Natural Hazards
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Lecture – 38
Tsunami and Related Hazards Part I

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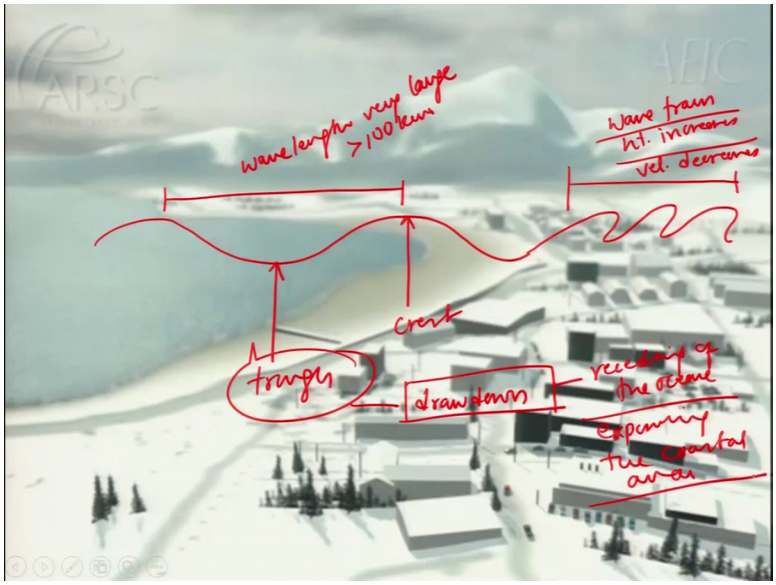

So, welcome back. So, in this small cartoon movie what do you saw that there is an sudden the sea receded, and then further it came back. So, the point was that we should not underestimate the tsunami waves. So, what we usually look at that in ocean you are having been very wide or wavelength. Whereas close to the coast we have is taking up of the waves and the height increases.

So, what we call this as an wave train, then height increases, velocity decreases and it will be more damaging. Whereas, in the ocean, the wavelength is very large you can go up to more than 100 kilometer. And this portion that is what you see is the trough and this is your crust. So, the trough part when it comes first, it will result into what we call the drawdown ok. So, this will result into the receding of the ocean, exposing the coastal area. Now let us see further.

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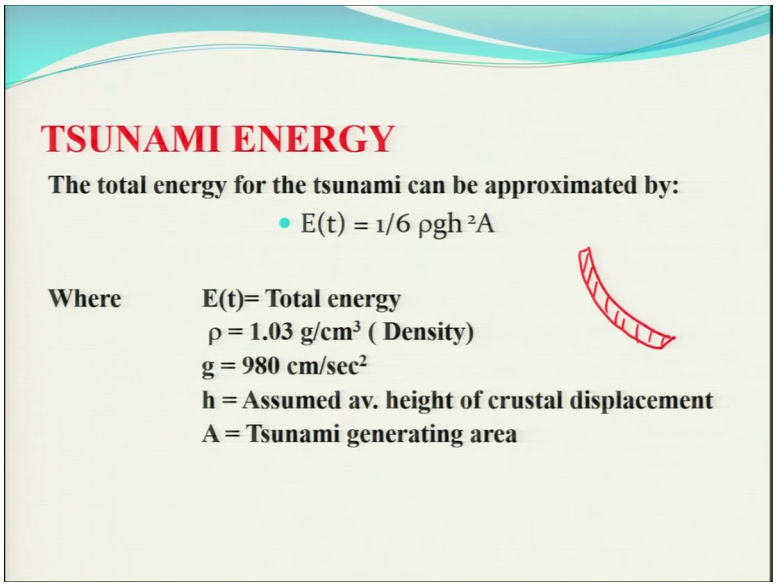

What we look at is the, if you want to calculate the energy conditions or the energy of the tsunami to total energy, it has been given as E t 1 by 6 rho gh square A, and what it means is that you have in total energy of the tsunami rho is the density of the ocean water and g is your gravitation acceleration.

Then height is either you have the actual height of this crust or the crustal displacement. So, you can assume the average height of the crustal displacement and A is the tsunami generating area. So, you need to have the and how much is the area which was ruptured. Now this all parameters will be taken into consideration when we are talking about the modeling part and that will be taken in at the end.

