ENVIRONMENTAL GEOSCIENCES

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Lecture-43

Various Stratigraphic Units of India: Tertiary Group and Quaternary Group

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We are discussing the Module eight. Module eight consists of various stratigraphic units of India and fossils, its mode of preservation and uses. We have already discussed the lecture one to lecture three. Now today we will discuss the lecture four which will consist of various stratigraphic units of India including the tertiary group and quaternary group.

The important concepts which will be covered in this lecture will be the introduction to the cenozoic group. Tertiary period, Tertiary of Sind-Baluchistan, Tertiary of the Himalayan Arc, that is the Siwalik system, Tertiary of Assam, important economic mineral deposits of Tertiary group, and then the Quaternary period will be discussed in this lecture. The Pleistocene system will be there. First of all, we will discuss the introduction to Cenozoic group. The term Cenozoic also sometimes known as Cainozoic, meaning new life, was introduced by John Philips for the era that followed the Mesozoic. The Cenozoic Era comprises the shortest and most recent phase of the Earth's history, embracing a total duration of about seventy million years.

The era is generally divided into Tertiary Period and Quaternary Period. The tertiary system of the rock formations that were laid down during that period has been subdivided into a lower Paleogene succession and upper Neogene succession. In view of the contrasting fossil assemblages of the two subdivisions, some geologists prefer to assign them independent status of system. Therefore, in a three-fold division, the Cenozoic Era comprises the Palaeogene, the Neogene and the Quaternary periods. Now we will discuss the Tertiary period.

The beginning of tertiary period is placed about seventy million years ago and the period came to an end at about one point five million years ago. Charles Lyell subdivided the tertiary period into three series known as Eocene, down of the recent, then Miocene, middle of the recent, and Pliocene, major of the recent. Later, Paleocene which is older

than eocene, and oligocene, which is younger than eocene, were carved out from the eocene succession. The paleocene, eocene, and the oligocene epoch constitute the paleogene period, whereas the miocene and pliocene epochs constitute the neogene period. The various epochs of the tertiary period have been further subdivided into successive ages on the basis of characteristic assemblages of flora and fauna.

Here you can see the subdivisions of the tertiary period. From the bottom we can see the Palaeocene, then the Eocene, then the Oligocene. These three coming under the Palaeogene period, whereas Miocene and Pliocene coming under the Neogene period. The eventful Tertiary Era witnessed some significant changes in the physiographic, environmental, faunal and floral characteristics of the surface of the globe. The ancient Gondwanaland was broken down into a number of fragments and these drifted gradually to form the modern southern continents. The great orogenic movement, which was responsible for the building up of the Alpine Himalayan and other equatorial mountain systems, was in operation during the Tertiary era.

The Himalayan mountains appear to have attained their present configuration in a series of five remarkable phases of uplift, of which the most important one occurred during the Middle-Miocene period. Along with the rise of the Himalayas, the geosynclinal basin that is the Tethys became progressively shallower. As a consequence the initial marine environment of the Tethyan sea gradually changed over to estuarine and, after the principal phase of the Himalayan upheaval in Middle-Miocene, fresh-water environment prevailed in the resulting inland basins. Along with the aforesaid changes in Physiography and environment, the older life-forms, which failed to adapt themselves to the new set-up, gradually perished and, in their place, new plants and animals were brought into being and these continued to develop and flourish during the Tertiary era. Amongst the plants, ferns, cycads, conifers, etc., which dominated during the Mesozoic, became much less important and were replaced by angiosperms that is the flowering plants.

The mighty reptiles of the Mesozoic era were, in a similar manner, practically extinct and, in their place, the mammals became the dominating group. The ammonites, which occurred in abundance in the Mesozoic seas, totally perished just before the advent of the Tertiary era. In India, Tertiary rocks are particularly well-developed in the Extra-Peninsula, where they occur practically all along the length of the Himalayan ranges. Characteristic geological successions of Tertiary rocks have been studied in Sind-Baluchistan, Jammu and the Punjab Himalayas, Assam and Burma, as well as in the Salt

Range and the Potwar plateau. Whereas In the Peninsula, on the other hand, small patches of Tertiary rocks occur in Rajasthan and along the coastal tracts in Orissa, Madras, Travancore, Cutch and Gujarat.

