Natural Hazards
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Lecture – 12
Plate tectonics and related hazards Part II

Welcome, back. So, in previous lecture we discussed about different type of Plate Boundaries.

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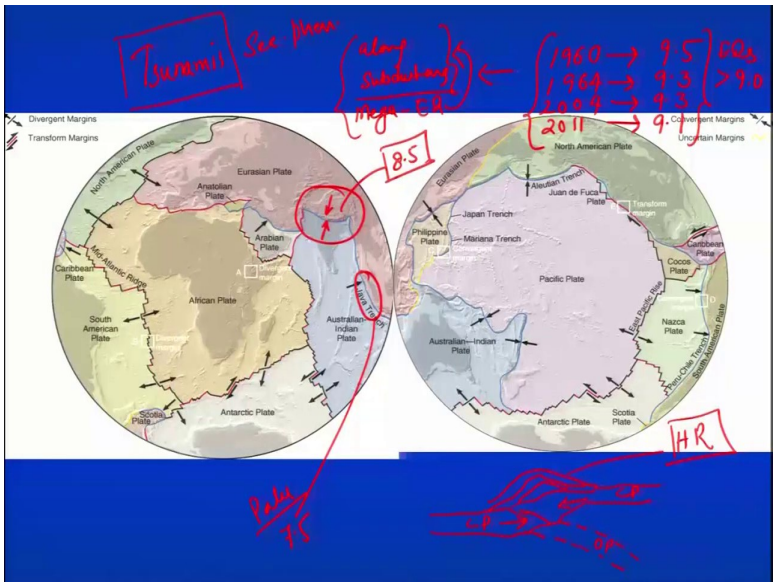

And, tried my best to explain you.

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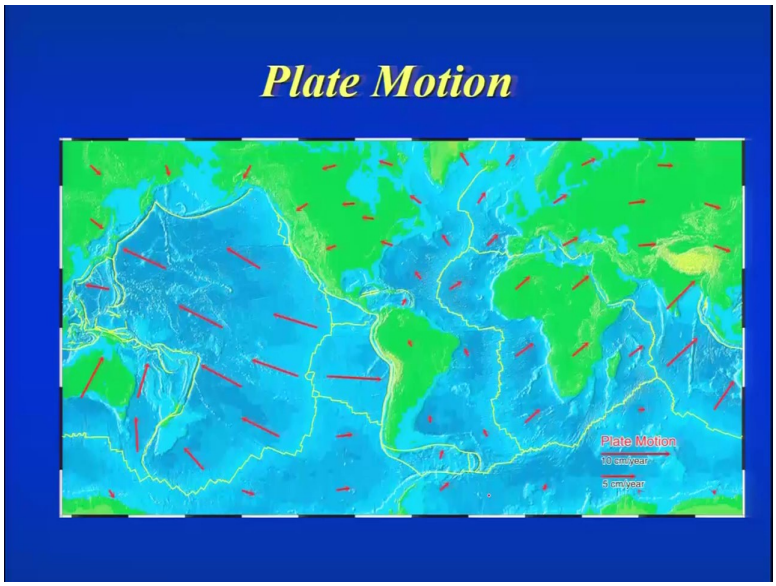

Now, further this was the last slide where we stopped. Now, the arrows which have been shown here are the plate motion. Now, this has helped us in understanding that how different plates are moving and with different velocity. This is very important a finding and the measurements which have been done by GPS and most of the countries now having a very good network. Even in India we are we are deploying as many as GPS we can under the projects we got sponsored from Ministry of Earth Science; not only the IIT, Kanpur is doing that, but there are many other institutions mainly the National Seismological Center, Ministry of Earth Sciences is at New Delhi is handling most of the deployment of a permanent GPS stations in India and we are also doing some part in Himalaya.

Now, the aim is to very precisely measure that what is the convergence rate or maybe the plate motion of the Indian plate. Now, if you see here we what we have like some places which we are having very long arrows indicating that the motion is very fast that is; that means, the convergence between the two plate boundaries is very large and this also has an implication towards the hazard in terms of the earthquakes.

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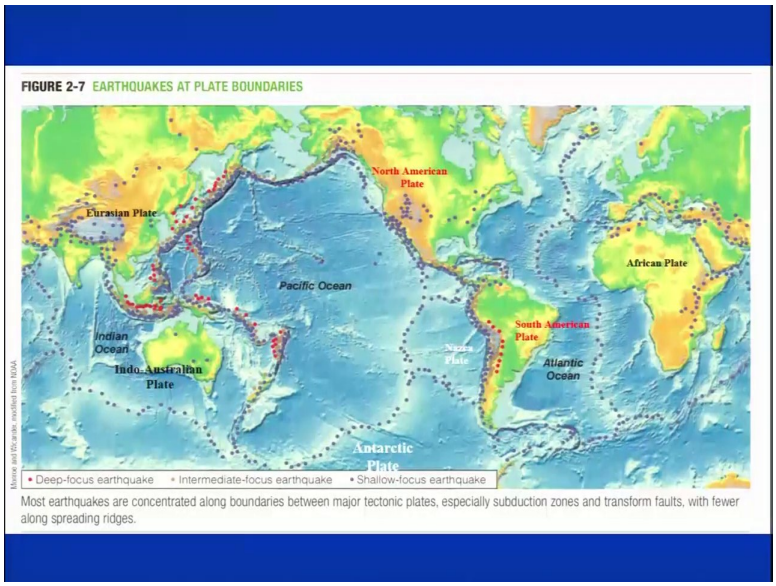

Now, if you look at this map which shows the relationship of the plate boundaries and the alignment or the orientation or you can say the locations of the earthquakes. Most of the earthquakes are along the plate boundaries. So, this also helps us in understanding that these plate boundaries are dangerous in terms of the earthquake and the hazard associated with it. And, not only that, we also are able to learn and understand that the earthquakes which are lying along the plate boundaries are not occurring at the same depth. We are having the deeper earthquakes which have been marked by red dots, then we are having the intermediate earthquakes and the shallow earthquakes.

