Plate Tectonics
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Week - 01
Lecture - 02
Interior of Earth- II

Ok friends, in the last class we are talking about this interior of the earth. and I was emphasizing on the crust. Why crust is important? Because in the lithosphere the crustal contribution is much much more as compared to this mantle contribution. Because if you remember our earlier class I was talking about the whole crust is involved and the part of the upper mantle is involved. So, that means, during plate interaction the crust and this crust the two different plates if you are interacting the crust is totally taking part in this interaction and the lower part of this lithosphere that is the mantle that is interacting. That's why the crustal compositional stratigraphy, crustal behavior, crustal rigidity, crustal composition that must has to be understand very clearly.

So, some facts about the crust only the upper part of the crust is available for the direct sampling either directly or by boreholes. Then geologic studies of the high-grade metamorphic rock that once upon a residing in the 20 to 50 kilometer depth that have been brought to the surface by subsequent tectonic activity provide the much useful information. For example, if you see in this figure we have a thrust which is coming from this depth and now it is overlapping on this part of this crustal system so, if you see here due to erosion this part it is removed so that means, now you see once upon a time which rock was at the depth now it is on the surface. So, this is the beauty of plate tectonics.

So, due to this crustal deformation, due to thrusting, due to folding the deeper rocks they come to the surface and the high grade metamorphic rock which was once upon a time it was in a high temperature and pressure regime now they are coming to the surface due to the plate tectonics and giving us the information about the deeper crustal composition. At the greater depth all the evidence about the crust are indirectly collected. Indirectly, if you see the most significant or the most widely used indirect study of the deeper crust or the deeper earth is the seismic source, the seismic velocities so, the seismic waves they are moving down and interacting with different crustal rock layers and they are coming as a reflected and refracted waves and we are studying here this reflected and refracted wave and we are getting the information what is happening inside. So, another one is the well logging. We have wells about 12 to 14 kilometer

depth.

So, we insert the instrument and these different properties that we record on the surface. So, based on these properties we interpret what rock type is inside as well as we have rock chips that is collecting from this a deeper part due to drilling. So, that can give us information. Then for shallow subsurface information this is the most significant or the most widely used most popular that is the GPR- Ground Penetrating Radar that is very efficiently been used nowadays for the shallow subsurface information. Apart from that we have the magnetic data, we have the gravity data.

So, if you see here, the magnetic, this is a fault and this how this magnetic anomaly is coming across the fault. Similarly, here we have a fault and this magnetic survey by air survey by magnetic and what this magnetic value we are getting just over this fault that is represented here and another is the gravity data. So, gravity data that means it takes the help of the density contrast of this earth material. So, here if you have a sedimentary basin we are getting negative gravity data as compared to the surrounding. So, that means I want to say these are the indirect evidence how we can study the subsurface geology and subsurface structures.

Much of our information are derived from the knowledge of variation with seismic velocities with depth and compared to it to the experiments conducted in similar pressure and temperature condition in the crustal conditions. So, that means we have this seismic data and we are doing experiment at the laboratory with similar pressure-temperature condition and we are observing what are the change in rock types with change temperature and pressure. Seismic velocity interact with the depth because it increases with pressure, density and rigidity because if you going down. So, the pressure increases and density increases and rigidity of the rock increases. Abrupt change in seismic velocity is caused by change in chemical composition.

However, gradational change is due to the phase change. For example, if you see here we are going depth. So, in the depth scale you see the pressure is increasing. Similarly this temperature also increasing. The wave velocity is increasing, but if you see for example, this P wave velocity there is a drastic change at the boundary, There is a drastic change at the boundary, there is a drastic change at the boundary, but there is a gradational change from this within that layer.

So, if it is the lower mantle if you see here there is a gradational change within that layer. This gradational change it is due to change in the phase. The phase means mineral

composition, but this drastic change composition. And pressure increases with depth about 30 mega Pascal per kilometer due to lithospheric rock burden and some places added by tectonic forces. For example, go to this Indian and Eurasian plate boundary.

Here thrust loading up to 100s of kilometer so that means, pressure will be more. And temperature it increases around 25 degree Celsius per kilometer. So, this is called normal geothermal gradient. And this normal geothermal gradient it is 25 degree Celsius per kilometer it is not same throughout the globe. So, in the ocean basin it is different, in the continent it is different, at the mid-oceanic ridge it is different, at the collisional zone it will be different, at the volcanic island it will be different.

So, though in an average this 25 degree Celsius geothermal gradient is there, but it is varies with the geological environment. So, the crust must be understood in detail because the layer we live in all our day to day activities that is on the crust only and agricultural activities that is in the crust only. Rocks are exposed for this crustal evolution. You see whatever the crustal evolution study that say in Precambrian time the crustal composition was that in the Proterozoic this crustal composition was that with a cretaceous the crustal composition is that how do we study it is the crustal evolution study it is based on the exposure of rock on the crust only. We cannot go into the mantle to study this evolution.

So, this crustal rocks at a different level they are derived by tectonic forces and they are exposed due to weathering and erosion nowadays on the surface of this earth so, this crustal evolution the temperature, pressure, the composition that are being studied by this crustal rocks. Geomorphic processes that change the landscape that work at our or near the surface. So, this is the process surface and near surface of the process. So, that is modifying this earth crust. So, that's why crust is very important to study.