Now we will discuss the Tertiary of Sind-Baluchistan. The Tertiary rocks are, perhaps, best developed in Sind and Baluchistan, where they exhibit a complete geological succession ranging in age from Paleocene to Pliocene. The mountains, which lie along the boundary between the provinces of Sind and Baluchistan, appear to have divided into two distinct parts. In Baluchistan proper, the Tertiary rocks were all formed under a marine environment and constitute three parallel zones running approximately north-south. Whereas in Sindh, on the other hand, the Tertiary sediments were laid down under a changing environment.

The lower tertiary rocks are of marine origin while the upper tertiary sediments appear to have been formed under freshwater. Here you can see the tertiary succession of Sind and Baluchistan. The bottom most is the Ranikot series comprises of upper and lower stages whereas the Laki series next one is having the Metings shale and limestone, Dunghan limestone, Gazij shale. Kirthar series is having the lower, middle and upper stages whereas Nari series is also having lower and upper stages. Gaj is having the lower and upper and Manchhar series is having the lower and upper stages of the age ranging from Paleocene to Pliocene.

In Sind and Baluchistan, the oldest group of Tertiary rocks is known as the Ranikot series, which is made up principally of limestones, shales and sandstones. The lower part of the series, composed of shales and sandstones with associated coal-seams and lignite beds, lies unconformably above the Deccan traps or the Cardita beaumonti beds. The Lower-Ranikot rocks contain remains of oyster and impressions of angiospermous leaves and are said to be of Paleocene age. The upper part of the series is on the other hand, made up mainly of limestones with associated argillaceous and arenaceous horizons. These limestones are very rich in fossils, of which the more important ones are foraminifers, corals, echinoids, gastropods, pelecypods and cephalopods.

The Upper-Ranikot rocks are said to be of Lower-Eocene age. The Ranikot series is overlain unconformably by the Laki series, which is developed characteristically in the Calcareous zone in Baluchistan and is made up principally of shales and limestones. The lower part of series, known as Meting shales, is well-developer in the Laki range and is composed of limestones and shales. The overlying Dunghan limestones are rich in fossils

and occur in the Bolan Pass and adjacent regions as well as in the Laki range. The topmost horizon of the Laki series is known as the Ghazij beds.

These are made up mainly of clays and sandstones with a few thin layers of limestone, coal and gypseous clay. The Ghazij beds are well-developed in different parts of Baluchistan. The chief fossils of the Laki series are foraminifers and echinoids and there also occur some gastropods and lamellibranchs. The whole of the Laki series is said to be of Lower to Middle-Eocene age and is regarded as the most important oil-bearing horizon in Sind, Baluchistan and adjacent parts of north-western India. The Laki series is followed upwards, with a distinct unconformity, by the Kirthar series, which is made up of shales, limestones and sandstones of Middle-Eocene age.

Characteristic outcrops of the Kirthar rocks occur in the Kirthar, Kimbu and other ranges in Baluchistan. The lower part of the series is composed of shales, sandstones, and limestones, which constitute an enormously thick column of sediments and are well-developed in Baluchistan. The Lower-Kirthar rocks contain remains of characteristic foraminifers. The Middle-Kirthar horizon is made up of limestones and occurs in Baluchistan as well as in Sind. These beds are followed upwards by massive limestones which form the topmost horizon of the Kirthar series.

The Upper-Kirthar rocks are known otherwise as the Spintangi limestones and are well-developed in Baluchistan. The Spintangi limestones contain remains of characteristic foraminifers. The whole of the Kirthar in addition to the foraminifers contains remains of a number of echinoids. The first remarkable break in the Tertiary succession in Sind, Baluchistan and adjacent regions is marked by the absence of sediments of Upper-Eocene age and Kirthar series is overlain, with a profound unconformity, by the Nari series of Oligocene age. This Stratigraphic break is correlated with the second phase of upheaval of the Himalayas, which was in operation towards the close of the Eocene period.

