ENVIRONMENTAL GEOSCIENCES

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Lecture-6

Week 1 Summary

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We have discussed already the module 1. In module 1, we have discussed about the introduction to the origin of the earth, internal structure of the earth, concepts of atmosphere, hydrosphere, lithosphere and their constituents and plate tectonics. We have seen in the different lectures the topics of the module 1. In this lecture we will discuss about the summary of the module 1.

The important concepts will be covered like overview of the earth and its evolution, the internal structure of the earth, concepts of atmosphere, hydrosphere and lithosphere, basics of plate tectonics and evidences for plate tectonics. So what we have seen, if we will go for the overview of the earth and its evolution, we are seeing that the subject geology, the science of the earth, the discipline itself has a great diversity in purpose and objective. For scientists and engineers, an understanding of geology is a tool utilized in designing and constructing any structure in contact with the earth or that interacts with its natural materials. In recent years, how geologists and other scientists view and study the Earth has dramatically changed. Like other sciences, geology used to be a separate and distinct field of study with minimal interactions with the subject chemistry, physics and biology except where necessary to address a particular problem.

The crux of the revolution in geological thinking is considering the earth as a dynamic system, one that is constantly changing and one in which components or subsystems interact to produce the changes that we can observe or changes that occurred in the past. The relationships between the land and the sea and the atmosphere are unavoidable. In practice, however, it is necessary to examine individual components of the system in detail without losing sight of the fact that all components interact with all other components. One way to subdivide the system is to think of the Earth system as composed of four important components or spheres, that is, the lithosphere, atmosphere, hydrosphere, and biosphere. These systems overlap in more ways than we can probably even conceive.

As biological organisms, we live in the biosphere, but our life is dependent upon all the other components as well. Now we have already discussed the earth, a part of the solar system. We have seen that the earth is a good example of an open system, one that receives matter and energy from its surroundings. As we all know, the Earth does not exist alone in space, but is itself part of a larger system, that is the solar system. It is difficult to understand the Earth as it is today without knowing how it evolved throughout its history.

In the diagram you can see the four different components or spheres, the lithosphere, atmosphere, hydrosphere and biosphere, all are overlapping among each other. You can see the top one is the atmosphere then the hydrosphere and this is the lithosphere and in it we are also seeing the ecosphere or biosphere so here we are seeing that in hydrosphere this is one of the important component of our earth system. Lithosphere is the same way important for our earth system. Biosphere giving plants and animals or even we are also surviving in this biosphere this system and atmosphere is lying just above the earth surface. So these four spheres are very very important for the sustaining of life on the earth system now the one of the important system is there that is the solar system. We have seen that the planet on which we live, that is the Earth, is only one of the nine planetary bodies that revolve around the Sun in the solar system. To put Earth in its proper perspective, we should briefly examine the characteristics of our planetary neighbours as well.

One of the most basic observations is that there are two groups of planets, four smaller planets orbiting close to the sun and four larger planets occupying the outer reaches of the solar system. The ninth planet Pluto is somewhat an exception to this grouping. The inner or terrestrial planets are dense bodies mainly composed of iron and silicate rocks. The four giant planets are much lighter in density because of their gaseous compositions. Although many ideas have been proposed to explain the origin of the solar system, this question is still a matter of debate.

In the most commonly accepted current hypothesis, the history of the solar system begins about 4.6 billion years ago with a large diffuse mass of gas and dust slowly rotating in space is a solar nebula. The matter in the solar nebula was just a tiny part of primordial system produced in huge explosion, the Big Bang, which is thought to have occurred about 15 billion years ago. About 10 billion years after the Big Bang, our solar nebula begins to contract due to gravitational forces and to increase its rotational velocity. At some point, a concentration of matter formed at the center of the nebula. Compression of matter raised its temperature to the point at which nuclear fusion was initiated.

The heavier elements in the solar system were inherited from earlier star formation and destruction cycles between the Big Bang and the solar system formation. The destruction of stars is accompanied by a giant explosion known as supernova which provides enough energy for the formation of heavy elements. As the planets began to develop through the repeated accretion of smaller bodies that crashed into them and added to their mass, their initial position in the nebula controlled their final composition for the Sun. Because the temperature was highest in the vicinity of the Sun and decreased with distance away from the Sun, the terrestrial planets were formed of material with relatively high boiling points. The Mercury, Venus, Earth and Mars are dense bodies of iron and silicate rocks.