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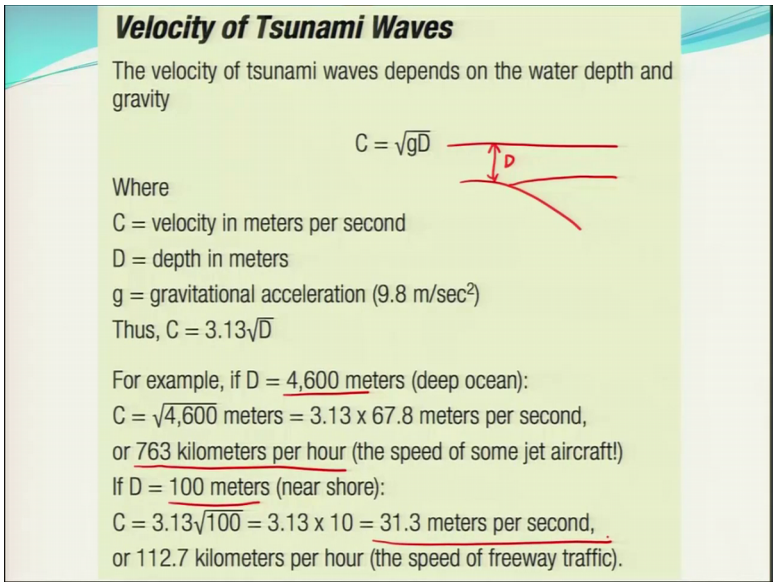

So, and for that was in total energy, this is for the velocity of the tsunami waves. So, if you have the tsunami velocity of the tsunami waves depends upon the water depth, as well as the gravity, where C is the velocity in meter per second, D is the depth of the water column and g is again the gravitational acceleration. So, it will depend on that wave exactly, so suppose you are having an subducting plate like this, and you have an water depth this one, so that we will result into the affect the velocity of the tsunami. So, if you are having the earthquake taking place in this shallower part, then we will have with a different effect, if you are getting the earthquake in the deeper part that is a displacement mainly, then you will have the different velocity.

So, if you know this, that is your D and you know you can calculate the velocity of the. So, for example, what has been given here is that you have the square root of g into D. So, if you have, so this you know is 9.8 and if you estimate or if you know the depth. For example, here it has been taken 4600, then you will get that here the depth is 100 then you will get three point ok. So, so you can have the speed of the tsunami of the velocity of the tsunami.

So, if, so again if you are having the greater depth that what is been shown here. So, for example, 4600 meters, then the velocity is much much higher here. If you are having like depth is hardly 100 meters and you are having the velocities is much much lower.

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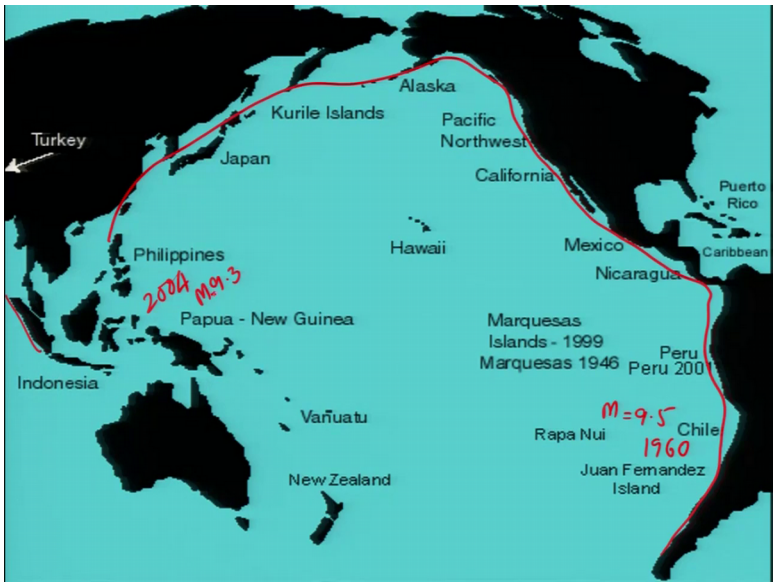

Now, these are the areas which are extremely prone right from the. So, this part which we have discussed is the part of the pacific ring ok. We can say the ring of fire where we have most of the subjection going on, and this is the Chilean part which has, it was responsible in triggering a 1960 Chilean earthquake, magnitude was 9.5. And another one was triggered here of 2004 and magnitude was 9.3.

