# ENVIRONMENTAL GEOSCIENCES

**Prof. Prasoon Kumar Singh**

**Department of Environmental Science and Engineering**

**Indian Institute of Technology (Indian School of Mines), Dhanbad**

## Lecture-5

## Concept of Plate Tectonics

Welcome to the Swayam NPTEL course on Environmental Geosciences. We are discussing the model 1. In the model 1, we have already discussed origin of the earth in lecture 1. Internal structure of the earth in lecture 2, concepts of atmosphere in lecture 3, and the hydrosphere, lithosphere and their constituents in lecture 4. It is lecture 5 related to the concept of plate tectonics.

In this lecture, we will learn about the different concepts related to the plate tectonics. So we are very much familiar, if you will see the figure, the words are very familiar related to our previous lectures, the oceanic crust, continental crust, lithospheric mantle, asthenosphere, mantle wedge, etc. We have seen, if you will just recall the previous lectures, we have seen the earth is having, earth's internal structure is having three important layers, that is the crust, the mantle and the core. So this crust is again having some divisions but the crust plus upper mantle, this is the mantle part, just mantle part is there. In this mantle part, this is the upper mantle and this upper mantle totally forms your lithosphere.

This totally forms the lithosphere. So this part is having heterogeneous type of rocks, means all the three types of rocks, they are very solid also. And just below the lithosphere, this portion, if you recall the previous lecture, this is nothing but this is the asthenosphere. This is first part. Second part, we have seen that crust in the continents remains thicker whereas in the ocean remains thinner.

The figure also tells you this is thicker and this is thinner. So this crust and upper mantle generally form the lithosphere and lithosphere are nothing but these are the types, different types of rocks, constituted by different type of rocks. They are hard. Since they are hard, they can able to move in this viscous part, that is the asthenosphere, which is viscous part. And as the rocks will move, definitely some movement will take place.

So this movement is generally discussed within the subject plate tectonics. The plate tectonics generally gives us the idea about the movement of the different types of plates and also the events of the earthquakes, volcanism, mountain building etc. on the earth's surface. So we will just, we will discuss the different type of major tectonic plates we are getting within the earth's surface. You can see we are having different types of plates also, Brazilian plates, then North American plates, then Caribbean plates. So, so many plates, African plates, Nazka plate, Cocos plate, so many plates are there.

You can see here, this is the Indian plates also here, Indo-Australian plate, then Pacific plate. So, so many plates are there, if you have the Juan De Fuka plate. So, so many major and minor tectonic plates are remaining within the earth's surface. And these plates movement generally take place through their boundaries. Their boundaries are remaining.

So through their boundaries, they are generally taking their movement also. They are moving in certain directions. So this figure also gives the direction also. Through the arrow, you can see very clearly the different plates are moving through their plate boundaries. And this is the plate boundaries.

If you will see this, this is the plate boundary. This portion is the plate boundaries. And generally this arrow shows the direction of the plate motion. So different types of this is very good figure in which you can able to know about the different types of plates, the direction of the plate motion and the different types of your movement also, conversion movement or diversion movement. So this we will discuss in later on.

So before going to the details about this, let us understand what is geosphere. So geosphere includes the rocks and minerals on the earth from the molten rock and heavy metals in the deep interior of the planet to the sand and beaches and peaks of mountains near to the earth's surface. So the geosphere includes the abiotic, non-living parts of soils and the skeletons of the animals that may become fossilized over geological period of time so this geosphere plays very very important role and it includes the different different types of rocks and minerals within the earth's surface. Now, understanding the plate tectonics. The term tectonics generally refers to the large-scale geological processes which deform the Earth's lithosphere, producing different types of landforms such as oceanic basins, continents, and mountains.

So we are getting different types of ocean basins, continents and mountains at different places because of the tectonic movement. Because this is a large-scale geological process, long-time geological process, but ultimately this tectonic movement is deforming the

lithosphere and ultimately changing the landforms on the Earth's surface, that is in terms of ocean basins, continents and mountains. Tectonic processes are driven by forces within the Earth. Whatever tectonic processes are taking place, these processes are driven by different types of forces which are generally occurring within the Earth's surface. These processes are part of the tectonic system, which is an important subsystem of the Earth's system.

So, if you wish to know about the plate tectonics, the lithosphere is broken into large pieces called lithospheric plates that move relative to one another. Processes associated with the creation, movement and destruction of these plates are collectively known as plate tectonics. So these are the processes through which the different types of destruction of the plates are taking place. Plate tectonics is a unifying theory. Why? Because as rocks are heated deep in the earth, they become less dense and rise.