Four elements i.e. iron, oxygen, silicon and magnesium make up about 90% of these planets. Jupiter, Saturn, Uranus and Neptune retain their volatiles because of their greater gravitational attraction and they are more similar in composition to the original solar nebula. Volatile elements were carried away from the inner part of the nebula by matter streaming from the Sun and perhaps by the inadequate gravitational pull of the terrestrial planets before they attained their total masses. Volatile gases like water, methane and ammonia were driven to the cooler regions of the giant planets. Jupiter, Saturn, Uranus and Neptune retained their volatiles because of their greater gravitational attraction and they are more similar in composition to the original solar nebula.

Now the differentiation of the earth. After the initial condensation of the Earth, its internal structure was very much different than at present. It probably consisted of homogeneous accumulation of rock material. At this point, the heating of the Earth must have taken place. The impacts from smaller bodies of accreting matter in the solar nebula, that is the planetesimals, were major contributors to the rise in temperature.

Their kinetic energy was transformed into heat upon collision with the growing planet. Compression of the newly condensed matter and energy released by the decay of radioactive elements disseminated throughout the Earth also helped in raising the temperature. Many scientists believe that during the first 500 million years of the Earth's accretion from smaller body, a giant impact might have taken place. The impacting body may have been so large that it tilted the Earth's axis to its current angle of 23° and brought the temperature of the young planet to or near the melting point. The consequence of the temperature rise was that the melting point of iron and nickel was exceeded.

These dense molten elements formed invisible globules in the magma ocean that existed at the Earth's surface and began to migrate toward the center of the earth. In the diagram also you can see the magma ocean is lying at the periphery and the mantle just inside and within it the core remains. Crust is at the top. So here sinking of molten iron and nickel toward the center of the earth to form its core. During early melting or partial melting of the Earth, due to the impacts of planetesimals from space, iron and nickel segregated into dense, immiscible globules which sank to form the core at the center of the Earth.

Planetesimals may have already been differentiated by radioactive heating prior to impact. We have discussed this thing while we were discussing about the structure of the Earth. A molten iron core began to develop at the Earth's center. This process released gravitational energy in the form of heating, leading to more melting and partial melting. The result was a density-stratified planet.

The dense core was overlain by a mantle composed of iron and magnesium silicate rocks. The lightest materials accumulated in a very thin layer near the surface to form the crust. The age of a rock sample can be determined by the abundance of certain radioactive elements. Although the oldest rock on the earth are about 4 billion years old, the planet itself is considered to be about 4.6 billion years old. So we have discussed these things while discussing about the internal structure of the earth, the crust, then mental and the core, inner core and outer core.

These things we have already discussed when we were discussing about the topic. Now, the internal structure of the Earth. Here we can see the differentiation of the Earth produced a planet stratified by density and temperature with a partially molten core of iron-nickel alloy, a cooler mantle composed of silicate rocks and a rigid crust made up of least dense rock materials. The planet began to function as a giant heat engine, a mode of operation that continues to the present day. The Mohorovicic discontinuity, or the Moho, has been recognized since the early 20th century.

The Moho ranges in thickness between 5 and 10 km beneath the ocean floor to about 40 km beneath the continents. The sharply increasing velocity of seismic waves at this interface probably represents a change in rock type to denser silicate rocks in the mantle below. In the 1960s and 1970s, a new view of the Earth's internal structure emerged. This view allowed geologists to integrate data and observations from many diverse fields into the unifying theory of the Earth's behavior called plate tectonics. The new model considers the Earth's molten outer core is a very active zone of circulation.

Movement is generated in the liquid outer core by convection. Here in the diagram also we can see the internal structure of the earth showing location of the lithosphere and asthenosphere, formation and movement of rising mantle plumes, descending cold slabs and several types of boundaries of lithospheric plates. Then we have discussed about the concepts of atmosphere, hydrosphere and lithosphere. So the concept of atmosphere and their constituents we will discuss. A mixture of gases, solids and liquids surrounding the earth extending several hundred kilometers is termed as an atmosphere. Its composition we have seen that the major constituents were nitrogen and oxygen. Nitrogen near about 28.09%, oxygen 20.97%.

Minor constituents were carbon dioxide and inert gases. Water vapor varies across region concentrated in the troposphere. Atmospheric layers of the atmosphere are troposphere, stratosphere, mesosphere, thermosphere and exosphere. Importance of this sphere is it supports life, regulates climate and protects against the solar radiation. So now the layers of atmosphere.

