation of mammals, which had existed for more than 100 million years before the Cenozoic Era. Palaeocene saw mammals growing bigger and occupying a wider variety of ecological niches. The mammals were small rodent-like to medium-sized mammals. Fossil evidence from the Paleocene is scarce. Small early primates, plesiadapids, marsupials and monotreme mammals were present.

b) Eocene Epoch

The Eocene began at around 56 myr ago and ended at around 34 myr ago lasting

Table 1: Position of Cenozoic in Geological time scale

Eon		Era	*Period*	Epoch	Major Fauna	Age (myr)
PHANEROZOIC		CENOZOIC	*Quaternary*	Holocene	Ice Age recedes, present interglacial begins. Rise of human civilization; domestication of animals and agriculture. Stone Age cultures give way to Bronze Age (3300 BC), Iron Age (1200 BC), many pre-historic cultures world-wide and industrial revolution.	0.0117
				Pleistocene	Pleistocene megafauna first flourishes and then becomes extinct. Anatomically modern humans evolve. Emergence of human stone-age cultures. Quaternary Ice Age continues with glacial and interglacial phases.	2.58
			Neogene	Pliocene	Several of the existing genera of mammals present. Hominids appear and diversify. Cool and dry climate.	5.3
				Miocene	Horses and mastodons diversify. Modern mammal and bird families become identifiable. First apes appear. Grasses spread.	23
			Palaeogene	Oligocene	Rapid evolution and diversification of mammalian and other fauna. Major evolution and dispersal of flowering plants	34
				Eocene	Archaic mammals flourish and continue to evolve; several "modern" mammalian groups appear. First grasses appear.	56
				Palaeocene	Mammals diversify into a number of primitive lineages. Many modern plants appear. Indian plate collides with Eurasian plate ~55 myr. Himalayan orogeny begin	66
		MESOZOIC		Cretaceous	Many new types of land dinosaurs evolve (*Tyrannosaurs*, duck-billed and horned dinosaurs). Flowering plants proliferate. Monotremes, marsupials and placental mammals appear. Primitive birds continue. At end of Cretaceous, major extinction wipes out dinosaurs and many other reptiles.	145
				Jurassic	Many types of dinosaurs. First birds and lizards. Small mammals common. Gymnosperms and ferns common.	201
				Triassic	First mammals and crocodiles appear. Reptiles dominant on land, seas and in the air. Modern corals and teleost fish appear. Many large aquatic amphibians; ammonoids very common.	252
		PALAEOZOIC		Permian	Synapsid reptiles become plentiful, amphibians common; cone-bearing gymnosperms replace earlier flora.At ~251 myr, major life, including trilobites, graptolites, blastoids, extinct.	299
				Carboni-ferous	Amphibians diversify, first reptiles and coal forests. Winged insects radiate, first land vertebrates. Early sharks diversify, echinoderms abundant; trilobites and nautiloids decline.	359
				Devonian	First clubmosses, ferns,seed-bearing plants (progymnosperms) and first insects (wingless) appear. Trilobites and armoured agnaths decline, jawed fishes and early sharks rule the seas. First amphibians still aquatic.	419
				Silurian	First vascular plants. First jawed fishes and many armoured jawless fish in seas. Corals, brachiopods, crinoids, Sea-scorpions abundant. Trilobites and mollusks diverse.	444
				Ordovician	Invertebrates diversify. Early corals. bivalves, nautiloids, articulate brachiopods, trilobites, ostracods, bryozoa, many echinoderms. First green plants and fungi on land.	485
				Cambrian	Major diversification of life. Most modern phyla appear. First animals with hard parts. First chordates. Trilobites, worms, sponges, brachiopods present. Prokaryotes, fungi, algae go on.	541
PRECAM-BRIAN	**Proterozoic**	*In upper part, fossil of complex multicelled organisms. Stromatolite fossils common. First multicellular organisms (~1200 myr). First Eukaryotes (~2000 myr).*				2500
	Archean	*Simple single-celled life (prokaryotic life such as bacteria and blue-green algae). Oldest probable microfossils.*				4000
	Hadean	*Formation of Earth. There is no evidence for life in this Eon. Oldest known rocks 3500-4000 Myr.*				4600

Modified after Cohen et.al. (2013).

