Natural Hazards
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Lecture – 39
Tsunami and Related Hazards Part II

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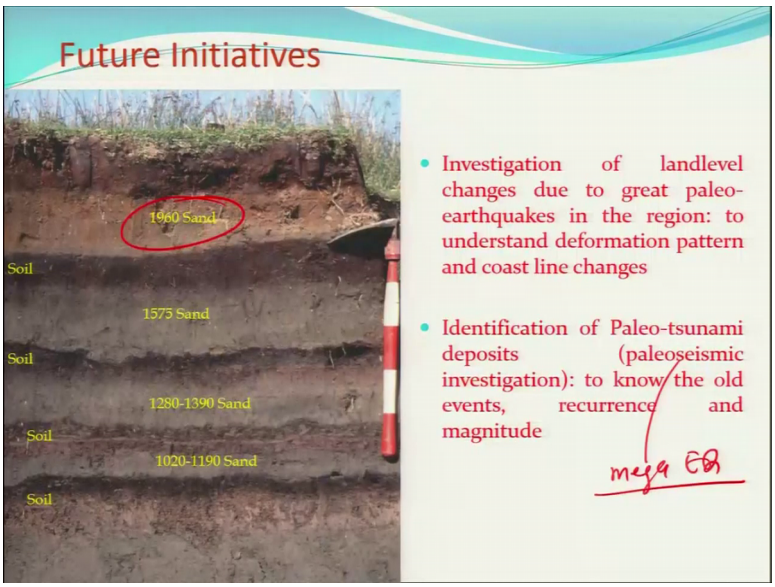

Welcome back. So, this was the last slide we discussed in the previous lecture talking about some signatures from Chile. Now let us see if you more example from Paleo-tsunami as well as from Andaman what we gather and what are the signatures one can look for if need to identify the ancient Tsunami signatures. And at the end considering all this information we will be giving you one lecture on particularly how we can model it and what are all parameters because this is one of the important parameters we have taken into consideration for calculating the Tsunami rupture area as well as the energy conditions, which we discussed in the previous slides regarding either the water depth or so.

But for us it was very important to understand that if such signatures are been seen in Andaman, then what will be the effect on the east coast and as well as in the Andaman area. So, that was our main aim to do that exercise which we will share with you in the next like next lecture or the towards the end of this course.

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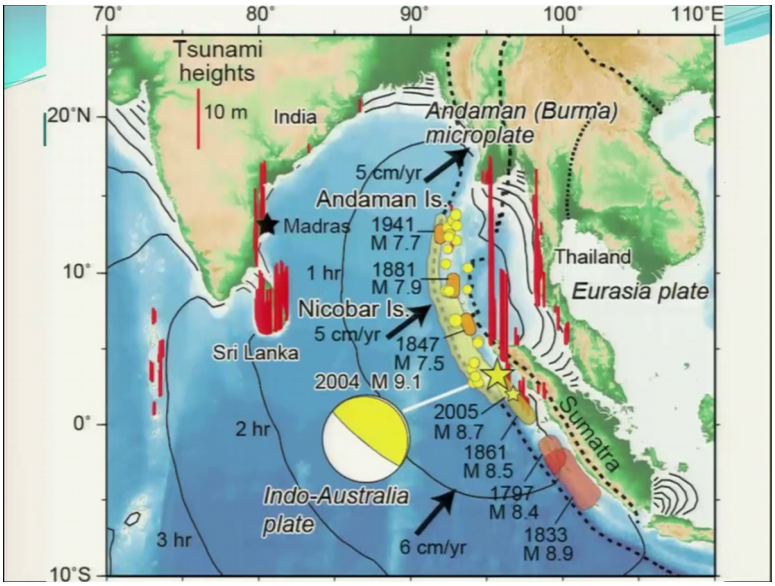

So, in total what the hazard is or people are address because of this hazard is mainly the water height or the wave height which is created by Tsunami.