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So, few major tsunami events in the pacific, so we have listed here, you can just go through it. So, this was the major tsunami. Whereas, these are in Indian ocean 2004 and

then again 2018. So, these are all pacific and below what you see is from the Indian ocean. So, you can understand that this was in September and another was been triggered in 2018, again in December and that was read, because of the Krakatau of volcanic eruption.

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So, or the destructive and the which, the destruction which was been observed in on 1960 Chilean earthquake.

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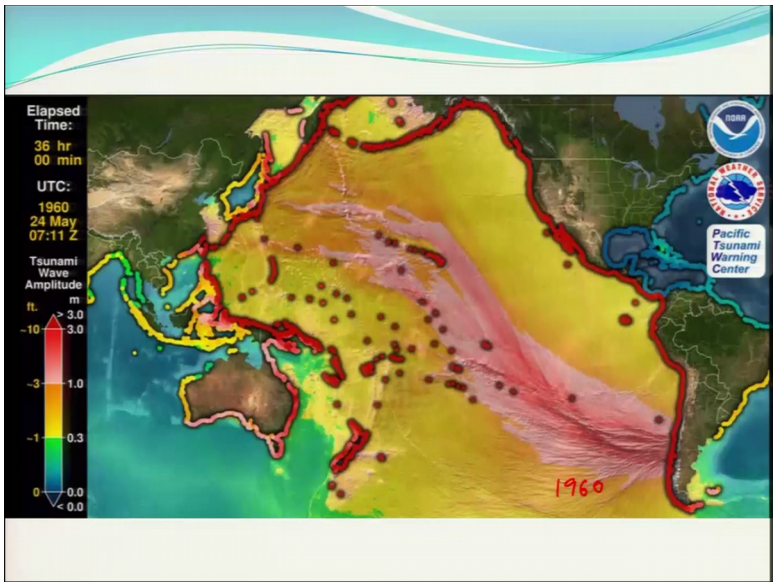

So, this what I was showing that we are having in, and this major subduction zones aligned along the best ring of fire, and this shows the 2000, 1960 rupture area and the directivity of the tsunami. So, it took almost like 24 hours to reach the Japanese coast, and the height also; like you can see the height close to the event is much much higher, and it reduces further as it move away from the rupture zone.

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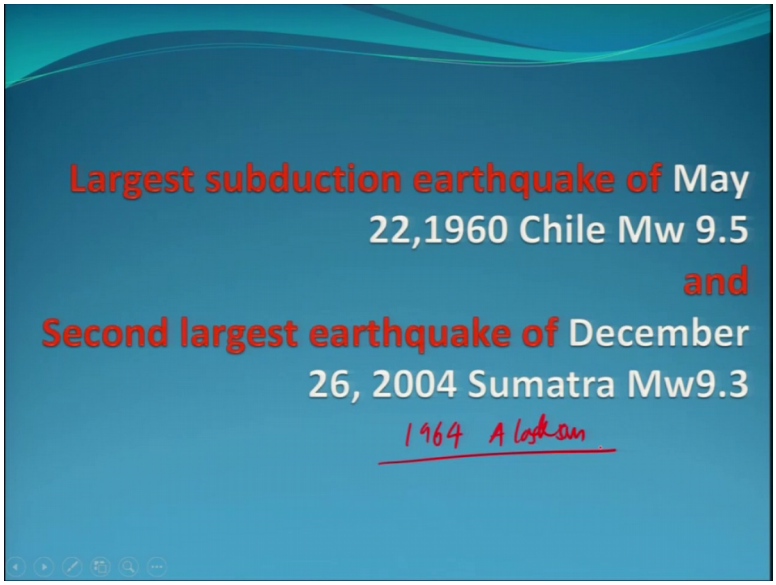

So, the largest subduction zone earthquake of May 22 1960, Chile magnitude 9.5 and another one is your, what we say is the 2004, 26 December Sumatra 9.3. So, this is 9.5 and 9.3. In some literature you will find that the 1964 Alaskan earthquake was been listed as the second largest.

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So, there is two areas were responsible of triggering, the damaging or devastating tsunamis and large magnitudes, or we can say mega earthquakes along the subduction zone. So, one was 1960 and another one is 2004.