nearly 22 million years, the longest of all the epochs of the Cenozoic Era. For most of the Eocene Epoch, the global climate was warm and rainy. Among the mammal groups that first appeared in the fossil record during this period are the perissodactyls, artiodactyls, proboscideans, rodents, and many primates. Adaptive radiation of adapid and the omomyid prosimians took place during this epoch. It is thought that the intense global warming allowed warm-adapted mammals to migrate between continents via land connections at very high latitudes. Early perissodactyls, such as the horse relative *Hyracotherium*, appeared right at the very beginning of the Eocene. By the end of the epoch, the planet was much cooler and the rainforest-like habitats that covered much of the continents gave way to more open woodland.

c) Oligocene Epoch

The Oligocene Epoch extends from about 34 myr ago to about 23 myrs. A cooling trend is prevalent throughout Oligocene. Mammals such as horses, deer, camels, elephants, cats, dogs, and primates began to dominate continents, except in Australia. Early forms of amphicyonids, horses (*Miohippus*) canids, camels, tayassuids, protoceratids, and anthracotheres appeared. In late Oligocene there was an expansion of grasslands and prairies that was linked to the expansion of grazing animals. Earliest new world monkeys, early anthropoids (*Parapithecus, Apidium, Aegyptopithjecus*), known largely from Egypt, emerged.

d) Miocene Epoch

The Miocene Epoch is the first *geological epoch* of the *Neogene* Period and it extends from about 23 myrs back to 5.3 myrs ago. It was a time of warmer global climates than those in the preceding Oligocene or the following Pliocene. The *grasslands* continued to expand and forests continued to decrease. During later part of Miocene, mammals were more modern, with easily recognizable canids, bears, procyonids, equids, beavers, deer, camelids, and whales. Apes arose and diversified during the Miocene, becoming widespread in the Old World (e.g. *Gigantopithecus, Sivapithecus, Dryopithecus*). A large number of ape species existed in Africa, Asia and Europe during this time. The first hominins appeared in Africa at the very end of the Miocene, which included *Sahelanthropus* and *Orrorin*.

e) Pliocene Epoch

The Pliocene epoch is the second epoch of the Neogene Period, which began about 5.3 myrs ago and extended to about 2.58 myrs back. During the Pliocene, continents continued to drift toward their present positions and Africa's collision with Europe cut off the remaining part of the Tethys Sea and formed the Mediterranean Sea. During the Pliocene, climates became cooler, drier, and seasonal, similar to modern climates. In Eurasia, primate distribution declined. Elephants, gomphotheres, and stegodonts were successful in Asia. Horse diversity declined, while cattle and antelopes were successful. During Pliocene, hominids became increasingly well-documented in the fossil record (e.g. *Ardipithecus ramidus, Australopithecus anamensis, Australopithecus afarensis, Australopithecus garhi, Australopithecus africanus, Homo habilis*).

f) Pleistocene Epoch

This epoch is the first epoch of the Quaternary Period that started about 2.58 myr ago and lasted up to 11700 years before present. The Pleistocene was a relatively short span of geologic time, which was a time of great global cooling, commonly known as "Ice Age". During the epoch, immense glaciers and ice sheets occurred at the North and South Poles and at all high altitudes. The cold periods or glacial were interspersed

with warmer phases or interglacial. The evolution of anatomically modern humans (*Homo sapiens*) took place during the Pleistocene, who then spread to different parts of the Earth. In addition to the woolly mammoth, mammals such as sabre-toothed cats (*Smilodon*), giant ground sloths (*Megatherium*) and mastodons roamed the Earth during this period. By the end of this epoch, a major extinction event of large mammals (e.g. mammoths, mastodons, sabre-toothed cats, ground sloths, cave bears, etc.) occurred (probably due to over hunting by humans and climate change) and continued into the Holocene.

g) **Holocene Epoch**

Holocene is the second of the epochs of the Quaternary Period that started about 11,700 years ago and is continuing. It is a period of warming in which the global climate became warmer. During this period many mega mammals, such as like woolly mammoth and woolly rhinoceros, became extinct. Humans developed agriculture and domestication of animals, which was followed by bronze and iron ages, development of civilizations, urban centres, governments, rapid population growth and the development of industrial revolution in 19th century.

Check Your Progress

1) In how many period and epochs Cenozoic era can be divided?