Because it may as we have discussed that it may go up to 30 meters also in some locations, but of course, it will depend upon the geomorphic configuration of the coastal areas and not only that the rupture area how much is the rupture area will decide the energy conditions and another one is the what we were talking about the directivity. So, the location how close and in what direction at what angle our location of or the site of interest has located depending on that we will see the damage pattern and all that or we can we cannot say that of course, there will be in damage.

But if we are sitting close to the coast without having proper understanding that what could be why wave heights and during particular Tsunami then we are definitely putting our self on risk and that will be the hazardous to us actually. So, what has been shown here is that, typically the water heights or the wave heights at the time of the Tsunami of 2004.

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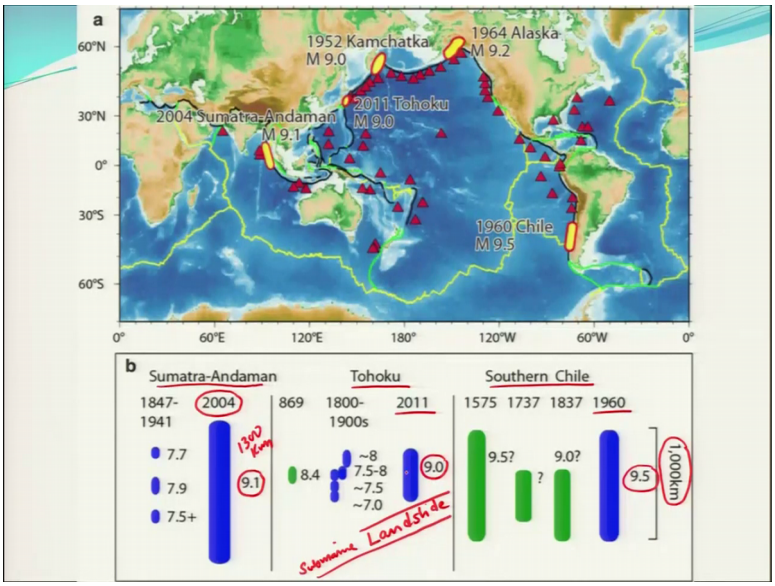

Now, one can do very easily if we have more of the stations the gauging stations which can help us in terms of issuing the early morning.

This is just to have in comparison because in last like 5 years or 6 years we had into a large magnitude or mega earthquakes, along the subduction zone one was in the 2004. Sumatra Andaman with 9.1 or 9.3 you can take and this one was 9 magnitude earthquake and 9.1 of Tohoku Japan 2011. So, the comparison what has been done here is that what was the rapture length which was observed and recorded at the time of the 1960 Chile in earthquake, the rupture length was around 1000 meters. Whereas, in with the 9 magnitude earthquake of 2011 Tohoku Japan the rupture length was around 500 meters which almost half than this one.

And then 9.1 earthquake or 9.3 you take you had 2004 that was Sumatra Andaman earthquake. Now as I told in the previous slide that this is extremely important for us to understand that what will be the wave heights and the energy conditions of the or the velocity of the Tsunami depending on the rapture length. So, if you look at the of course, this was quite devastating, but the rupture length here even with the magnitude less than 9 as compared to this one. This is 9.5 and this is 9.1, the rapture length was almost like 1300 kilometers.

So, scientists suggest that probably this was because of the triggered earthquakes in the next segments, and those segments were been also ruptured and resulted into the 1300 long ruptured length. Whereas, here the magnitude was 9 the rupture was not so, high, but the

effect of the Tsunami was very unusual and this they have correlated or with the tsunamis which I have happened the past with the less rupture length, but they say they have suggested and they to some extent have proved that this was because of the submarine huge landslide .

So, submarine landslide was responsible for the unusual Tsunami effect.