The Nari series, developed characteristically in Sind and its lower part is composed of fossiliferous limestone beds, which were deposited under a marine environment. These massive limestones are intercalated with argillaceous and arenaceous bands and contain an wealth of fossils. The upper part of the Nari series is made up of unfossiliferous sandstone and shale beds. In a few zones, however, the characteristic foraminifer Lepidocyclina dilatata occurs in abundance. The Nari series is of Oligocene age-its lower and upper parts corresponding respectively to Lower and Upper-Oligocene.

The common fossils associated with the Nari series are foraminifers, echinoids, Lyria, Cypraea, gastropods, pelecypods etc. The Nari series is followed by the Gaj series of Lower-Miocene age. The lower part of this series, composed mainly of limestones and shales and contains remains of characteristic foraminifers and pelecypods. The upper part of the series is, on the other hand, made up mainly of shales. These shale beds are, at places, gypseous in nature and contain characteristic fossils like Ostrea latimarginata, Ostrea gajensis, pelecypods, etc.

In addition to these, the Gaj series are also contain some echinoids and gastropods. The lower and upper parts of the Gaj series are equivalent respectively to the Aquitanian and Burdigalian stages of and Lower-Miocene of Europe. Oligocene and Lower to middle Miocene rocks are represented, in other parts of Baluchistan, by the Khojak shales, Hinglaj sandstones and the Bugti beds. The topmost horizon of the Tertiary succession is known as the Manchhar series. The conglomerates, sandstones, and clay beds which formed the principal constituents of this series were deposited under a freshwater environment. The lower part of the series is made up of conglomerates and sandstones and contains remains of mammals of the middle to Upper-Miocene age.

The upper part of the series is composed of sandstones, conglomerates and clay beds of Pliocene age. The Manchhar series may be considered equivalent to the Lower and Middle-Siwalik rocks of north-western India. We will discuss the tertiary of the Himalayan arc, that is the Siwalik system. The Himalayan ranges are arranged in the form of an arc. the convex side of which lies towards the Indian subcontinent.

All along the length of the Himalayan arc, the foot hills on the convex side exhibit a perfect development of the tertiary rocks. The width of this belt of tertiary rocks, however, is not uniform all through its length. Towards its western extremity near Jammu, the belt is wide and contains older tertiary rocks of marine origin. In the eastern and central parts of the Himalayan arc, on the other hand, the belt is rather narrow and is composed only of younger tertiary rocks formed under estuarine and freshwater environment. In the Himalayas, tertiary rocks have been studied in the Punjab, Jammu, Kashmir, and Simla Garhwal areas.

In the tertiary formations, only the Siwalik system occur continuously all along the whole length of the Himalayan foothills. The generalized tertiary section in the western part of the Himalayan region has been shown here. You can see the bottom-most is the hill limestone series, then the chharat stage, then the murree series, then coming the Siwalik

system consisting of lower, middle and upper series. Here in this Murree series, you can see the Fatehganj zone, lower and upper stages are there whereas in the Siwalik system, the different stages are Kamlial, Chinji, Nagri, Dhokpathan, Tatrot, Pinjor and Boulder Conglomerates. The Murree series occurs in Jammu and adjacent areas while its equivalents to Simla-Garhwal area known as Dagshai and Kasauli beds.

The Chharat stage and Hill limestone are developed characteristically in the Potwar plateau. In Kashmir, on the other hand, the Chharat stage lies above the Ranikot series. In Simla-Garhwal area, again, the Hill limestone and Chharat stage are both absent and, in lieu, there occur laterites, shales, sandstones and impure limestones, which are together known as the Subathu beds. The Subathu beds are considered equivalent to the Laki series of Sind and Baluchistan, Arkose, grits, sandstones, shales, limestones and conglomerates of Eocene age have also been found to occur in Ladakh and Mount Kailas, in central Himalayas. Tertiary rocks of Eocene age occur towards the western side contains remains of foraminifers. In Jammu and the Punjab, the Tertiary succession commences with the Hill limestone, which is made up mainly of massive nummulitic limestones.