So, shallow earthquakes are mostly most dangerous one, because as I have discussed in one of my lecture where I was talking about the 2015, Gorkha earthquake there we would we emphasized upon not what was the focus that is the depth of the earthquake it was hardly 15 to 20 kilometers.

Now, if you look at come down to India here we have mostly the collision zone which initially I explained that it the plate oceanic plate ahead of this continental plate subducted below. So, we are having right now the two continents have collided, but still we have the older plate which subducted initially. Hence we are having the collision plate boundary here, but this portion which we are having Sumatra Andaman and Arakan subduction zone we have the subduction zone like one plate is subducting beneath the another one and mostly what you see here is that you are having the shallow earthquakes.

So, this is morevery much like in terms of the hazard. The hazard posed by such earthquakes is very high and the risk is also very high to the people who are staying in this region.

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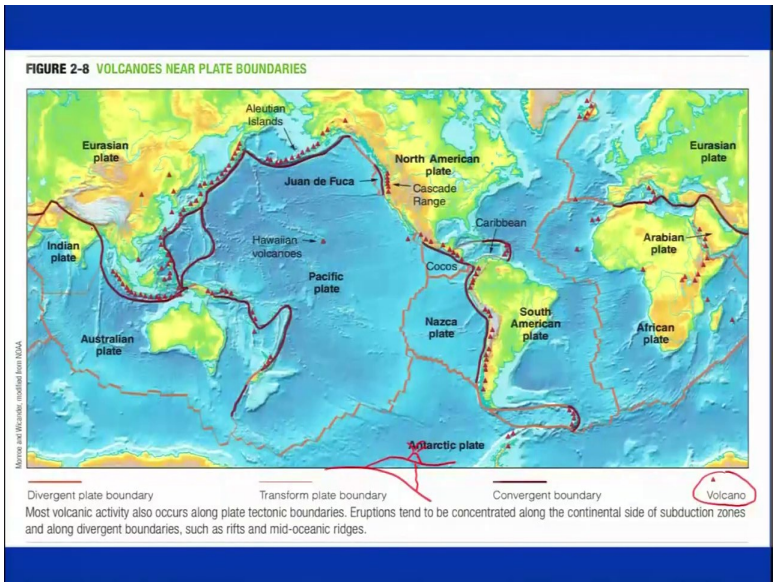

Now, one more important thing which you should remember is that and I explained in one of the previous slides in previous lecture that wherever we will have the one plate subducting below another one we may have the signatures of volcanic eruptions.

So, this is shows the that the volcanoes are alsoin a in a typical environment or the relationship between the two plates you will find that where one plate is subducting below the another one you have the volcanic eruptions otherwise you will not see the volcanic eruptions on in all plate configurations it is difficult because you need to have the source which will melt in the deeper part of the earth's interior and result into the volcanic eruptions.

So, again if you look at this is in subduction zone. So, we do not have we have volcanoes here, but we do not have the volcano volcanoes here in this area.

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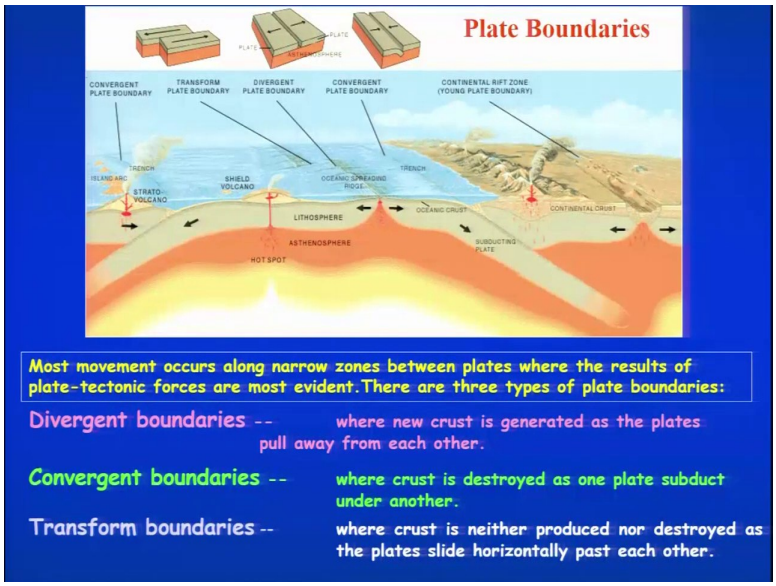

Now, plate boundaries I say I was discussing we have mainly we can classify in three major categories; one is convergent transform and divergent plate boundaries. So, most movement occurs along narrow zone between plates where the results of plate tectonic forces are most evident. There are three type of plate boundaries, one is your divergent plate boundary which you can see here this one. So, you have a divergent plate boundary where the new crust is generated as plates pull away from each other. So, we also termed this is a constructive plate boundary because there is no destruction which is taking place and may it always new plate is been added up.

Now, how they came to know that there is an addition of the of the plate as one moves away from the spreading centers what they found was that close to the spreading center I just put a line here. So, if you move away from the of the away from the center then the rocks or the or the material the molten mass or the magma which came up what we found that we have if you move away we have older rocks if you come closer then you are having younger rocks. So, this was the finding which helped us in understanding that every time there is an addition of crust along these spreading centers.