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7.3 QUATERNARY PERIOD AND PLEISTOCENE GLACIATIONS

Quaternary Period of the Cenozoic Era is the youngest period of the geological history of earth. It consists of two epochs: the Pleistocene and the Holocene. Pleistocene Epoch is unique in Earth's history as it has witnessed very cold conditions also known as glaciations or ice ages. One of the striking features of Pleistocene was the slow lowering of temperature of earth culminating in what is known as Ice Age. In fact it was not a continuous ice age but a series of very cold periods interspersed with warmer phases. The cold phase is generally termed as a glacial phase while the warmer phase known as interglacial phase. During Pleistocene, ice sheets expanded, from out of Antarctica and Greenland, and higher altitudes in the mountains. During the coldest phase, the glacial conditions prevailed as far south as 39° latitude north. Countries which now have a temperate climate then experienced the arctic cold of polar region and were covered under ice sheets.

After several years of work, the scientists have been able to show that there have been at least four major glaciations with several interglacial periods when ice retreated during the Pleistocene Epoch. Within the span of the glaciations, there were some warm periods, called Interstadials, when ice retreated. At its maximum, the great ice sheets covering northern Europe and most British Isles were nearly two miles thick. It extended over whole of Scandinavia, the Baltic Sea, and far into Russia and Germany. Less extensive glaciers covered the Alps, the Himalayas, the Pyrenees and other high mountainous

areas. During glacial maxima, the sea level fell by as much as 500 feet as much water got locked as ice. A glacial phase may be defined as a cold period of increased precipitation leading to snow formation at higher altitudes and its accumulation at poles and solidification into ice and leading over time to the formation of glaciers.

Penck and Bruckner distinguished four glaciations and three interglacials on the basis of their work in the Alps. The glacial phases were named by them after four small rivers which flowed down the side of Alps into the Danube Basin. The Alps glaciations and their estimated ages are given in Table-2. A pre-Gunz glacial phase, termed Donau, has also been identified in many sub-polar regions,, occurring during the Villafranchian Age of Pleistocene (Bhattacharya, 1990).

Table 2: The four glacial phases of the Alps

Sr. No. of Glacial Phase	Glacial/Interglacial Phase	Approximate Age (Years Before Present or BP)
	Post-Glacial Phase	10,000 BP
4th Glaciation		100,000 BP
	Riss-Wurm Intergllacial	
3rd Glaciation	Riss Glaciation	200,000 BP
	Mindel-Riss Interglacial	
2nd Glaciation	Mindel Glaciation	400,000 BP
	Gunz-Mindel Interglacial	
1st Glaciation	Gunz Glaciation	600,000 BP

7.4 EVIDENCES OF PLEISTOCENE GLACIATIONS

A glacier is a permanent (relatively speaking) body of ice, consisting largely of recrystallized snow that shows evidence of downslope or outward movement due to the pull of gravity. The main evidences of the occurrence of glaciations are as follows:

1) *Moraines*: Moraines are the debris produced by the erosional activity of a glacier. It consists of non sorted random mixture of different sized fragments of angular rocks in a matrix of fine grained, sand- to clay-sized fragments that were produced by abrasion within the glacier and have a form different from the underlying bedrock. Depending on their position in relation to the glacier, moraines can be Ground Moraines, Medial Moraines, Lateral Moraines and End Moraines. Moraines are definite evidence of the presence of glaciers and glaciated conditions. Other evidences of glaciers are U-shaped Valleys, hanging valleys, erratic, etc.

2) *Sea Level Fluctuations*: During glacial periods much sea water was tied up in glaciers so sea level was lower. During interglacial periods, sea level was higher due to release of water by melting of the ice.

   i) *Evidences of Lower Sea Level*: During low sea level or glacial phases, the level of sea was much lower than the present level.

      a) Submerged organic remains of land plans and animals

b) Submerged deltas

c) Anomalous faunal distribution

ii) *Evidences of Higher Sea Level:* During interglacial phases, the ice sheets melted and sea level rose higher than the current sea level.

a) Fossil bearing marine sediments

b) Cliffs by waves of sea.

3) *Loess*: It is a wind blown deposit found in the periglacial zone. The deposit is of material coarser than clay but finer than sand. It is caused by the presence of a glacier nearby.Examples are of Loess deposit in Danube River valley and those in Kashmir valley. The latter is known as Kaerwas locally.