These limestone beds are interstratified with shaly carbonaceous horizons and the upper part of the formation contains Assilina granulos and other foraminifers of Laki age. The Hill limestones range in age from Lower to Middle-Eocene. In Kashmir, cherty nummulitic limestones of Ranikot age constitute the bottommost beds of the Tertiary succession. The Hill limestones of Jammu and the Punjab and the nummulitic limestones of Kashmir are overlain by the Chharat stage of Middle to Upper-Eocene age. The Chharat stage is composed of nummulitic shales, limestones and marls. In Kashmir, however, the bottommost beds of this stage are made up of carbonaceous and pyritous shales and ironstones.

The Murree series, which includes the Fatehjang zone forming its is divided into two parts. The lower part of the series is composed of shales, sandstones and conglomerates, which are said to have been deposited under a brackish environment. These rocks contain only a few remains of pelecypods and some impressions of leaves of plants that is sabal major. The upper of the series is made up principally of soft sandstones which appear to have been deposited in fresh water and are found to contain some remains of mammals and leaf impressions of angiospermous plants. The Murree series is Lower to Middle-Miocene age and its constituent rocks have served, in north-western India, as the reservoirs, which contain deposits of petroleum.

Towards the south-eastern side of Jammu, the Murree series thins out gradually and, in the Simla-Garhwal area, it is altogether absent. The Subathu beds of Eocene age are, therefore, overlain by the Dogshai and Kasauli beds of Lower to Middle-Miocene age. The Dagshai beds, which overlie the Subathus, are composed of quartzitic sandstones and shales of Lower-Miocene age and are said to have been formed under a brackish environment. The overlying Kasauli beds are made up principally of sandstones of Middle-Miocene age, which were deposited under fresh-water and contain leaf-impressions of angiospermous plants and remains of pelecypods. There exists a stratigraphic gap but no discernible unconformity between the Dagshai beds and the underlying Subathu beds. The Dagshai and Kasauli beds of Simla hills are considered equivalent respectively to the lower and upper parts of the Murree series of Jammu and neighbouring areas. The deposition of the Murrees and their equivalents was followed, during the Middle-Miocene, by the principal phase of upheaval of the Himalayas.

As a result, the mountains were uplifted considerably and the convex side of the Himalayan arc was fringed by a narrow and elongated depression, within which the sediments of younger age accumulated and gave rise to the Siwalik system. The Siwalik sediments, derived mainly from the Himalayan mountains, appear to have been deposited under a continuous stretch of shallow water and their enormous thickness is suggestive of their deposition in a slowly sinking basin. The Siwalik system, named after the Siwalik hills, is developed of along the foot-hills of the Himalayan arc. It is mainly composed of sandstones, conglomerates, silts and clays, which were formed under brackish and fresh-water environment. All over their wide areal extent, the Siwalik sediments are more or less uniform in nature.

They are often unsorted and contain alternating layers of coarse and finer materials. All these characteristics indicate that the sediments derived from the more and less uniform parent rocks, were carried down by torrential stream and deposited seasonally in river or lagoon, which occupied a continuous basin along the whole length of the Himalayan foot-hills. From a study of the nature of the Siwalik sediments, it has been inferred that the Kamlial, Chinji and Nagri stages were laid down under a warm and humid climate while the Dhok Pathan period witnessed a relatively dry climatic condition. The Upper-Siwaliks, on the other hand, appear to have been formed under a cold climate. After their deposition and compaction, the Siwalik rocks were affected by the Subsequent phases of upheaval of the Himalayas and, as a result, they have often been subjected to folding faulting and thrusting. An appreciable portion of the Siwalik strata is devoid of fossils.

In several localities, again, these rocks contain a number of remains of reptiles, mammals, fishes and plants. Of all these remains however, the mammalian fossils are of paramount importance not only in dividing the Siwalik system into three subdivisions and seven stages but also in visualising the trends of evolution and migration of some of the animals. The remains of mammals are generally available in the form of isolated pieces of teeth, jaws, skulls and other hard parts. The Murree series of Lower-Miocene age is followed upwards by the Kamlial stage, which constitutes the bottommost horizon of the Siwalik system and is composed mainly of pseudo-conglomerates that is red sandstones with nodules of clay and purple shales. The overlying Chinji stage is made up of greyish sandstones, greyish sandstones and red shales and contain a wealth of fossils.