Then we have another one is convergent plate boundary where crust is destroyed as one plate subduct under the another one and these are the convergent plate boundaries where is one plate as the oceanic plate is subducting below the continental plate or you are having an oceanic plate subducting below an oceanic plate. Now, the older oceanic plates

will be relatively heavier than the younger one. So, this will subduct below the younger oceanic plates.

And, if you see the sketch also tries to explain that the subducting plate which has been moving down or subducting down when it reaches the asthenosphere there is melting which starts and that results into the deformation of the volcanic arc or the volcanoes on continental plate or in the oceanic plate and this we termed as an island arc and the area close to this subduction are termed as trenches. These are termed as trench and trench will be the contact where will be the deepest portion between these two plates and in the area where you are having the plate boundary.

So, if you if I put in sketch here then this was the overriding plate and this is the subducting plate and suppose you are having in your erupt putting an ocean here. So, this will be the deepest part there is this term that trench. So, you can recall if you are asked that what do you mean by trench here in relation with the plate boundaries. Then finally, we may have the third one is the transform boundaries where crust is neither produced nor destroyed as the plate slides horizontally past each other.

So, this transform plate boundaries are been shown here actually. I will just remove this part so that you can clearly look at these are the transform plate boundaries and they are associated with the spreading centers see these lines here are the transform plate boundaries. So, one is your constructive plate boundaries, another is your destructive plate boundaries and further last one is your transform plate boundary.

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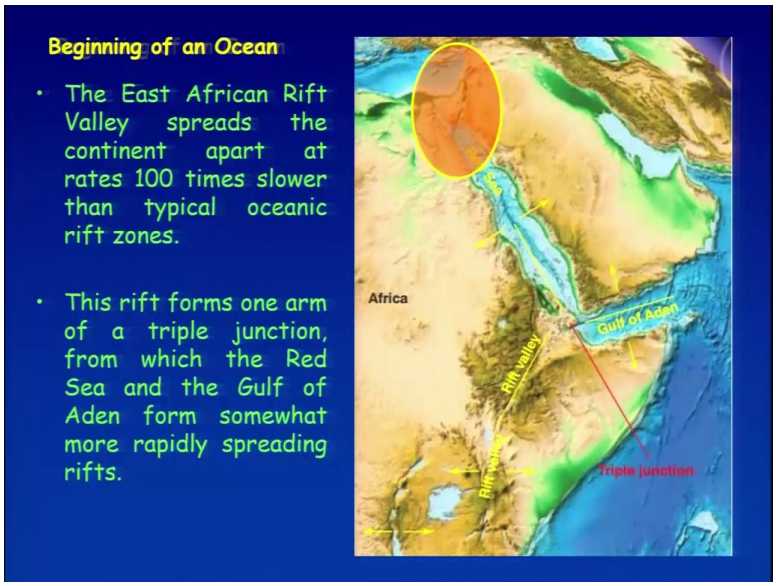

Now, another example is which I would like to add here is of triple junction where three plates are moving away from one another. So, we have three plates here which I have been with then the area is termed as triple junction.

So, we have the East African Rift Valley spreading away this one here, we have another one the along the red sea. So, you have African plate and Arabian plate here and then we have the area along the Gulf of Aden which is also moving away. See the yellow arrows are showing the drifting of the different plates with respect to one another. So, the East African rift valley spreads the continent apart at the rate of even 100 times slower than typical ocean rift zones. So, this process along the African Rift Valley is very slow.

But, recently this was evident that some areas in this region has split it apart. If I will see if I have a movie then we can show or maybe in the next lecture we can show that movie which where the people have been watching that how things have moved. But, of course, this phenomenon is very slow and maybe it will take a long time to break this land into two parts and you will have a new ocean along this boundary. So, this rift forms one arm of a triple junction from which the red sea and the Gulf of Aden forms somewhat more rapidly spreading the rift. So, these two are comparatively moving faster than this one.

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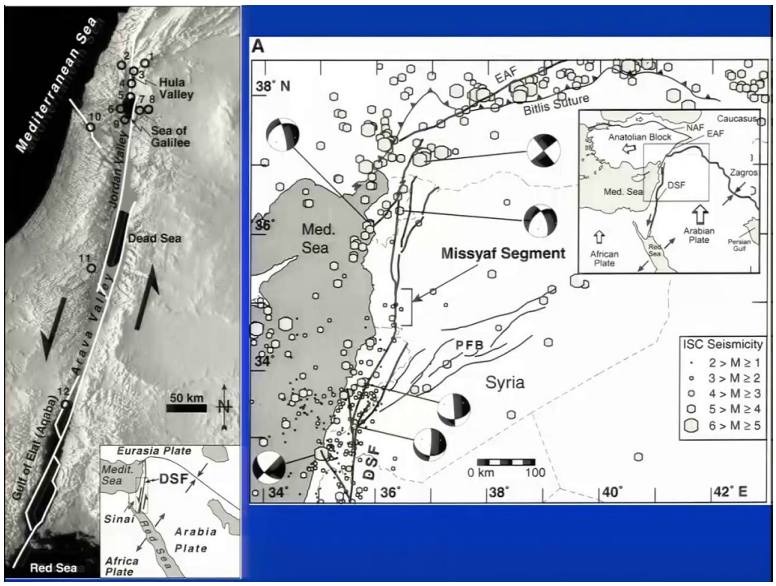

Now, coming to this example is way good here which has been shown as how they did sea fault.