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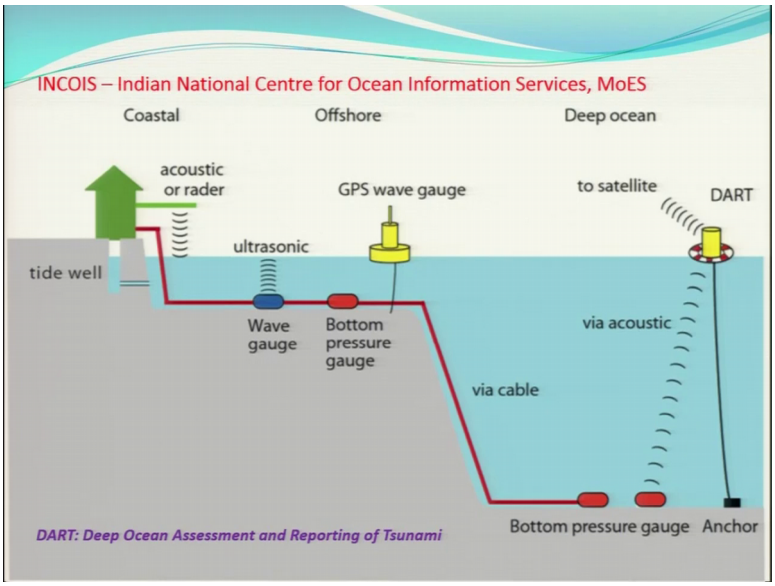

So, there are now in India also in Indian Ocean we have the bottom pressure gauges as well as we have that this is a whole system, which has been termed a dart, DART is a Deep Ocean Assessment and Reporting Tsunami. So, based and we have now in Indian ocean which has been handled by Indian National Centre for ocean information services by Ministry of Earth Science is located in Hyderabad also in INCOIS. So, this institution or organization is having their own system of issuing that is what we call an early warning system.

So, usually this whole configuration runs like this and immediately the information has been sent to the respective centers as well as it will be getting the information even at the tidal levels because of that. So, as soon as the earthquake has been triggered, so the, it the system starts sending the information to the respective organizations.

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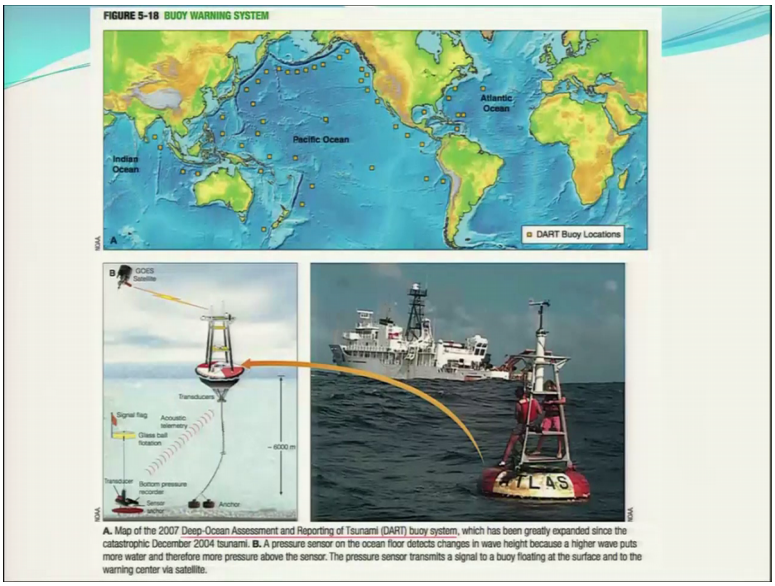

So, this is one how it looks like, this is the buoy, which has been placed and if you see the distribution. So, particularly in like the pacific ring of fire through people the countries who were having like this type of events visited very regularly like US, and Japan and all that they are having multiple stations. But India right now of course, we have two, but I am quite confident that the INCOIS having much more data points over here or the buoy which are been sitting therefore, the warning system.