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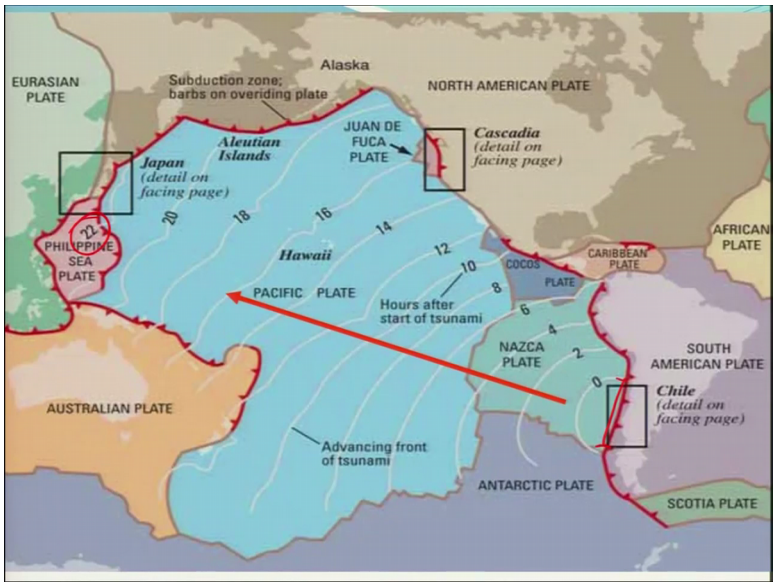

So, let us see case study of the Chilean earthquake; that is 1960, magnitude 9.5. So, it took if you see this these are the time which has been given, based on the modeling, it took almost 22 hours to reach this coast. So, as I was talking about that the more of the

earthquake was been triggered here and the tsunami was generated, but the region which is sitting adjacent or adjoining the pacific was affected.

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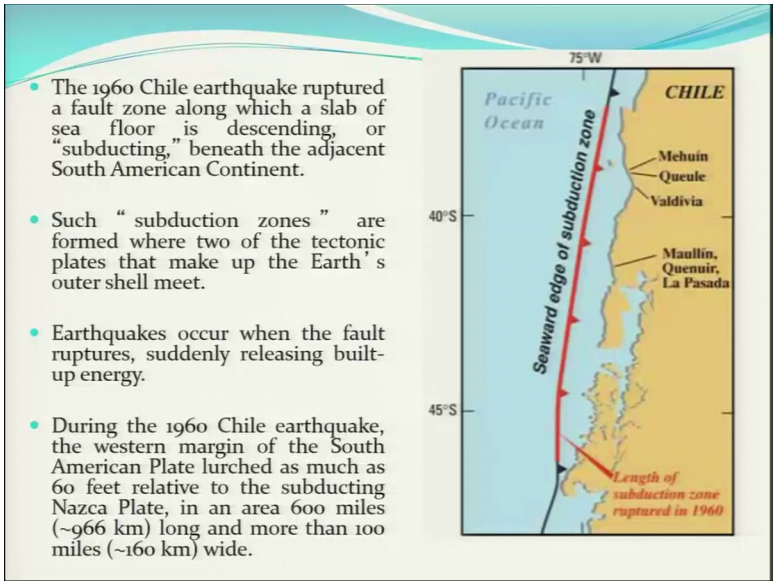

So, I will not get into the detail of this, but you can, when you get the slides you can look at the details here. But let us move further and then see what we learn from this 1960 tsunami signatures.

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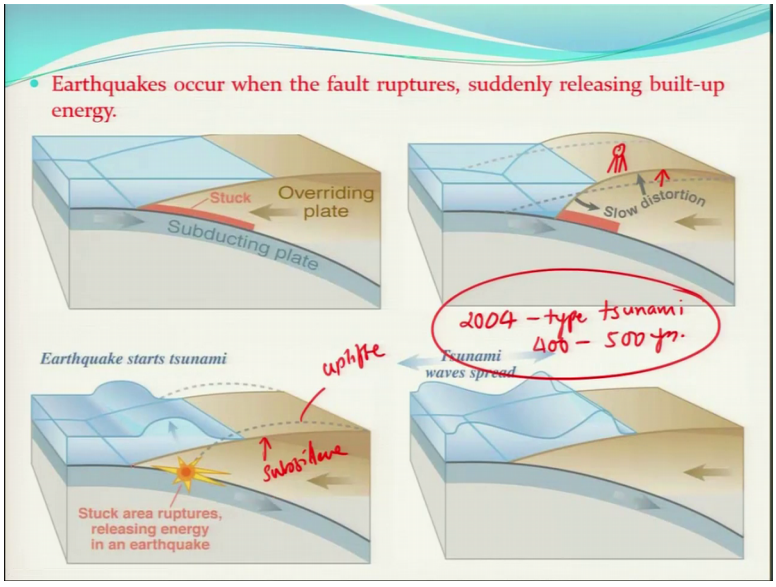