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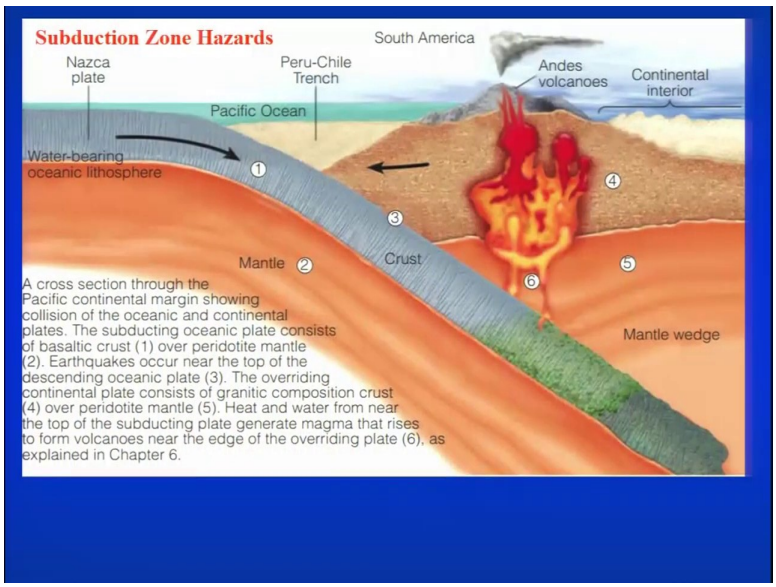

So, this I have already explained that if you are having the oceanic plate subducting below or the continental plate and then we will have one hazard which is related now will be the volcanic eruptions another one is that if this moves and we have water on top of it so, along with the earthquakes which will be and very like mega earthquakes we

will also have this tsunami because there will be in disturbance of the water column which is sitting on the top of this.

So, we have like in such situations about the plate boundaries which we talk about subduction zones we have three-fold hazard which is associated with such tectonic framework.

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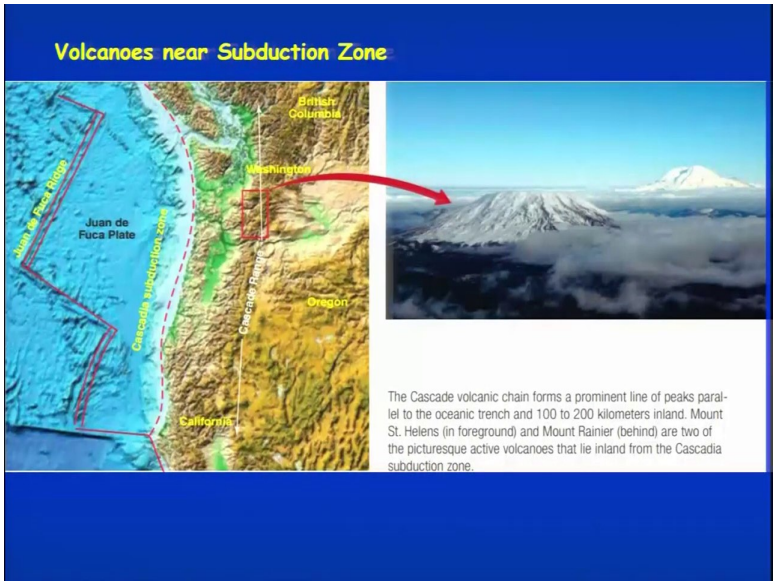

So, on the surface also when you are having the oceanic plate subducting below the continental plate you can see beautiful volcanic cones or the eruptions which are been seen in along the subduction zone.

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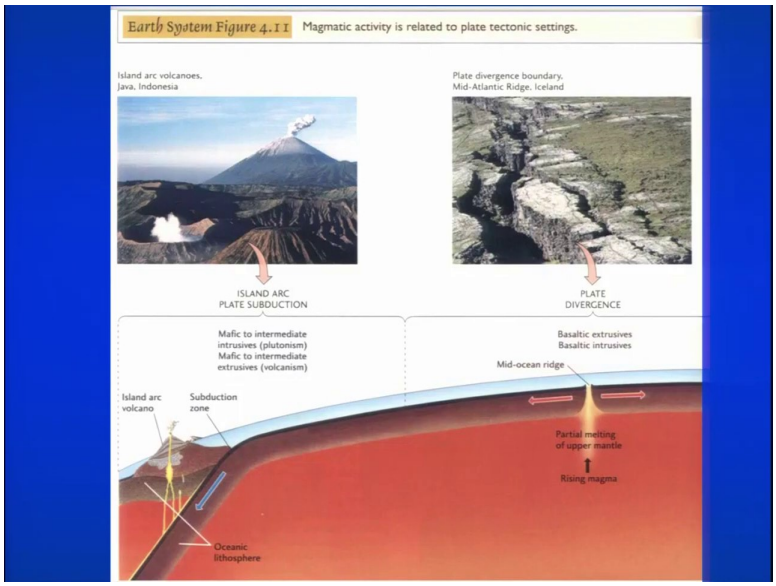

Now, coming to this part here and this is one of the best examples which one can see of the divergent plate boundary which has been experienced or seen on the surface. This is an example on the Iceland. So, one maybe you are having the plate subducting below you will have the volcanoes which has been shown here and you have an island arc here, but at the places where you are having the magma chamber available below it and then you are having gain the both the plates are moving away then you will see and spreading out or diverging boundary of the play along the plates.

So, magnetic activity related to plate tectonics you can have in two different ways. So, one is your formation of the island arc, another you are having the divergent plate boundaries.