4) *River Terraces*: River terraces are the remnants of earlier floodplains that existed at a time when either a stream or river was flowing at a higher elevation before its channel down cut to create a new floodplain at a lower elevation. A river terrace is a bench or step that extends along the side of a valley and represents a former level of the valley floor. A terrace results from any hydrological or climatic shift that causes renewed down cutting. A terraces can also be left behind when the volume of the fluvial flow declines due to changes in climate. When there is more water the river volume increases and its erosional activity is enhanced. It deepens its bed thus forming a terrace. It is understood that terraces also indirect evidence of glacial and interglacial periods. Glacial periods have been reported to be associated with aggradation and interglacial periods with incision (De Terra and Patterson, 1939).

Check Your Progress

2) What is meant by moraines? What do they consist of?

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7.5 PLUVIALS AND INTERPLUVIALS

When the arctic temperate and sub-temperate regions were experiencing glacial and interglacial phases, the tropical and subtropical regions were passing through pluvial or wet and inter-pluvial or dry periods. These have left their evidences in the form of river terraces and lake deposits.

1) **River Terrace:** A river terrace also provides evidence of pluvial phase followed by an inter-pluvial phase. It is also formed in the same principle as mentioned above. The deposits are marked by alternating deposit of gravel and silt. With higher amount of rainfall volume and velocity of water in the river increases. The rocks and other materials carried by river are turned into gravels. With the onset of dry condition, that is with reduced amount of rainfall river loses its capacity to carry loads and instead of gravels silt is deposited. Examples may be given of the

Subarnarekha, Luni, Narmada and Kortaliyar river terraces from East, West, Central and Southern part of India respectively.

2) **Lake Deposits:** In the interior of various continents there are several lakes which provide evidence of pluvial and inter-pluvial periods. During pluvial phase (wet phase) these lakes have been expanding and during an inter-pluvial (dry phase) the lakes have shrunk. These lakes have been expanding and shrinking thus submerging and exposing the surrounding areas and life forms. African lakes provide ample evidence of three pluvial expansions of lakes when lakes Nakuru, Elementaita and Naivasha in Kenya expanded to form a single lake during a pluvial phase.

7.6 CAUSES OF PLEISTOCENE GLACIATIONS

The exact reason behind Pleistocene glaciations is difficult to pinpoint. However several explanations have been given in the past to explain the reasons for their occurrence. These can be grouped into two types of theories: Astronomical and Geographical (Plate tectonic).

A) Astronomical Theories

Several astronomical theories are available for the cause of Pleistocene Glaciations.

1) *Increased concentricity of the earth's orbit*: This theory has its basis in a theory known as Croll's Hypothesis. In the 19th Century, James Croll published an article entitled "on the eccentricity of the earth's orbit and its physical relation to the glaciations" showing the calculation of how the gravitational pulls of the sun, moon, and planets subtly affect the earth's motion and orientation. This theory depends upon two phenomena:

   a) Eccentricity of Earth's orbit

   b) Precession of equinoxes.

   The change in earth's orbit, which is now nearly circular, from more elliptical to less elliptical has been periodic. So when the orbit is more elliptical, Earth may have very long and intense winters and short but very hot summers, having a cumulative effect leading to, over a period of time, into growth of glaciers and a glacial phase. The opposite would happen when the orbit becomes less elliptical or circular. Croll's theory was further developed subsequently by Milutin Minankovitch, a Serbain geophysicist who calculated these irregularities in Earth's orbit said that it would come across the climatic cycles known as Milankovitch's cycles. It has been postulated that the eccentricity of earth's orbit fluctuates with a periodicity of 92,000 years and the precession period (variation in the way the Earth wobbles on its axis) shifts in every 21,000 years.

2) *Variation in the angle between earth's axis and plane of orbit*: Another explanation that has been given to explain Pleistocene glaciations is the variation in the angle between earth's axis and the plane of its orbit. The period of this motion is believed to be 40,000 years. At present the angle is 23°, 27´, and it is known to have varied between 21°, 39´ and 24°, 36´. The increase of obliquity of this angle intensifies seasonal difference, by taking northern hemisphere away from sun, resulting in cooler conditions. It has been estimated that a change in the plane of Erath's orbit by 1° may cause a change of 5°C, which may be sufficient to bring glacial phase.