Hot materials, including magma, magma is the hot materials within the interior of the earth that is near to the core, we are getting magma, which ultimately remaining in the very high temperature leak out generally through certain weaker planes and are added to the surface of plates at spreading centers. As the rocks move laterally, they cool. eventually becoming dense enough to sink back into the mantle at subduction zones. So subduction zone is a very very important zone where generally the rocks are moving laterally and cooling and eventually it is becoming dense so much dense that it can sink back into the mantle so this zone is generally termed as subduction zones and this type of circulation is known as convection type so convection type of circulation is taking place Now see the plate movements different types of plate movement there are generally three types of plate movement subduction, obduction and collision.

Here, in the case of subduction, generally when an oceanic plates, whenever I am discussing about the oceanic plate or continental plate, definitely it is related to the oceanic lithosphere and continental lithosphere. So when an oceanic plate sinks beneath a continental plate, you can see here, it is just, just oceanic plate is just sinking to the continental plate. Two oceanic plates sink beneath each other at a convergent plate boundary then such type of processes is known as subduction process so when an oceanic plate definitely the oceanic plate will be thinner plate this is thin thin and this is thick so when an oceanic plate sinks beneath a continental plate or two oceanic plates sink beneath each other. Then this type of sinking is coming under the subduction type of movement and it generally takes place at convergent plate boundary. So the boundary is required for their sinking.

So whenever any oceanic plate is sinking beneath a continental plate or any oceanic plate or two oceanic plates sinking beneath each other, then it will sink definitely at some plate boundary which is known as the convergent plate boundary. So such type of movement of the oceanic plates is termed as subduction. Subduction process recycles the lithosphere or earth crust and upper mantle and back into the mantle. Subduction zones are marked by oceanic trenches and the descending plate melts to create pressure in the mantle which can lead to volcanoes. What volcanoes we are getting on the Earth's surface.

So because of the subduction process, because of the subduction type of movements of plate. Now, obduction, when a continental plate is pushed beneath an oceanic plate, which is unusual because the plate's density favors subduction. You can see here continental plate has just post beneath the oceanic plate. So this is unusual type of movement but it takes place.

So this type of movement is termed as obduction. The oceanic plate buckles and a new mid-ocean ridge forms, turning the obduction into the subduction. And when the two different types of plates, you can see here the two plates, neither subduction nor obduction, the oceanic plates and the continental plates or two oceanic plates or two continental plates, whenever collide and push towards To form large mountain, you can see heaps are generated, large mountain ranges, then these type of collision or movement are known as collision and this type is known as the orogenic belts. These belts are known as the orogenic belts.

So, orogenic belts are developing because of the collision type of plate movement whereas subduction zones are denoted by the subduction type of your plate movement. So, generally three types of plate movements are there, subduction, obduction and collision. Now, discussing about the plate boundaries. So what we have seen the movement take place within the or among the different types of plates. So these movements generally take place at certain boundaries and these boundaries are termed as the plate boundaries.

So generally the locations of earthquake and volcanoes are defining the plate boundaries. A lithospheric plate may include both a continent and a part of an ocean basin or an ocean region alone. It means that lithospheric plate may constitute by a continental plate, by an oceanic plate or by the combination of continental and oceanic plate. So some plates are very large and some are very small, though they are significant on a regional scale. For example, the Juan de Fuca Plate of the Pacific Northwest Coast of the United

States, which figure I have given in the previous slides, you can see there also, which is relatively small and is responsible for many of the earthquakes in Northern California.

So, these plate boundaries are responsible for the locations of earthquakes and volcanoes on the Earth's surface. Now, the different types of plate boundaries. So, what we have understood already, first the lithosphere, lithosphere nothing but it is the upper part of mantle as well as the total crust and these lithosphere generally constituting the lithospheric plates. These are nothing but these are the rocks only and these plates are having certain movement. Generally, three types of movement we have seen, collision, subduction, obduction.

But all these three types of movement will take place from a certain area, which is known as plate boundaries. So, these type plate boundaries are responsible for bringing different, different plates or giving us your earthquakes and volcanoes on the Earth's surface. So, now I will discuss about the types of plate boundaries. Principally or importantly there are three important types that is Divergent, Convergent and Transform. So these boundaries These boundaries are not narrow cracks as shown on maps and diagrams but are zones that range from a few to hundreds of kilometers across.

It is not a smaller area, it is ranging from few to hundreds of kilometers distance. So plate boundary zones are narrower in ocean crust, oceanic crust you will get narrower plate boundary zones and the broader in the continental crust. So this is about the types of the plate boundaries. Now one by one we will discuss the divergent plate boundaries. Divergent plate boundaries occur where the new lithosphere is being produced and neighboring parts of plates are moving away from each other.

So two different parts of the plates are just moving away from each other. Typically this process occur at mid ocean ridges and the process is called as sea floor spreading. So this is very very important terms in geology, mid oceanic ridges and this process just the movement of the plates is known as the sea floor spreading. Mid-oceanic ridges form when hot material from the mantle rises up to form a broad ridge typically with a central rift valley. Molten volcanic rock that is erupted along this rift valley cools and forms new plate material.