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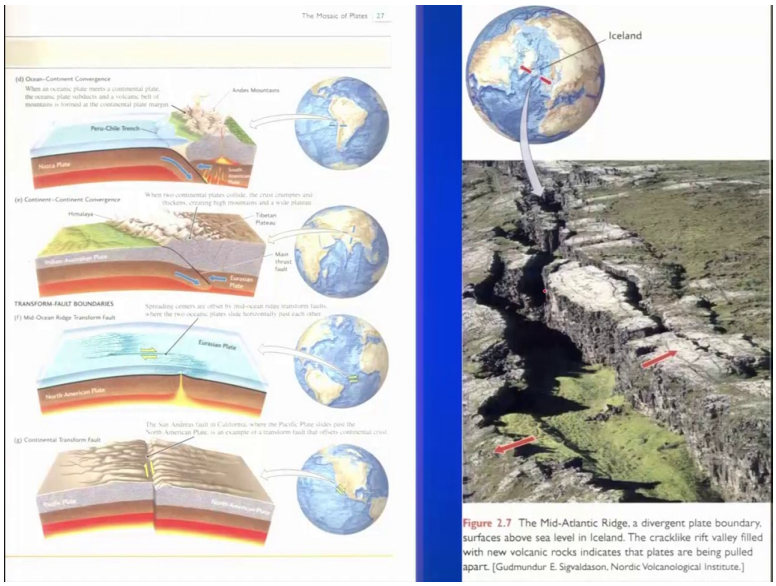

So, this is an example from on Iceland. So, if you take from here all these figures what we see is that from where we are getting the magma source, one plate subducting below the another one this is an example of Nazca plate and along the Peru, Chile trench we have we are having the south African American plate the which shows the evidence of volcanoes here. Then we have another is Tibetan plate and we are having the Himalayas, but as I told that now we do not have any evidence of the volcanic adoption here because two continental plates have collided.

So, we are having the continental-continental convergence, but previously we experienced and we have the evidence that they were and the volcanic eruptions in the past when we had an oceanic plate was subducted below and reached the asthenosphere. Then we have transform plate boundaries and we also see at some places the example of transform plate boundaries; for example, in US. The American and Pacific plate boundaries they are also showing the transform movement and this is one of the example of the mid Atlantic ridge which has been shown here which comes right into the surface in the Iceland of it shows that two plates are moving away from one another.

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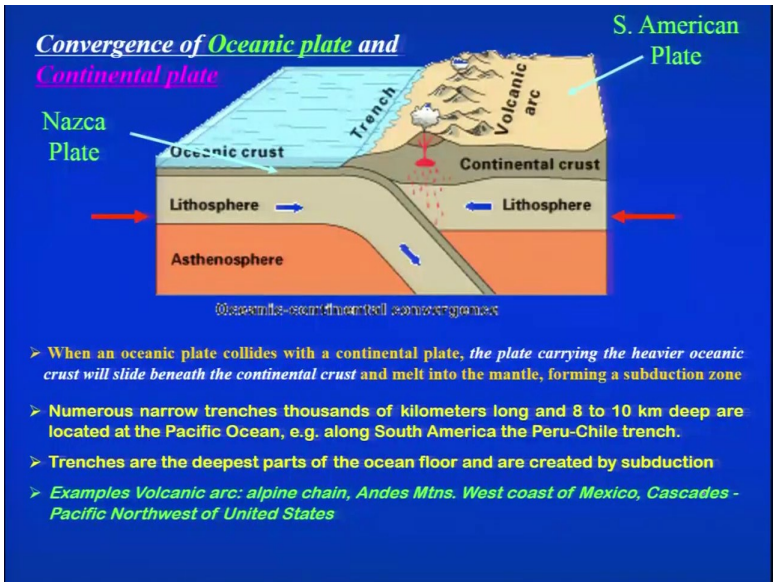

So, convergence of oceanic plate and the continental plate if you look at. So, we have for example, the Nazca plate, we have on the on the right-hand side we are having the South American plate it I was showing the example in the previous slide. So, the oceanic plate which is heavier, we will subduct below the lighter one that is your continental plate. These are a few examples where you will be able to see we the volcanic arcs mainly in Alpine, Andes, West Coast, Cascadia and Pacific north of United States.

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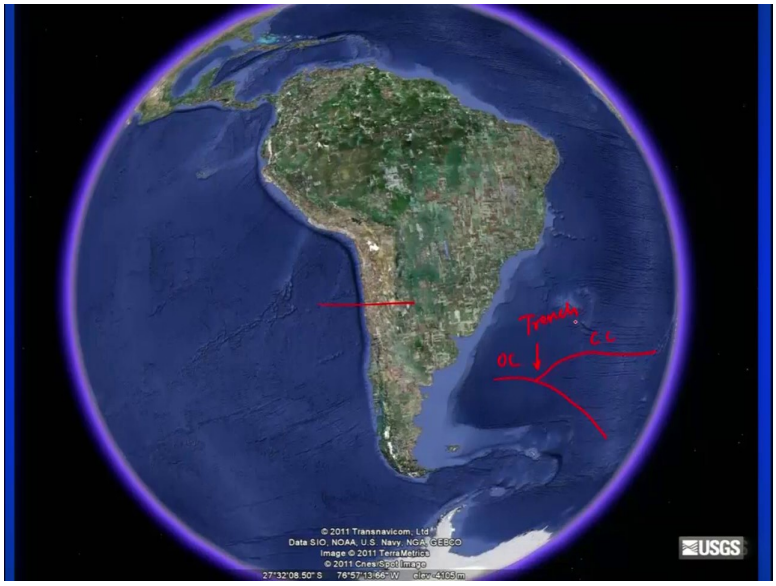

Now, let us see I have some field photographs of this. So, on Google earth if you look at the trenches looks like something like very sharp boundary between the two plates and this is what the darker part which you see here is the deepest portions. If you take the cross section here how it looks like is that this is going down and then you are having the continent. So, this is your continental crust and this one is your oceanic crust and this portion is your trench.