The layers of atmosphere we have already discussed in the lecture. Here we will just summarize the important points. We have seen that the atmosphere consists of five different important layers. That is troposphere, stratosphere, mesosphere, thermosphere and exosphere. Now for troposphere the altitude is up to 12 km.

It is the thickest at the equator. Feature, important features of this layer is that it is very important for weather formation. In this layer the temperature decreases with altitude that is -1°C per 165 meter height. Second important sphere is the stratosphere. Here the altitude remains up to 12 to 50 kilometer.

So from 12 to 50 kilometer is the stratosphere. Important features of this layer is that this layer consists of ozone layer and this ozone layer absorbs the ultraviolet radiation. In this layer stable air condition remains and here the temperature increases in the upper part of the sphere. Next is the mesosphere from 50 to 80 kilometer altitude it is the mesosphere. And here, this is the coldest layer of the atmosphere, that is minus 60°C to -90°C. And in this layer, generally, the meteors burn up here. Next layer is the thermosphere.

Altitude is about 80 to 690 kilometer. It is the hottest layer. This thermosphere is the hottest layer. Temperature is 500°C to 1500°C. This is a very highly ionized layer of atmosphere and this layer supports the GPS and radio signals.

Next is the exosphere. Beyond 690 km in the atmosphere is termed as exosphere. So this layer is having sparse particles like hydrogen and helium and this layer merges into the space. So these are the layers of the atmosphere. In the atmosphere, we have seen the different boundaries also.

We have seen the first boundary is the tropopause, which is coming in between troposphere and stratosphere. And this boundary marks a constant temperature zone that is minus 55°C. Next boundary is the stratopause. Stratopause is the boundary between stratosphere and mesosphere. And the height is near about 50 to 55 km.

Here the temperature peaks around 0°C to -10°C. Mesopause is the next boundary between mesosphere and thermosphere, near about at the altitude of 80 to 85 km. And this is the coldest atmospheric region in the atmosphere, that is minus 90°C temperature. And next boundary is the ionosphere which is part of the thermosphere. Here the electrically charged particles aid communication that is radio and GPS. So these are the boundaries and its features. Next sphere is the hydrosphere. Hydrosphere is a continuous layer of salt and fresh water on the earth including oceans, seas, lakes, rivers, groundwater, ice and water vapour.

Now the coverage of hydrosphere. We have already seen that oceans cover near about 71% of the earth's surface with an average depth of 3800 m. And in water distribution manner we have seen that oceans contains 97% of the earth's water whereas fresh water i.e. river, lakes, groundwater, glaciers etc. remains only 3%. The function of the hydrosphere is that it helps in regulating the climate and maintains the hydrological cycle. It also supports the marine and terrestrial life and it is essential for nutrient cycling and transportation. Next sphere is the lithosphere.

The solid outer layer of the earth including crust and upper mantle. Composition of lithosphere, Rock types, igneous rocks generally form the 95% of the lithosphere, shale, sandstone, limestone and metamorphic rocks made up of the rest of the part. Elemental composition wise, we have seen that it is dominated by oxygen, nearly 50%, followed by silicon, aluminium and magnesium. Mineral composition wise, we have seen that the Plagioclase feldspar is the most prevalent; apatite is the least abundant. Function of the lithosphere, it supports ecosystems, agriculture and human settlements.

It provides nutrients for plants and it is a rich source of mineral. Facilitate plate tectonics shaping the earth's surface. Now we have also discussed about the plate tectonics. So here we will just see what we have discussed in the earlier chapters. We have seen that one of the greatest accomplishments in geology during the past few decades has been formulating a new theory and that theory is called as plate tectonic theory.

This theory revolutionized the science of geology because it provided a comprehensive model that linked with the internal behavior of the earth to its surface features. With plate tectonics, the distribution of earthquakes and volcanoes makes perfect sense. Plate tectonics integrated and replaced the earlier theories of the continental drift and sea flow spreading, incorporating heat flow, gravity and magnetism into the new paradigm. According to the plate tectonics model, the uppermost part of the earth is divided into the upper rigid lithosphere, which includes the older divisions of the crust and upper mantle. And the underlying warm plastic layer that is asthenosphere.

The lithosphere is broken into about 12 major plates which slowly move laterally over the earth's surface. Plates are rigid slabs of lithosphere that moves as a unit. Here in this figure you can see the different plates are here. The Eurasian plate, the African plate, the Indo-Australian plate, the Philippine plate, the North American plate, South American plate, Caribbean plate. So in this way we are seeing that on the earth we are having so many plates and the major plates of the lithosphere is very well shown in the figure.