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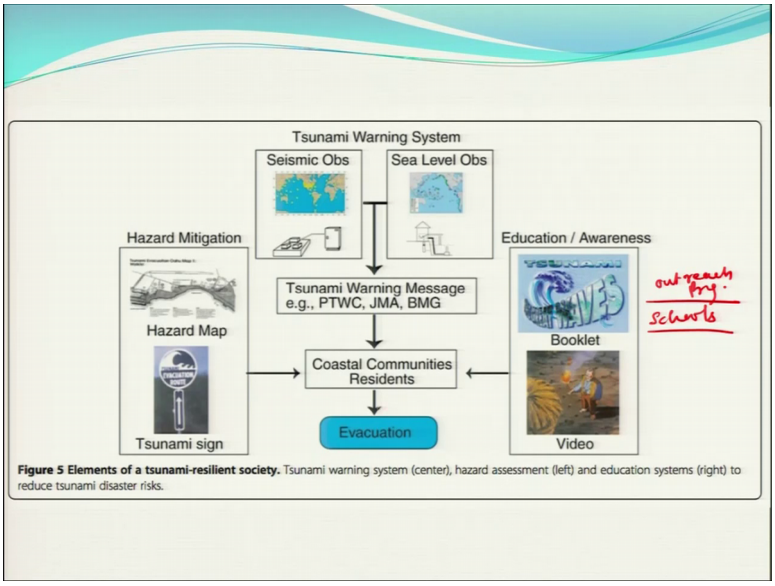

So, this is how it works the Tsunami warning system in mean total. So, like this is an elements for Tsunami resilient society if you want to go ahead with this and to reduce the hazard or to assess the hazard, we need to adequate the system. So, this is basically extreme most important. So, in US or in Japan and other countries what they have done is that they have built a platform as and how to adequate the people about the hazard and how to minimize it that is very important. So, the main aim is to adequate and to reduce the disaster risk actually.

So, this is how you can make your the Tsunami resilient society. So, starts from the basic in the awareness mainly and that we can be done at the grass root level. So, you can do in the schools. So, for kids what they have done; they have prepared the cartoons and the booklets, and videos which can help us in to up to with their understanding that how they can make sure that such warning is been issued. So, they will so, modules have been done and all that, and in villages also they do the awareness camping and all that.

So, mainly what we would say that the outreach programs. So, it should be done. Then this information mainly depends for in case of our country we have different type of hazards.

So, depending on that one can design the information brochures or they can have an outreach programs and do it. In the coastal areas those who are staying in the coastal areas, for them it will be extremely important. So, it goes to the for in case of the Tsunami mainly. So, it goes to the coastal community residents then and along with that to reaching this point of that is the final evacuation all that Tsunami warning system works in.

So, seismic observation from different points they will gather as well as the sea level observation from the tidal gauge and then combining this 2 information which is coming from the DART system as well as from the tidal gauge system, a warning or the information goes to the center and then they will issued a warning.

So, this is in case of Japan that what they are having, that they are having different system like us. In India we will have INCOIS. So, INCOIS will give this information to the coastal residents and then they will decide the evacuation plan. But before getting into this that this is very commonly done at the grass root level which is constant; constant process need to be done because this will happen or activated when there is an event.

Again this part that is a hazard mitigation, preparation of the hazard map and then putting Tsunami signs that is for evacuation which place or location will be the safest in case of when the warning is issued. People should know about it, the sign boards likewise we are we are aware about the sign boards while driving. So, these are also this evocation science will be available in nearby areas where they have located. The best place to save yourself and move to the high grounds that will again based on the map which you have prepared that.

What is the expected inundation if such an type of event like I am talking about the event in terms of the magnitude and the energy will be triggered,

so, what will be the height during that event and how much ground or the area in the coastal region will get inundated and which are the locations, where you can move that is on the higher ground.

So, the mitigation part will depend on completely on the understanding of the past Tsunami events. So, here the what we were talking about the Tsunami deposits and identifying the energy conditions all that will be helpful. So, this is an complete process where the aim is to have the Tsunami resilience society and to reduce the mainly the Tsunami disaster risk.