So new plate are also gradually forming because of this type of geological processes. So continents can be rifted apart to and in fact most ocean basins are believed to have originated through continental rifting you can see in the figure also just from the middle it is just you can see here rift valley is there this is the rift valley and the continental crust

and moving separately in two different directions as the continental rifting begins Crust is stretched, thinned and fractured. Crust is stretched here, become thin and then fractured. Once it will fracture, what is happening?

Eventually the continental pieces are fully separated and oceanic crust is formed between them. So here you can see this part has broken, so oceanic crust is forming here. Now, the ocean basin widens as divergence continues and gradually it widens. So, this is the rift valley. We have seen in this diagram also.

Here you can see rift valley is here and then the oceanic crust is just forming between the two continental pieces and then gradually the ocean basins widens as the divergence continues. So, this is about the divergent plate boundaries. Now convergent plate boundaries. Convergent boundaries occur where plates generally collide. So if one of the converging plates is oceanic and other is continental, an oceanic continental plate collision takes place.

So the higher density oceanic plate subducts into the mantle. beneath the leading edge of the continental plate and producing a subduction zone when an oceanic continental plate collision take place what is happening compression is exerted on the lithosphere resulting in shortening of the surface of the earth like pushing a table cloth to produce folds so folds are nothing but these are just the your crumbles okay so this process of deformation produces major mountain chains and volcanoes such as Andes in South Africa and the Cascade Mountains in the Pacific Northwest of the United States. So, this is about the facts of the convergent boundaries, split boundaries. Now, transform boundaries, this is the third type.

Transform boundaries or transform force Also, we can say occur where the edges of two plates slide past one another, just sliding to one another. The most common locations for transformed plate boundaries are within the oceanic crust. Some occur also within the continent. So, such type of boundaries are generally called as transformed boundaries. This is a picture which is showing a well-known continental transform boundary near to the San Andreas Fault in California.

Here it is a very good example of the transform boundary. You can see in the figure also a well-known continental transform boundary located near to the San Andreas Fault in California, where the rim of the Pacific plate is sliding urgently past the rim of the North American plate. So this is a very good figure through which we can understand about the subduction zone, the spreading center, the types of the plate motion and the transform

fault occurring near to the San Andreas fault and the Pacific fault. So this is about the transform boundary. Now this map is also showing the locations of the earthquake and volcanoes.

So the dotted one is the locations of the earthquakes whereas the red triangle, small triangle is showing about the locations of the volcanoes. So this all earthquakes and volcanoes locations generally falls near to any plate boundary. So the boundaries between the lithospheric plates are geologically active areas. Most earthquakes and many volcanoes are associated with these boundaries. Plate boundaries are defined by the areas in which concentrated seismic activity takes place.

Over geologic time, plates are formed and destroyed, cycling materials from the interior of the earth to the surface and back again at these boundaries. The continuous recycling of tectonic processes is collectively called the tectonic cycle. Now, what's the importance of plate tectonics? Generally, the theory of plate tectonics is useful in explaining the phenomenon like continental drift, the mountain building where two continental plates collide with each other. Island arcs, where an oceanic plate undergoes subduction beneath a continental plate.

Oceanic trenches, ocean floor spreading, mid-oceanic ridges, where plates diverge. So this is about the importance of the plate tectonics. So we can conclude this module 1 that earth formation and structure the earth originated around 4.5 billion years ago from a rotating cloud of gas and dust and over time it developed a layered structure with core, mantle and crust. So these layers each with distinct properties govern the plant's geodynamics and contribute to its internal heat and magnetic field. Interconnected spheres, the Earth's atmosphere, hydrosphere, and lithosphere are fundamental components that interact to sustain life and regulate Earth's environment.

The atmosphere provides gases essential for life, the hydrosphere supports climate and water cycle, and the lithosphere forms the land and ocean flows driving geological processes. Plate tectonics and geological processes. The theory of plate tectonics explains the movement of the Earth's lithospheric plates driving earthquakes, volcanic activity and mountain formation. These dynamic processes shape Earth's surface and contribute to the ongoing evolution of the planet. Understanding the plate tectonics is a key to understanding many geological phenomena and their impact on the environment.

So this is very much required in the beginning of the subject Environmental Geosciences which we have discussed from lecture 1 to lecture 5. Environmental implications, it refers

to the effects, consequences or impacts that human actions, natural processes or changes in the environment and the planet's ecosystem, resources and overall health. Climate change, human activities affecting the atmosphere contribute to the global warming natural disaster plate tectonics result in earthquake volcanoes and tsunamis causing widespread damage water ability changes in the hydrosphere effect water supply and distribution leading to droughts of flooding. Soil degradation, Lithospheric changes can lead to erosion and the destruction of the fertile soil. And biodiversity loss, atmospheric and hydrospheric changes disrupts the ecosystem leading to habitat loss and species destruction.

So this is about the references. Different references I have taken for making the lectures of module 1 from 1 to 5. Thank you very much to all.