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So, we had an opportunity to look at this the volcanoes here. Of course, it was they are active, but at that point of time when we visited the Chile at that time it was not active.

So, this is the trench portion here and at the backdrop here what you see the topography is the mountains and within that we see a few volcanoes active volcanoes.

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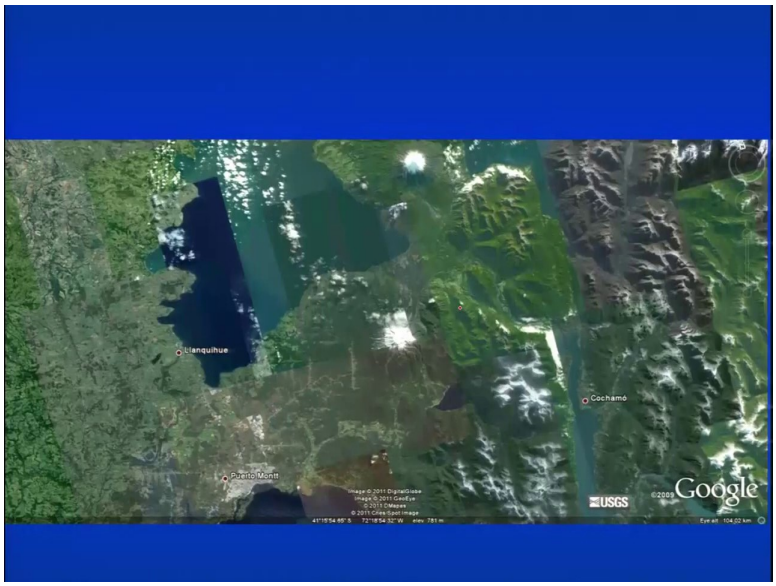

So, this is an example of this.

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And, feel photograph you look at. So, these are few examples of on Google earth we have clipped up.

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So, this is one of the volcano which has been compared with the Mount Fuji. The name of the volcano is Osorno. Now, this is in South America on South American plate and this is on in the Japanese islands, Mount Fuji. So, this is compared based on their appearance, they look very similar.

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There is another example of the volcano in Chile.

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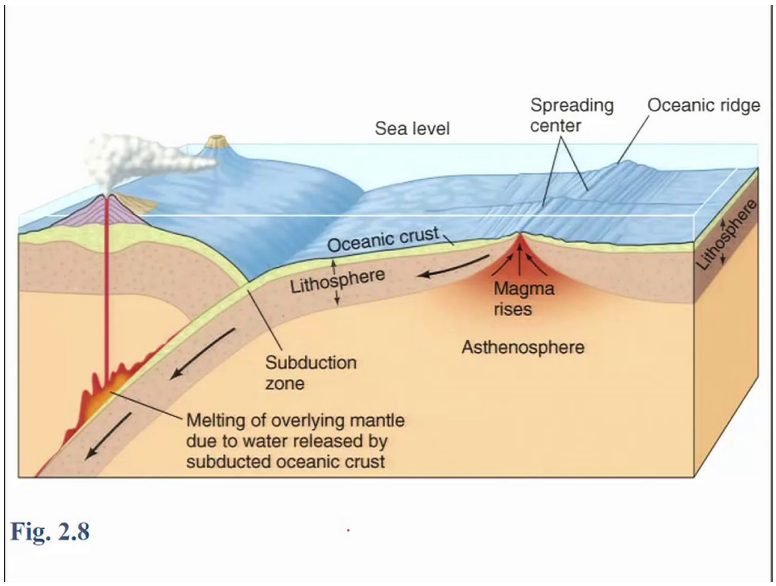

Fig. 2.8

Now, there is another example of from Hawaii.

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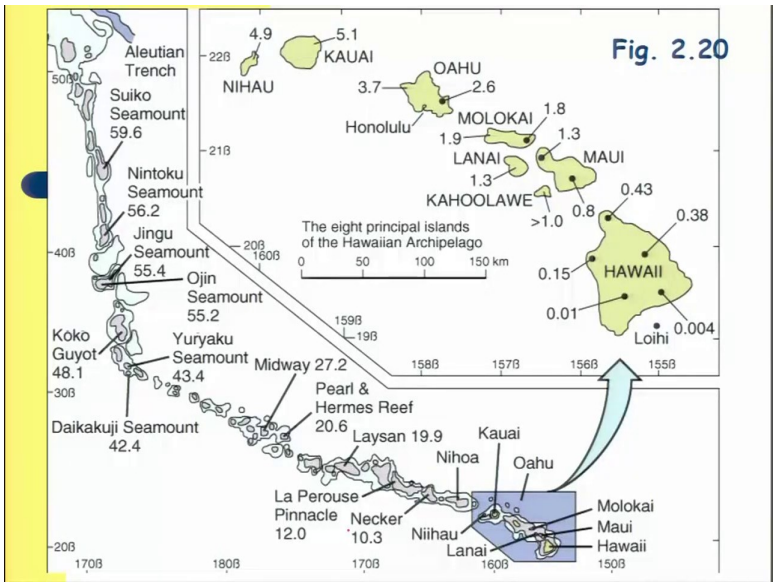

So, what is the most important aspect which we should understand out from this that over the time when this one plate is subducting below the another one and this is one example where we will have volcanoes, but in other cases if we have a hotspot which is supplying the magma to the surface it will also result into the formation of the volcanic chain. So, if the plate is moving on the top of part then it will keep on having the volcanic eruption.