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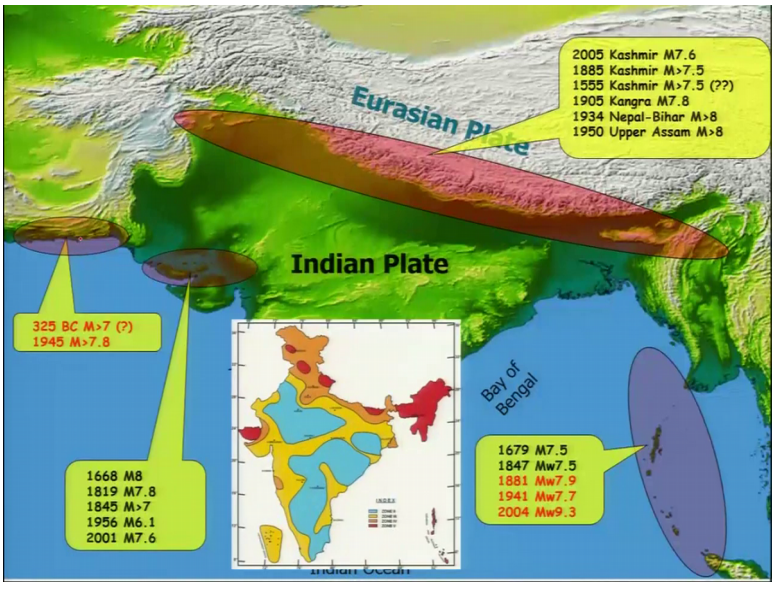

So, now India and this we have we all know that from all sides we have been cordoned by the hazardous zones like one is in Himalaya in the north, in the east of course, in this area is also in part of the Himalayan deformation.

And then we are having an Andaman here and then in this side if we look at we have Kutch even and then we have Makran subduction zone. So, we know that this area is capable of triggering the Tsunami because of its setting; mainly a subduction zone and we are having in.

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So, what usually happens during such mega earthquakes, this was the best lesson to learn of 2004. So, with this photograph which we took is from the west side of the coast of Andaman, where the west side of the coast uplifted. So, if you take an Andaman island like this and then you move further known having the Car Nicobar along that and then you go down to the (Refer Time: 14:09).

So, you have there is Andaman island. So, east and west so, west side got uplifted and some places and most of the eastern side got subsided. So, this was very clear signatures which were we observed during our survey. So, this is the example of an small island which got uplifted on the west coast. Now such observations are very much important to be recorded because this will affect day to day life in the region as well as the coastal like habitat will also be affected. So, aquatic life will get affected as well as the vessels which are coming in through the ocean route and all that it should also need this information.

So, mainly the coast guard of the navy and owning commercial way vessels which are travelling or getting into this area should require that what will be the water depths. So, water depths mainly changed or after the 2004 Sumatra Andaman earthquake.

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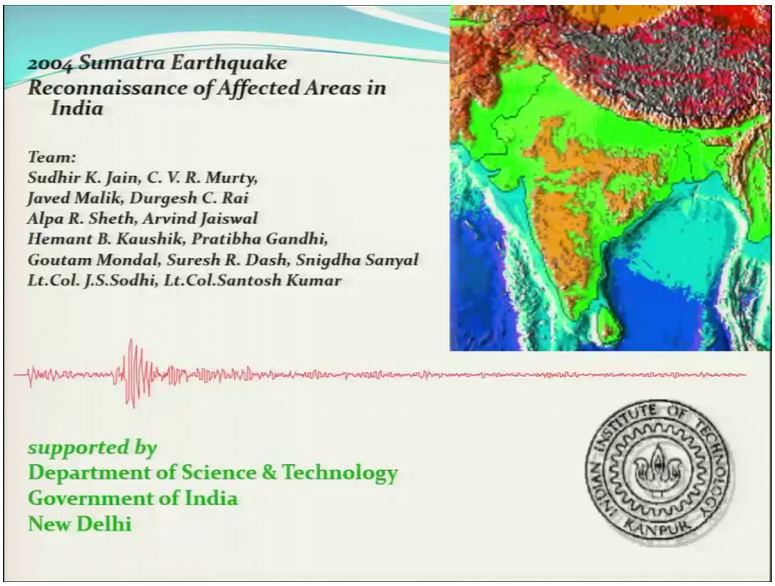

Now, this I will quickly share what we observed and what was the aim of conducting this reconnaissance survey immediately after 2004. Sumatra Andaman earthquake, the team has been listed here. We were of couple of us were from Civil Engineering department at that time, and then we had and some officers Lieutenant Colonel Sodhi and Santosh from army, who were doing their M-Tech here at the department of Civil Engineering and of course, now they might be have been placed at very high rank.