The chief mammalian fossils of the Chinji stage are Carnivora, Proboscidea, Equidae or horses, Suidae, Giraffidae etc. In addition to these, the Chinjis contain remains of reptiles and pelecypods. The ancient horse, Hipparion, is said to have migrated from North America to India during the Middle-Miocene period. The Kamlial and Chinji stages together form the lower part of the Siwalik system. The Nahan beds of Hardwar and neighborhood may be considered equivalent to these Lower-Siwalik rocks.

The last phase of upheaval of the Himalayas was in operation during the Lower-Pleistocene period and was followed by the deposition of coarse sediments belonging to the Boulder conglomerate, which constitutes the topmost horizon of the Siwalik system. This stage, composed of coarse conglomerates, grits, sandstones and clays, lies unconformably above the older beds and appears to have been deposited under a cold glacial climate. The boulder conglomerates, are unfossiliferous and range in age from Lower to Middle-Pleistocene. They are also known as the Lei conglomerates. The whole of the Upper Siwalik succession, made up of Tatrot, Pinjor and Boulder conglomerate stages.

The deposition of the Boulder conglomerate horizon was followed by a period of diastrophism, as a result of which the Upper-Siwalik beds were gently folded. The close of the Siwalik period was marked by the celebrated Pleistocene glaciation, during which the Himalayan glaciers came down upon the foot-hills and further down to the adjacent plains. Under such extremely cold climate, many of the Siwalik mammals perished and the remaining ones migrated to comparatively warmer regions and thus, survived the cold spell. The whole of the Pleistocene period, however, did not witness as uniformly intense glacial climate. In all five distinct glacial periods have so far been recognised and these are separated from one another by four intervening interglacial periods.

The silt and loess deposits on the Potwar plateau appear to have been formed during the third glacial period. The extensive Karewa formation of Kashmir and adjacent regions is regarded as a group of lacustrine and fluviatile deposits, which were laid down principally during the period of Pleistocene glaciation. The formation is divided into two parts, of which the lower one is composed of conglomerates, carbonaceous shales, lignite, sands, gravels, varved clays, etc., with a few pre-glacial beds lying at the bottom. The upper part is made up of sands, clays, varved clays, and erratic boulders of glacial origin. The Karewas lie upon older formations and have been affected by the last phase of uplift of the Himalayas.

The formation contains mammalian remains like Elephas namadicus, Equus, Sus, Felis, Rhinoceros, Bos, Sivatherium, etc. of Astian to Villafranchian age. Now we will discuss the tertiary of Assam. We have already discussed the tertiary of Sind and Baluchistan and the Himalayan Arc. Now we will see in Assam how the tertiary rocks have developed. In addition to Sind, Baluchistan and the Himalayan arc, Tertiary rocks and well-developed in the north-eastern and south-eastern parts of Assam, where they exhibit a more or less complete geological succession ranging in age from Paleocene to Lower-Pleistocene.

In respect of their lithological characters, the Tertiary rocks of Upper Assam differ appreciably from those of Central Lower Assam. The generalized geological succession of tertiary of Assam has been shown here. You can see at the bottom, the Jaintiya series is there, then the Barail series, then the Surma series, then Tipam series, then Dupitela series, and then the Dihing series. And under it, the different stages are also there, that the Thema stage, Sylhet stage, Kopili stage, Laisong stage, Jenam stage, Renji stage, Bhuban stage, Bokabil stage, Tipam stage, Girujan clays. In Upper or north-eastern Assam, Manipur and the Naga hills, the oldest Teritary rocks are known as the Disang series which is composed of unfossiliferous shales and sandstones.

The Disang series possibly ranges in age from Upper Cretaceous to Upper Eocene. In Central and Lower Assam, on the other hand, the Paleocene and Eocene formations together constitute the Jaintia series, which is made up mainly of sandstones, limestones and shales. The bottommost beds of the Jaintia series, composed of limestones and sandstones, and is known as the Therria stage. Although this stage does not contain any characteristic fossil, the presence of typical foraminifers of Ranikot age, in the overlying limestone beds, is suggestive of its Paleocene age. The Therria stage is followed upwards by limestone beds with intervening horizons made up of sandstones and these together constitute the Sylhet stage. There are, in all, three important limestone horizons in the

Sylhet stage. The lower sandstone horizon contains seams of coal, which are workable in some parts of the Shillong plateau. The three limestone horizons contain characteristic remains of foraminifera and are considered equivalent to the Ranikot, Laki and Kirthar series of Sind-Baluchistan.