For the most part of the active geological processes are concentrated at the plate boundaries. Movement of the lithospheric plates is driven by the convective flow of material in the asthenosphere. Rock in the asthenosphere is soft and plastic because it is near to its melting point. Upwelling plumes of hot metal material impact the base of the lithosphere and spread laterally outward, cracking apart or rifting the lithosphere in the processes. Volcanoes erupt to form new lithosphere in the cracks that form as the plates split apart.

The plates move until they reach a zone of downward flow in the asthenosphere. Here the lithosphere plates are carried down or subducted into the asthenosphere and may become partially melted. Here you can see in this diagram that drifting is caused by rising plumes in the asthenosphere, subduction of lithospheric plates at the other end of the plate. Here you can see the subduction is going on in the asthenosphere. Now the evidence of plate tectonics.

The first evidence is of continental drift. One of the earliest precursors to the plate tectonics theory was put forth in 1912 by Alfred Wegener, a German meteorologist who proposed that the continents had moved great distances laterally across the Earth's surface through geological time. The shapes of the coastlines of Africa and South America which would fit together like the pieces in a jigsaw puzzle if the continents were closer, were one of the main lines of evidence for this idea. Wegener's theories, which became known as continental drift, proposed that all the continents were once assembled into a huge continental mass, and it is called as Pangea, and that they then drifted apart to their present positions. So this is about the continental drift.

Wegener summarized geologic evidence suggesting that the continents were once joined together. This evidence included several types. First is the mountain belts, structural trends, and rock types found on different continents would be continuous if the continents were assembled as in Pangaea. Second, the distribution of numerous fossil species formed on several continents could be explained if the continents had been originally joined. Third, rock types that form under specific climatic conditions were encountered in regions whose present climate is very different.

For example, rocks containing coal and tropical plants were discovered in the polar regions. Wegener's hypothesis was largely discounted by scientists of the day because of the implausible mechanism to which he attributed the drift of the continents. Wegener suggested that the granitic rock of the continents had moved laterally through the stronger, denser mantle rock. Then, second evidence is the theory of seafloor spreading. The most dramatic evidence about the origin of the ocean basins was obtained from the paleomagnetic studies of the ocean crust.

The symmetrical bands of alternately magnetized volcanic crustal rock provided important evidence for the sea floor spreading theory, which proposed that the new crustal material was formed by the volcanic eruptions at the crest of the mid-oceanic ridges. And that slow lateral movement of the crust away from the ridges was occurring. Other geophysical evidence suggested that the layer in motion consisted of crust and upper mantle which was subsequently named the lithosphere. This rigid slab could move laterally above a hot plastic layer and it is called as the asthenosphere. Plates and plates margins.

Plates can be considered slabs of lithospheric material that generally have interiors with boundaries marked by highly active geological processes including earthquakes and volcanism. The new lithosphere is being formed at divergent plate boundaries including the mid-oceanic ridges and the lithosphere is being destroyed or deformed at the convergent plate boundaries where plates collide. A third major type of boundary that is transform faults marks locations where plates are sliding laterally in opposite directions. Different geological processes characterize each type of plate margin. So different geological plates characterize with the different plate boundaries also.

First one is the divergent plate boundaries. Divergent plate margins occur where rising convection currents in the asthenosphere nearly reach the Earth's surface. The rising mantle material causes extremely high heat flow which causes lithosphere to bulge upward. Second type of plate boundary is the convergent plate boundaries. Convergent plate boundaries mark the zone of contact or collision where plates move toward each other.

One of the plates consisting of oceanic lithosphere will be forced downward below the overriding plate. A process is known as subduction. If both the plates are composed of oceanic lithosphere, the margin is known as an oceanic convergent margin. Alternatively, one plate may be composed of continental lithosphere. The margin is then known as continental convergent margin.

Both types have a descending lithospheric slab with a trench near the point of contact between the two plates. And the trenches are linear troughs in the ocean floor that run along the plate boundary. They are the sites of greatest ocean water depths. Next type of boundary is the transform boundaries. The third major type of plate boundary is the shear or transform boundary.

Lithospheric plates are sliding past each other along vertical fractures known as transform faults at these boundaries. Transform faults can connect sediments of spreading ridges, spreading ridges with subduction zones or segments of subduction zones. The transform fault with the relative movement of the two plates ends at the spreading ridge even though fracture zones continue along the trend of the transform fault beyond the ridge segments on both the sides. And transform faults are present in both oceanic and continental lithosphere. Thank you very much to all.