3) *Change in the intensity of solar radiation*: It has been suggested that the solar

heat received by earth from sun is not constant and may have considerably diminished during glacial phases. It was postulated by Huttington that there are periodic recurrence of sun spot cycles which may be glacial and interglacial. This is also known as 'Huttington's Hypothesis'.

Check Your Progress

3) What is 'Huttington's Hypothesis'?

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B. **Geographical Causes**

1) *Changes in earth's Atmosphere*: Atmospheric Factors- the composition of the Earth's atmosphere - can be studied from air bubbles trapped in ice in the polar ice sheets, by studying drill core samples. The study of these ice core samples have revealed that:

   i) During past glaciations, the amount of CO_2 and methane, both greenhouse gasses that tend to cause global warming, were lower than during interglacial periods.

   ii) During past glaciations, the amount of dust in the atmosphere was higher than during interglacial periods, thus more heat was likely reflected from the Earth's atmosphere back into space.

2) *Changes in Oceanic Circulation*: Small changes in ocean circulation can amplify small changes in temperature variation produced by astronomical factors.

3) *Tactonic Causes*: The continental uplift in late Pliocene or early Pleistocene, leading to upliftment of mountain chains like the Alps, the Rockies and the Himalayas, caused an increase in the average height of continents. This could have lowered the surface temperature, more so at higher altitudes and latitudes, thus precipitating colder or glacial conditions.

Thus we see that there are several theories for the occurrence of glacial phases during the Pleistocene. However, no single theory or cause can on its own explain it. It is possible that a combination of factors may have given rise to Pleistocene glaciations.

Check Your Progress

4) How did the continental uplift affect glaciation?

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7.7 SUMMARY

Earth's history is divided by the geologists into several phases. The Cenozoic Era is the most recent of the three major subdivisions of animal history. The Cenozoic is divided into three periods, namely the Palaeogene, the Neogene and the Quaternary. The Cenozoic is sometimes called the 'Age of Mammals', because the largest land animals, mammals, appeared on earth during that time. The Palaeogene is subdivided into three epochs: the Palaeocene, the Eocene and the Oligocene. The Quaternary is divisible into two epochs: the Pleistocene and the Holocene. Pleistocene is the first epoch of the Quaternary Period that started about 2.58 myr ago and lasted up to 11,700 years before present. Holocene is the second of the epochs of the Quaternary Period that started about 11,700 years ago and is continuing. It is a period of warming in which the global climate became warmer. Pleistocene is a period of climatic fluctuation. On higher latitude and altitude climate alternated between cold and warm phases, because of change in snowline. These phases are known as glacial and interglacial respectively. In the tropical and equatorial regions climate fluctuated between wet and dry condition, because of difference between average annual rainfalls. These are known as pluvial and interpluvial periods respectively. Evidences of glacial phases are found in deposits of moraines, loess, sea level changes and river terraces. Evidences for alternating dry and wet conditions are also found in river terraces, alternating deposits of gravel and silt and in changes in lake water level. Causes of climatic fluctuation are explained by various theories, namely, astronomical and geographical. Quaternary is most important for archaeological anthropology. During this time bio-cultural evolution of man had taken place. It provides understanding for the environment and time dimension which caused the changes in man and his culture.

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7.9 ANSWERS TO CHECK YOUR PROGRESS

1) The Cenozoic is divided into three periods, namely the Palaeogene, the Neogene and the Quaternary, and seven epochs, viz. Palaeocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene and Holocene.

2) Moraines are the debris produced by the erosional activity of a glacier. It consists of nonsorted random mixture of different sized fragments of angular rocks in a

matrix of fine grained, sand- to clay-sized fragments that were produced by abrasion within the glacier and have a form different from the underlying bedrock.

3) According to the 'Huttington's Hypothesis' solar heat received by earth from sun is not constant and may have considerably diminished during glacial phases. It was postulated by Huttington that there are periodic recurrence of sun spot cycles which may be glacial and interglacial. This is also known as 'Huttington's Hypothesis'.

4) The continental uplift in late Pliocene or early Pleistocene, leading to upliftment of mountain chains like the Alps, the Rockies and the Himalayas, caused an increase in the average height of continents. This could have lowered the surface temperature, more so at higher altitudes and latitudes, thus precipitating coder or glacial conditions.