The Sylhet stage, thus ranges in age from Lower to Middle-Eocene and is overlain by the Kopili stage, which is composed mainly of alternating horizons of shales and sandstones. The Kopili stage contains remains of foraminifera of Upper-Eocene age. The Disang series of Upper Assam and the Jaintia series of Central and Lower Assam are both overlain by the Barail series, which is made up of sandstones, shales, carbonaceous shales and coal-seams. In Central and Lower Assam, the bottommost stage of this series is composed mainly of sandstones and some shales and is known as the Laisong stage. The rocks of this stage range in age from Auversian to Bartonian. The overlying Jenam stage is made up of shales, carbonaceous shales and sandstones of Lattorfian that is Lower-Oligocene age. The Renji stage, which lies above the Jenam stage, is composed mainly of sandstones and a few shaly horizons. It is said to be of Upper-Oligocene age.

In Upper Assam, on the other hand, the oldest beds of the Barail series are together known as the Naogaon stage. This stage is made up of sandstones and is considered equivalent to the Laisong stage, which is described above. The overlying Baragoloi stage, composed of sandstones, carbonaceous shales and contains workable seams of coal. The Baragoloi stage corresponds roughly to the upper part of the Liasong stage and the lower part of the Jenam stage of Central and Lower Assam and is overlain by the Tikak Parbat stage, which is made up of carbonaceous shales and workable coal-seams. The Tikak Parbat stage of Upper Assam is said to be equivalent to the upper part of the Jenam stage and the lower part of the Renji stage. The coal-seams of the Baragoloi, Makum, Tikak, Nazira and Ledo coal-fields of Upper Assam belong to the Baragoloi and Tikak Parbat stages of the Barail series. In addition to coal, deposits of petroleum are associated with the Barails. The sediments, which gave rise to the Barail series, are said to have been laid down under marine and estuarine environments. The rocks contain only a few fossils, which indicate that the Barails range in age from Upper-Eocene to Upper-Oligocene. The deposition and compaction of the Barail sediments was followed by a period of uplift and erosion and the younger Surma series, therefore, overlies the Barails with a distinct unconformity. Of the two stages of the Surma series, the older Bhuban stage is composed of sandstones, arenaceous shales and conglomerates and contain fragmentary remains of shells.

Some of the important fossils of this stage are Cancellaria, Scutus, Basilissa that is Mollusca etc. The Bhuban stage ranges in age from Upper-Oligocene to Lower-Miocene and a major portion of this stage is of Aquitanian age. The overlying Boka Bil stage, made up of sandstones, arenaceous shales, ferruginous sandstones and silts and is developed mainly in Central and Lower Assam. The rocks of this series contain a number of remains of pelecypods and lower gastropods of Lower-Miocene age. The Bhuban stage of the Surma series is said to contain a few oil-bearing horizons, one of which was worked in the Badarpur oil-field. All over Assam, the Surmas are followed upwards by the Tipam series which has been divided into two stages. The lower stage, known as the Tipam sandstones, is composed of coarse-grained ferruginous sandstones and some intercalated bands of shale, conglomerate and lignite. This horizon in Upper Assam, contains a few oil-bearing horizons. The Tipam sandstones occasionally contain pieces of fossil wood and are estimated to be of Lower-Miocene age. The overlying stage is known as the Girujan clays and is made up mainly of mottled clays with some interstratified beds of sandstone, sandy clay and lignite.

These rocks together contain pieces of fossil wood. The Girujan clays are said to be of Lower-Miocene age. In Central and Lower Assam, the Tipam series is overlain, with a distinct unconformity, by the Dupi Tila stage. This stage is well-developed in the Surma valley and is composed of sandstones and clays, which are devoid of fossils. In Upper Assam, on the other hand, the Tipam series is overlain unconformably by the Namsang stage and is well-developed near Digboi. This stage consists of sandstone grit and conglomerate beds which contain no fossil. Some of the pebbles forming the conglomerate beds appear to have been derived from the sandstone beds and coal seams of Barail series.