Now, this for example, from Hawaii also helped us in understanding and a realizing or accepting the hypothesis which was been given as in continental drift that the plates moves from or it moved from its original locations.

So, this is the island chain of main Hawaii which we see almost like it takes turn over here and this is for this is the location where you are having the most active volcanoes in this region recent there was 2017, if I am not wrong there was the active eruption which was been reported from this island.

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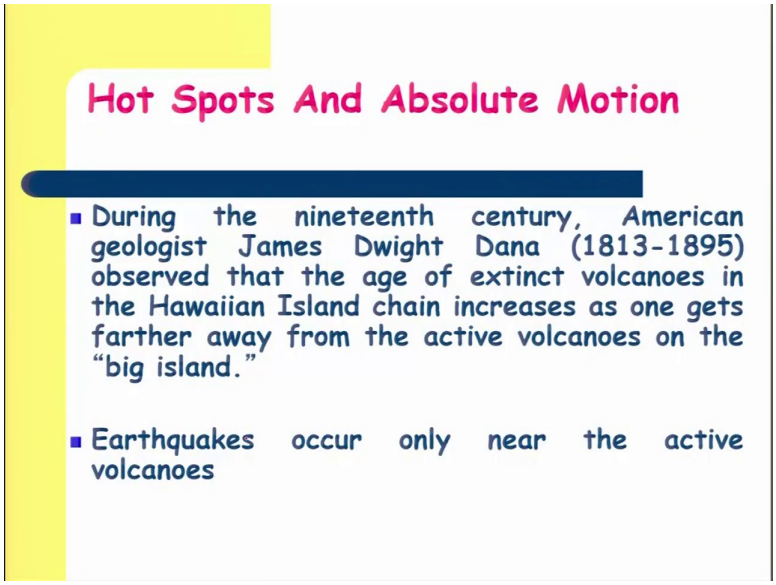

Now, hotspot and absolute motion this was again it came in and that during the nineteenth century American geologies geologist James Dana observed that the age of extinct volcanoes in Hawaiian island chain increases at one gets farther away from the active volcanoes on the big island. So, this is the big island which they have marked. So, if them they move away then they found that the one of the ages are increasing.

Earthquakes occur only near the active volcano. So, this is connected with the magma which has been pushed to the surface and because of that the fracturing and cracking and moving of the magma or the movement of the magma is causing the earthquakes.

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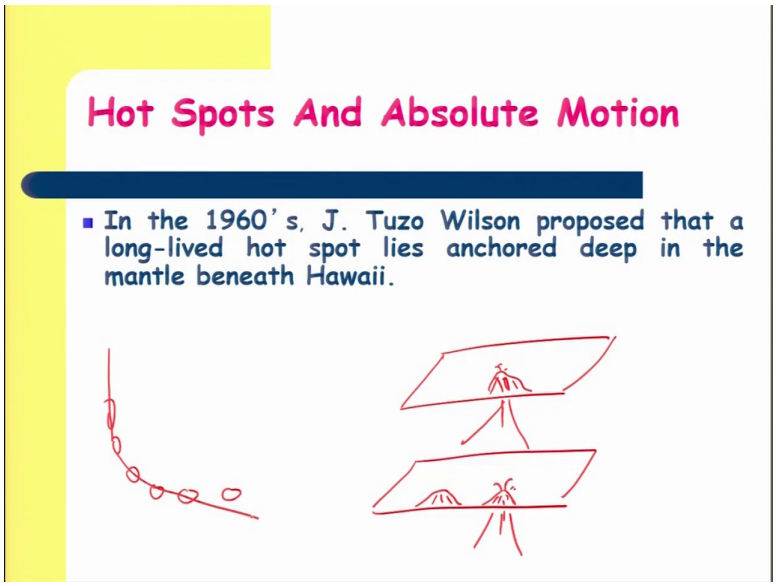

So, in 1960, Wilson proposed that long lived hotspot lies anchored deep in the mantle beneath the Hawaii. So, what he wanted to suggest us suppose you are having an and piece of plate here and then we are having in hotspot which is pouring out the magma on the top, ok. So, you have in volcanic eruptions here. Now, once this moved further then for example, this has moved further then you have this volcano will become dormant and this place is again having the chamber. So, you will have another active volcano over here.

So, that is how the whole chain was been formed, but another important feature which they observed was that they had like the volcanoes here like this and then there was a sudden change in the direction. So, this I will explain in the next slide how they tried to map it and how they like concluded that the plate movement is there of course, as well as the plate direction or the or the direction of the motion changed over the time.

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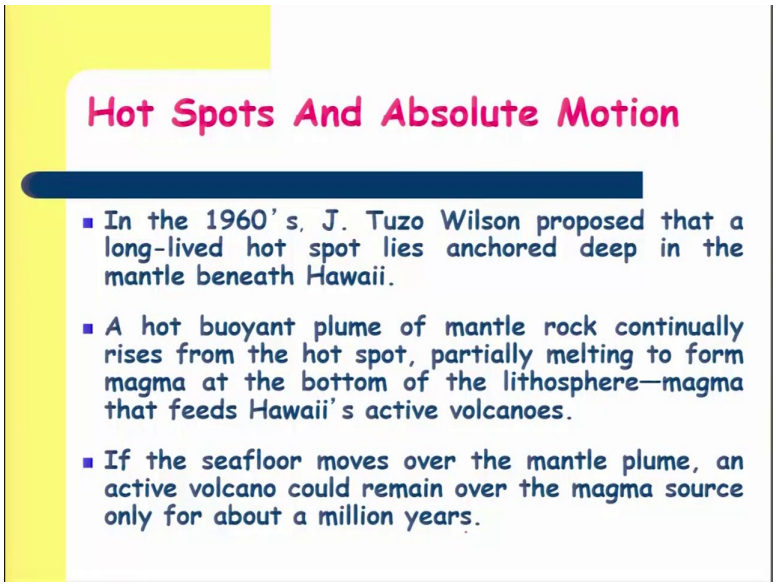

Further a hot buoyant plume of mental rock continuously rises from the hot spot partially melting to form magma at the bottom of the lithosphere and magma that feeds Hawaii active volcanoes. So, this is the source of the magma which feeds the active volcanoes.