So, earthquake occur when the fault rupture, suddenly release built up energy. This was shown in one of the cartoon movie, where slowly the locked area, I will result into the

development of the strain and the deformation of the overriding plate, which can result in to either subsidence or uplift of this region, but this will be a very slow process and can be picked up based on the keeping if you are having the GPS stations. So, if you have multiple GPS stations you can easily make out the change in the elevation or the deformation which has been experienced over the time.

But this will be an very slow process so it will take years and as I told that in terms of the 2004 type tsunami. The recurrence or is around 400 to 500 years, but the source can be anywhere in the subduction zone. So, what it explains the similar pattern what we have seen in the movie, that initially and this, the overriding plate and the sub ducting plate, and then will keep on moving and it is shown by this arrow, but the locked area will result into the deformation in the overriding plate. And finally, when the energy is released or the overriding plate slips and this has been shown by.

So, this portion has been shown by the dotted lines here, and what is, what we see is that there is an uplift here. So, the land has moved up and then at the time of the release this was the land which was uplifted. And at the time when it was released it has come to this level. So, it got, this is what we call these subsidence. So, the land level change is very prominent at the time of the major earthquakes or what we call the mega earthquakes along tsunami around the subduction zone. And finally, what we see is the inundation by the tsunami waves which spreads over the region.

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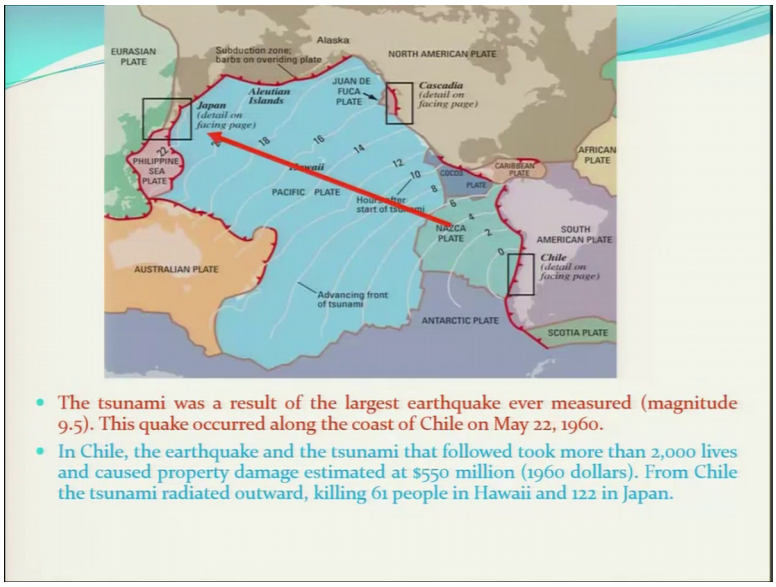

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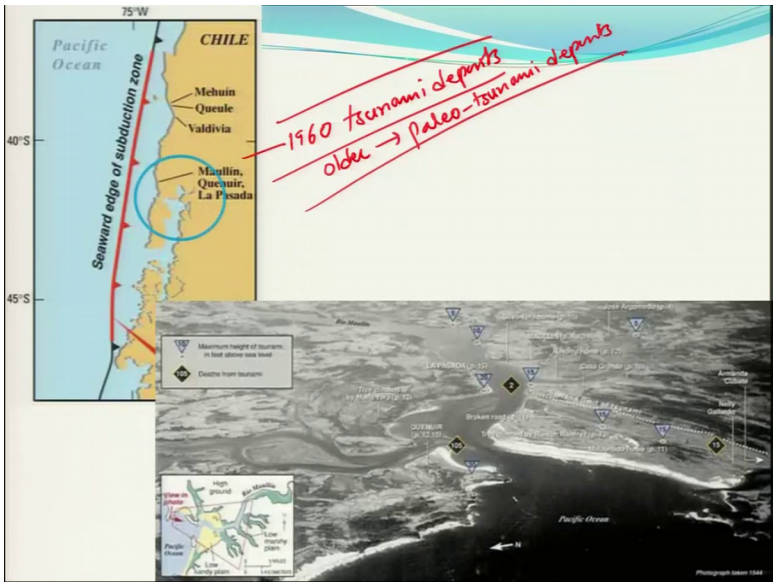

So, these are few signatures which we observed when we did field survey in Maullin, in Chile, which was in the epicentral area. This is the area which has been shown as in ruptured area and the survey which was been conducted here was very important in terms of that it was close to the region of the subduction or the rupture area.