The Namsang and the Dupi Tila stages are both said to be of Miocene to Pliocene age. The topmost horizon of the Tartiary succession in Assam is known as the Dihing series, which lies unconformably above the older formations and is composed of pebble-beds with intercalated beds of sandstone and clay. The constituents of these pebble-beds are considered to have been derived mostly from the rocks belonging to the Barail series. The Dihing series is well-developed practically all over the Tertiary belt in Assam. Plant remains, in the form of impressions of leaves and pieces of carbonised wood, occasionally occur within the rocks of this series. The Dihing series has been affected by the last phase of the Himalayan upheaval and is estimated to be of Pliocene to Lower-Pleistocene age. The Tipam and Dihing series are together considered equivalent to the

Siwalik system of north- western Himalayas. Now we will see the important economic mineral deposits of Tertiary group.

The Tertiary rocks in India contain a number of deposits of rocks and minerals of economic importance. The Ranikot and Laki series of Sind-Baluchistan and the Barails of Assam contain several important seams of coal. The Dandot seam of the Punjab Salt Range, the Palana lignite deposit of Bikaner and the coal-seams in some of the coal-fields of Khasi, Garo and Jaintia hills are of Eocene age. The coal-seams in the coal-field of Upper Assam, however, are associated with the Barail series. The lignite deposit of Neyveli and Travancore are of Miocene to Pliocene age. The nummulitic limestones of Eocene age are well-developed in Sind-Baluchistan and in Central and Lower Assam and are very useful in the manufacture of cement. The deposits of petroleum, associated with the Tertiary rocks are, however, of paramount importance. The oil-fields of West-Punjab have their source rocks lying within the geological formations of Eocene age. In Upper Assam and in the Surma valley, deposits of petroleum are associated with the Barail series, the Bhuban stage of the Surma series and the Tipam sandstones. In the Digboi oil-field, the Tipam sandstones constitute the productive horizon while the Nahorkatiya field derives oil from the Barails. This was all about the tertiary. Now we will see the quaternary period.

The quaternary period beginning at about one point five million years ago comprises the Pleistocene that is most recent and the Holocene that is the recent epochs. The Pleistocene Epoch covering the major part of the Quaternary Period forms one of the most interesting epochs of the earth's history. The Homo sapiens evolved to a position of dominance over all other kinds of life during the Pleistocene Epoch. The Pleistocene Epoch is also characterized by a marked fluctuation of climate. Glacial ice covered over one-third of the continents during the glacial ages of the Pleistocene Epoch. Five such glacial ages have been recorded in the Pleistocene succession. They are in order of their succession, Biberian, Danubian, Gunjian, Mindelian, Rissian and Wurmian ages. The glacial ages were interrupted by inter-glacial phases during which many glaciers receded and others disappeared. The deposits belonging to Pleistocene and recent ages cover an enormous extent of the country and are spread over a great part of plains of northern and central India forming the Indo-Gangetic Alluvium.

Pleistocene and recent deposits are also devoloped in many other parts of the country, and those of special importance are Karewas of Kashmir, the Deserts of Rajputana, and the Laterites of Madhya Pradesh and Deccan. Now the quaternary period that is the

Pleistocene system. The first we will discuss about the Indo-gangetic alluvium. The Indo-Gangetic alluvial plains are spread over whole of Uttar Pradesh, greater part of Punjab, and Bihar, Bengal as also over northern part of Rajputana and in Sind. The rocks of the Indo-Gangetic Alluvium are all of fluviatile and subaerial origin and consist of clays, gravels and loose and compact sands. These deposits generally form a continuous as well as uniform sequence still in progress and hence no strict distinction into stages is possible. It is customary, however, to classify them into Newer Alluvium-including the 'Khadar' of the Punjab-and the older Alluvium-comprising the "Bhanger" of the Ganges valley.