So, if the seafloor moves over the mantle plume an active volcano could remain over the magma source only for about a million years. So, further it will move because the motion of the plate is not so fast, so, it will remain for at least a million years there and then the next volcanic eruption will be experienced.

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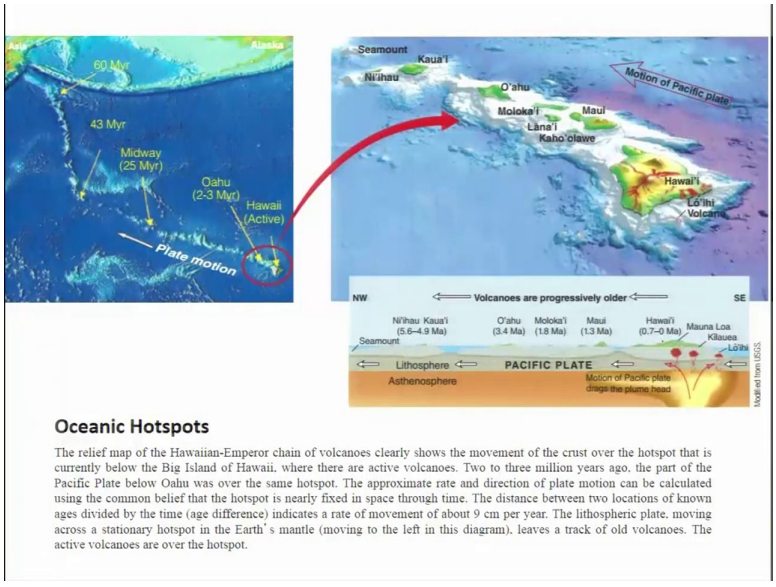

Oceanic Hotspots

The relief map of the Hawaiian-Emperor chain of volcanoes clearly shows the movement of the crust over the hotspot that is currently below the Big Island of Hawaii, where there are active volcanoes. Two to three million years ago, the part of the Pacific Plate below Oahu was over the same hotspot. The approximate rate and direction of plate motion can be calculated using the common belief that the hotspot is nearly fixed in space through time. The distance between two locations of known ages divided by the time (age difference) indicates a rate of movement of about 9 cm per year. The lithospheric plate, moving across a stationary hotspot in the Earth's mantle (moving to the left in this diagram), leaves a track of old volcanoes. The active volcanoes are over the hotspot.

So, this is what you are having this is the big island here and these are all dormant volcanoes or the sea mounts. So, this has been shown as the presence motion of the of the plate I was just moving above the magma chamber here. So, if you look at the edges here it shows that if you move away from this active big island, then you are having like at present you are having 0.720 million years and that is the present and this is here 1.3, 1.8, 3.8, 5.6 to 4.9. So, as you move away from the in the north-west from the big island then these islands are having the older edges.

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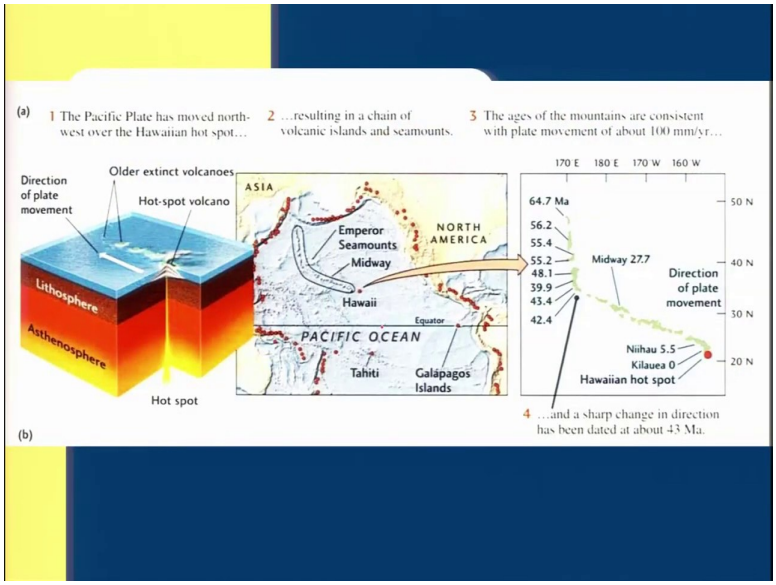

So, what they observed was the first the pacific plate has moved north-west over the Hawaiian hotspot which is located here resulting in a chain of volcanic island and sea mounts. Third, the age of the mountains are consistent with the plate movement of about hundred millimeter per year, that is how they have they have come to the conclusion or the influences which they have made is that one island will stay over the hotspot for a million of years.

So, at this point of portion there is a sharp change in the direction which was around 43 million years back. So, there may be in some event which might have caused the change in the direction, but of course, this was the this was not the direction which was observed in the present motion. Presently it is moving in this direction, but other the older ones are showing that they were having a different almost north-south direction.

So, I will stop here and we will continue in the next lecture.

Thank you, so much.