As well as the subduction zone and the evidence or the, the interviews which were been conducted from the survivors, helped us in identifying, even not only the in the 1960 tsunami deposits, but also the older one which we call as an paleo tsunami deposits.

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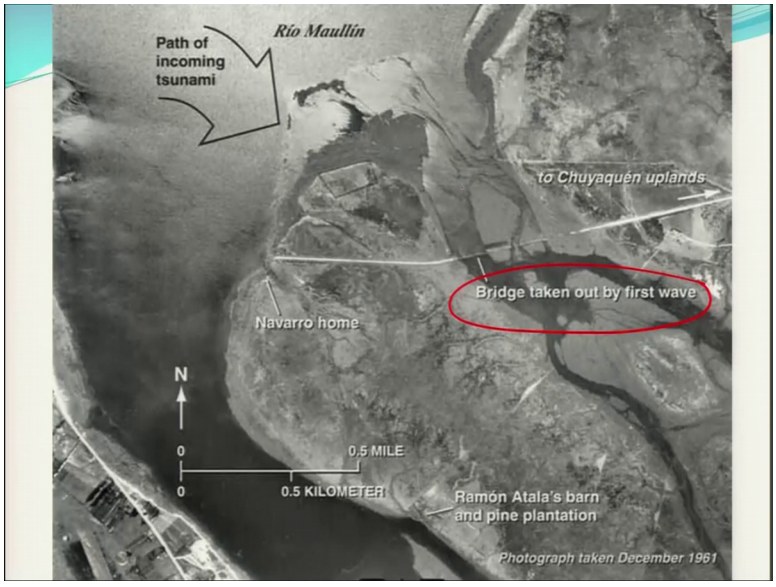

So, these are some satellite pictures which were taken just after that, and which shows the path of incoming tsunami and this bridge was destroyed by the first wave which enter into the (Refer Time: 15:00) area.

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So, this were the pictures from the town of Maullin.

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This is quite interesting, this picture was been taken before and you can see that there is an, one of the major river which is flowing along this one and the floodplain area, there are some residential houses and this area was earlier been used for agricultural practices.

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But after just after that what you see is only few trees were been left out, everything was been wiped off. And then since this channel is this area is close to the coastal region, the tidal inundation was quite frequent, and this area was; like people were forced to leave this area, because it is now getting inundated during the high tide.

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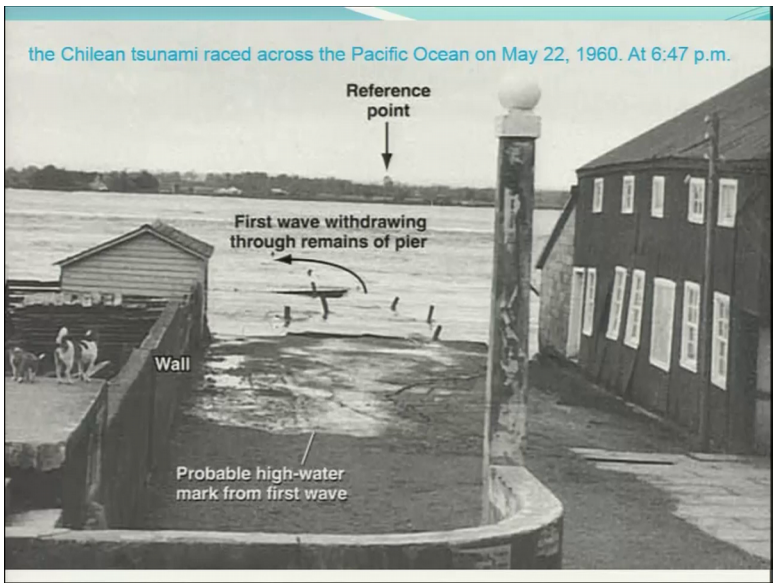

So, again another good indication of that, so the first wave arrival which has been seen here.