The older alluvium what the Vengar covers is Areas of Uttar Pradesh and Bengal where they generally form highlands. The newer alluvium or Khadar is low lying and stands seawardly where it merges into deltas of the Gangas and the Brahmaputra. The delta of Indus is also in the general sense extension of Khadar. The "Khadar"-which consists of calcareous concretions occurring as bands or dispersed nodules in the alluvium-is a characteristic formation of alluvial deposits, especially in those with marked clayey component. Kankar is formed as has been explained somewhere else due to capillary rise of ground water in periods of drought and its evaporation near the surface.The Bhanger deposits have yielded some fossils of elephant and horses from which it is assigned a middle Pleistocene age. The Khadar deposits are much newer and comparatively recent. Next is the Karewas of Kashmir. Here Comparatively older alluvial formations are spread over more than half of the area of Kashmir Valley, extending from Shopian to Baramula. These are composed of silts of different colours, and sands with embedded moraines. They are generally horizontal but show dips varying between five degree to twenty degree where they rest against the slopes of Pir Panjal. The Karewa formations have been divided into a lower and upper group, there being a marked erosional gap between the two stages. These deposits are thought to range from Pliocene to upper Pleistocene in age and have in their record, a clear evidence of the Pleistocene glaciation of the Pir-Panjal Himalayas. Karewas are regarded chiefly as lake deposits. Many fossils of plants and animals of different groups have been discovered from both the divisions.

Next is the desert that is Thar of Rajputana. The Rajputana deserts form an exceptionally wide track six fifty kilometer in length and one sixty kilometer in width of Indian surface covering part of Rajputana. These wind-blown deposits have concealed almost all the other geological formations below them. The surface of the desert is not uniformly smooth. It is frequently raised into longitudinal and transverse dunes, small hillocks,

plateaus, and is pierced by the projection of older rocks at places where the cover is thin. The composite sand grains are uniformly rounded and indicate their windblown nature.

Quartz is most common of the minerals of the sand of these deserts; felspars, hornblende and calcareous grains are other important constituents. Next is the laterite of peninsula. In the peninsular India, laterite deposits are the most important of Pleistocene formations. The deposits consist chiefly of the rock known as laterite, which is hydrated oxide of aluminum and iron in composition and soft and vesicular in texture when fresh. though it becomes quite hard and compact when exposed to air.

The lateritic rocks generally occur as capping the hills and plateaus of Madhya Pradesh and Deccan, at heights ranging from those of coast to two thousand meters with a variable thickness between twenty to sixty meters. Laterite deposits are classified also, that is low-level laterites when they occur at heights lower than six hundred meters, and high-level laterites which include deposits above six hundred meters height. The low-level laterites are actually derived from the erosion of high-level laterites and are generally less massive in character. The high-level laterite is regarded as much older in age, ranging from Pliocene to Pleistocene whereas low-level laterite is younger in age. Now, just summarizing the lecture,

We have first discussed about the introduction Tertiary, Cenozoic group in which we have discussed that the The Tertiary period of the Cenozoic Era marks significant geological events, including the uplift of mountain ranges and the evolution of modern flora and fauna. It is divided into Paleogene and Neogene periods, characterized by marine and continental sedimentary deposits. Secondly, we have discussed about the Tertiary of Sind-Baluchistan where we have discussed The Tertiary formations comprise thick marine sedimentary sequences, including limestone, shale, and sandstone, representing major transgressions and regressions of the Tethys Sea. These deposits are crucial for understanding the region's paleogeography and hydrocarbon potential. Next, we have discussed about the tertiary of the Himalayan Arc. The Tertiary deposits of the Himalayan Arc include molasse sequences formed due to the India-Asia collision, consisting of thick sedimentary successions like the Siwalik Group. These deposits record the orogenic processes and climate changes of the region. Then we have discussed about the tertiary of Assam.

The tertiary formation of Assam mainly consists of coal bearing sequences, deltaic deposits and marine sediments including the Surma and Barail groups. These sequences

play a key role in the petroleum and coal industries of northeast India. Economic mineral deposits of tertiary group include petroleum, natural gas, coal, limestone, and phosphate, which are crucial for industrial applications and energy resources in various parts of the world. Lastly, we have discussed about the Quaternary Period, which is the most recent geological period spanning from about two point five eight million years ago to the present. It is characterized by repeated glaciations, the evolution of modern humans, and significant climate fluctuations.

Thank you very much to all.