Additionally there are direct or indirect it is affected this national economy. The crustal composition if this crustal composition is mostly metallic the crust is metal rich that it will add to national economy. Then we have already discussed about how the neighborhood relationship, then this agricultural food habit and the region, then our groundwater availability if this it is for example, you go to Deccan and you go to the Granitic terrain there will be groundwater problem because the crustal composition does not allow the groundwater to store there. But in contrast, if you come to the Ganga plain, you come to the coastal plains of India it is mostly alluvium. So, that means we have plenty of groundwater there.

Then our geography, geomorphology and weather it is defined by the crust because if

you go to this say again Deccan trap there will be high radiation even if in March and April you cannot stand on that. So, it affects the weather. The earth crust is upper rigid part of the lithosphere the base of which is defined by a prominent seismic discontinuity that is called Mohorovicic discontinuity or Moho. So, going from crust to sudden deeper we have to face this discontinuity that is Moho. So, it is a sudden discontinuity sudden change in seismic velocity it is due to the crustal compositional change.

So, Moho it is or theMohorovicic discontinuity it is represent the drastic compositional stratigraphic change from earth crust to mantle. So, it is the crust-mantle boundary which is represented by the Moho. Then the crust can be divided into three sub divisions. We can say it is a continental crust, the oceanic crust and the transitional type of crust. The continental crust it is totally up continent.

So, if you go to this peninsular India the Peninsular Gneissic Complex (PGC) it is a continental crust. If you go to the oceanic region you go to this Arabian sea or go to this Indian ocean it is of basaltic nature. This crustal composition is the basaltic it is the oceanic crust, but in between there is a transitional crust. So, at the margin of this continent at the volcanic islands they are neither fall in the continental composition nor fall in the pure oceanic composition So, they are called the transitional crust. So, continental crust it is range from 30 to 70 kilometer thick and comprises 77 percent of the crust by volume and 40 percent by area.

And the oceanic crust ranges 3 to 15 kilometer in thickness, comprises 54 percent of this crustal area and 17 percent by its volume. So, now you see here around 55 percent and this is about 40 percent, and the remaining is the transitional crust. So, these are the islands, the island arcs, the continental margin they are representing the transitional crust. Only the uppermost part of the crust is available for direct study at greater depth. All the information about the composition and structure is indirect that we have already discussed we have seismic, we have magnetics, we have gravity, we have GPR, we have well logging all these are the indirect evidence which used to study the deep crustal composition.

Geological studies of high-grade metamorphic rock once upon a time they are residing at a greater depth they are coming by thrusting activities, they are coming by exhumation, they are coming to the surface and they are giving us the direct evidence. And the foreign rock fragments like xenolith you see here this is the xenolith it is coming from the deeper part due to magmatic eruption they are also giving the information about the direct study about the crustal composition at depth. And the direct study of this oceanic crustal composition it is derived from ophiolite. So, what is exactly ophiolite we

will study in detail while we will talk about the oceanic crust in the mid-oceanic ridge system, but here I can say just the ophiolite is nothing it is the remnant of the oceanic crust that is abducted during this collision during this subduction. So, this is remaining at the surface now.

For example, if you see this picture these are the field photographs of ophiolites and in the geological map if you see these red space red place are the places of ophiolite. So, that means, it is indicating in the northern part of the Indian subcontinent or the Indian plate while this Tethys ocean was existing these crust this oceanic crust it was representing the tethys ocean. So, once the Tethys subducted under the Eurasian plate the remnant of this oceanic crust it is remaining here and they are giving access to the direct study of this oceanic lithosphere. Then variation of the seismic velocity to depth results from number of factors such as increase in pressure. So, if you see here we are going down the pressure increases.

And once the pressure increases if the rapid increases the incompressibility, rigidity and density over topmost 5 kilometer as pore spaces are decreased, fractures are closed. So, thereafter the increase of these parameters with pressure is balanced by decrease in the resulting from the thermal expansion. So, with increasing temperature so that there is a little further change in the velocity. So, that means, once we are going down with increasing temperature the expansion increases, but this pressure is there to balance it. Velocity is changed with chemical composition and also change in the mineralogy resulting from the phase change that we have already discussed.

So, the velocity it is maybe of drastic change or maybe gradual change. The drastic change is due to the compositional variation and the gradual change is due to the mineral change or the phase change. Abrupt velocity is discontinuities are usually caused by this change in chemical composition while the gradational velocity boundaries are normally associated with the phase change. And this crust if you see the few minutes back we are talking about the crustal type. Here you see the continental crust one is the shield another is the platform, then orogen, then continental margin arc, then transitional type is rift, island arc, submarine plateau, then inland sea basin, then oceanic is oceanic ridge, ocean basin, marginal sea basin, volcanic island, trench.

So, that means, these three type of crust there exist, but mostly we will deal with continental crust and the oceanic crust. The third one transitional crust though existence is there, but in plate tectonics it will be less discussed. However, this continental type of crust and oceanic type of crust will be much discussed. Thank you so much.

We will meet in the next class. Thank you.