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And then second one which has wiped off this small hut which was been seen in the previous photograph.

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Now, this photograph is now from Japan, and is, I was talking that the tsunami was been coined, the word was been coined by Japanese people. So, they had like better understanding or still they are now of course, they are having an better understanding than all of us, because they have such events very frequently occurring in the their area.

So, the tidal station person found that there is some change in the tide level. So, he quickly inform the people in the nearby region and ask them to move on high ground.

So, this is what you see the people have moved on the high ground and this guy is running. So, the first wave hit just inundated this area. So, water entered from here and just inundated this portion, but still the people have time to run up. And they very well understood that there will be in second wave which will be powerful. So, this was the first wave we just came and flooded the area.

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The next one was powerful. So, if you see the timing in the previous photograph this 4:40 AM and another photograph which was been taken and just in 5 minutes of gap. So, the impact of the second wave was much more devastating. So, this is what we were talking about that it should not consider that all waves will not be as powerful; like if the first wave is coming we should understand that it could be in calm wave, but the second wave could be a powerful one.

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Third, and just after 5 minutes again the water froze and more like destruction was been experienced.

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And finally, at 7:30 you can see the that water reached up to this portions. The previous one if you look at water reached as this one, and then this was the you know one. So, a station, the train station which has been shown in the next slide is this one here. So, window were still intact at the second wave, it was broken pushed inside and then lot of debris was there, along with that the window is gone.

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So, again coming back to Chile what we found is that there are the, still there are remnants of some jetties which have been constructed for getting into the boards, but now it is lying in the submerged tidal flats.

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So, in, this is during the high tide it gets submerged. So, nobody is using this area anymore.

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And the soil which was used or the area which was been used earlier for agricultural purposes, now it is under erosion and the another evidence could evidence which you can see is of dead forest, because of the inundation of the saline water, the vegetation or the trees which were growing in this floodplain area will not survive.

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So, this is the inundation and so this type of signatures are very crucial for us and we can, what we can see is the constant soil erosion which is going on and this is, this was the fertile soil.

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So, you can see the soil erosion, constant soil erosion. And the picture which I were showing the black and white picture was from this area, where people used to stay but few who survived from this they moved to the high grounds and now they have settled here on this high ground. And in most of the evacuation process the areas which are like prone to such tsunami events, they will put the sign for the people, if there is an tsunami warning to move on high grounds.

So, this is one of the best way, that if you understand the phenomena or the process, then immediately one should move on the high ground. So, now, this whole area is getting in converted into tidal marsh and people have moved on this higher grounds.

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So, this is what it shows the erosion and the previous soil, which is now under the tidal erosion.

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So, what we do is, basically we try to study the tsunami steadygraphy. So, we if you dig these subsurface and try to see the different lithology. So, whenever there is an event which has occurred in the past or which will occur in the past will get preserved in the sediment records.

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So, this was in simple way out and we did and very promising results were been obtained. So, we were having the team from an one of the renowned Tsunami Geologists from US Brian Atwater, myself here person from Chile, and these two guys are from Indonesia, and another scientists from India.

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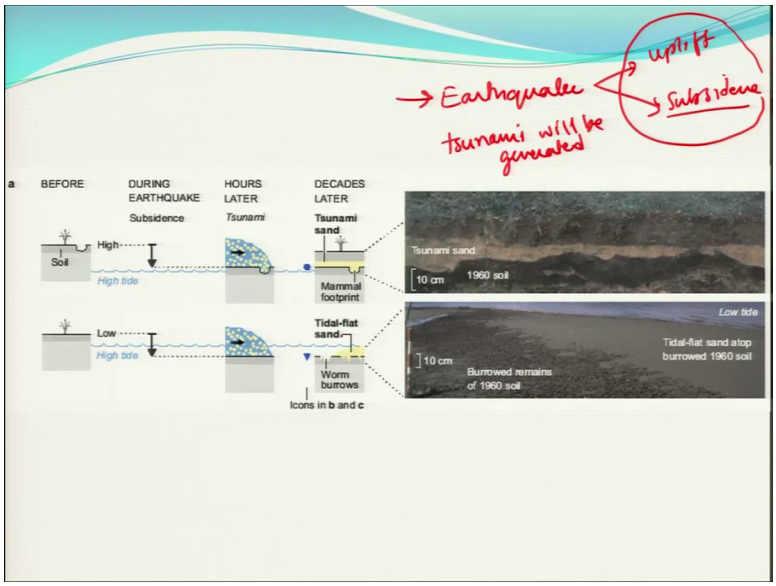

So, what we found was that there was, like very clear cut demarcation or sharp contact between the blackish soil which was at the time available on the surface during 1960, and then there was an deposition of the tsunami wave, a tsunami sand during 1960 event. So, the diagram here it explains that you have, before you are having an soil here then you have, like during an earthquake you have subsidence, for this is for example, if the land goes down, then this level has reached here and then tsunami will come. So, first what you have is the earthquake. So, any region when first will be an earthquake that will result into either uplift of the area or subsidence of the region.

And followed by this that is ground shaking and the displacement tsunami will be generated. So, tsunami wave will arrive later, but before the tsunami, arrival of this tsunami wave this process we will take place. So, I get up lifted or subsided. So, in this case what has been shown here and in what we was observed during 1960 earthquake was subsidence, because the area which was been used for agricultural purposes is now getting inundated during the high tide, and that indicates that the area has subsided, or sea level has remained same, sea level did not fluctuate, but the area subsided.

So, what we see here is that you have the sand which is coming in and then was deposited and later after years of erosion and the next weeks of deposition what we see is, that this unit is preserved, and then we are having another set of soil which is coming up and then we have vegetation which has. So, this will, this signature of the sediments

or the tsunami sand got trapped between the two soil units. So, this is 1960 surface so and then the tsunami came in 1960 event and then there it was an soil formation here. So, the next event when it will come, it will deposit on the top of this one, and then again same process goes on. So, what we see is the couplet of the soil sand soil sand, if it is an ideal condition.

Of course, there will be some regions within the same area we will undergo more erosion, because of the burrowing activities which has been shown here. So, this will destroy to some extent the deposits or it will not allow the full preservation or these signatures of the tsunami in the tidal flat region.

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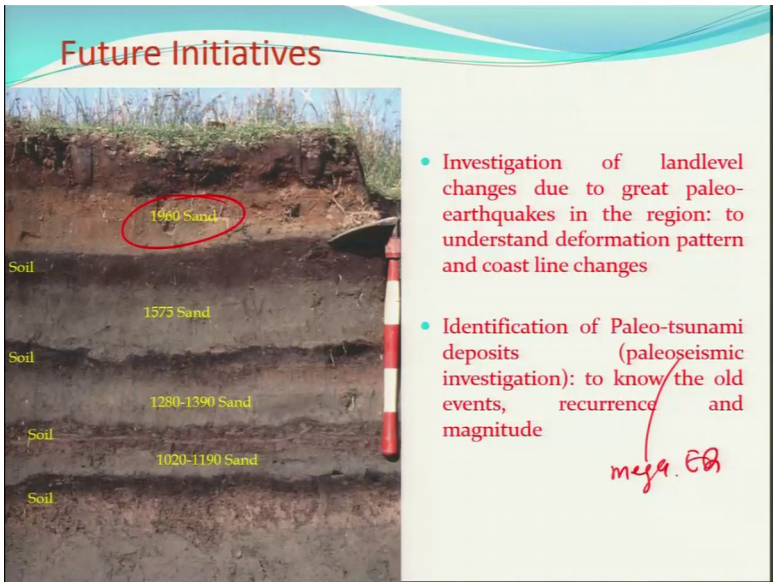

So, if you look at the section from Maullin then what we see is, that we have soil then soil, here soil here and in between we are having some sand units so this clearly indicate that there was, there were repeated events in this region which definitely affected the area in the past also.

So, this was not the only one which was responsible for such sort of and devastation. So, we had another one is 1575, and then during 1280 to 1390 80 and there was another one 120 and 1190. So, what we basically identified in this that we have been having multiple events, and based on such type of investigations we can identify the Paleo tsunami events. So, this was the slide we prepared just after the visit to Chile in 2005, and that what we did was as in future initiative. So, we applied the same technique in Andaman to

identify the Paleo tsunami and paleo seismic. Paleo seismic is basically we are talking about the signatures of mega earthquakes. So, I will stop here and we will continue in the next lecture.

Thank you so much.