So, we had an very big team from Civil Engineering and process Murty and Jain, Professor Durgesh Rai and then people from the industry also joined Alpa and Arvind, and we conducted in very quick survey for couple of days. Teams were distributed and we covered almost the entire batch of Andaman and Nicobar right from North to South.

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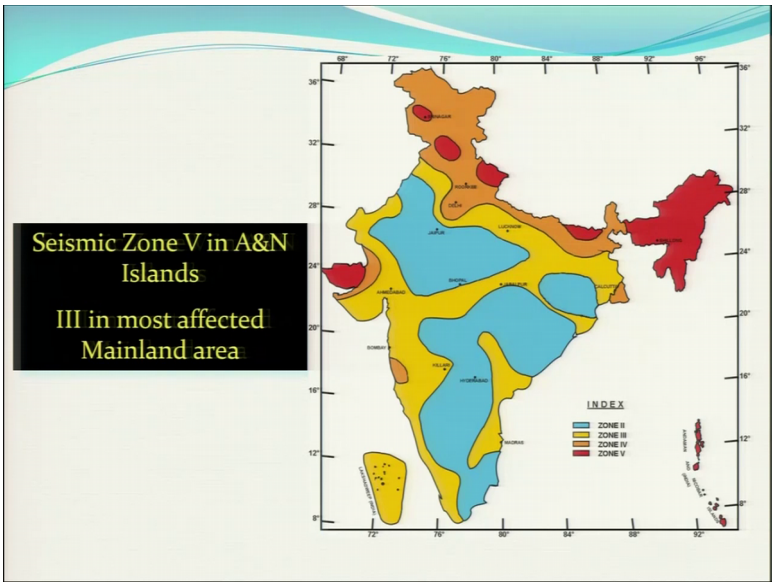

So, quickly just we can look at that what happened in the in this area and then what was the effect to some extent here, but I am not going to talk about this one, but I am mostly of this area.

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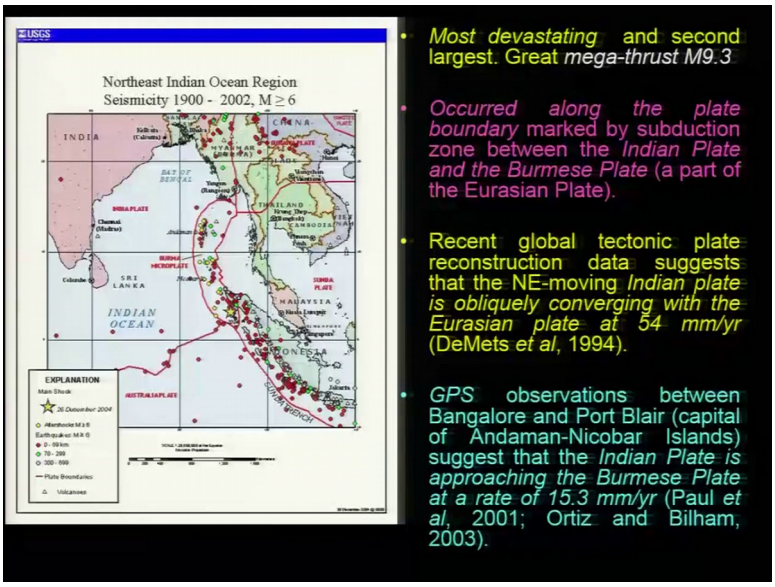

So, Andaman is in a very ideal tectonic has an very (Refer Time: 17:00) tectonic setting to trigger large magnitude or mega earthquake since along the subduction zone. And this is again we can justify having the understanding from the past events.

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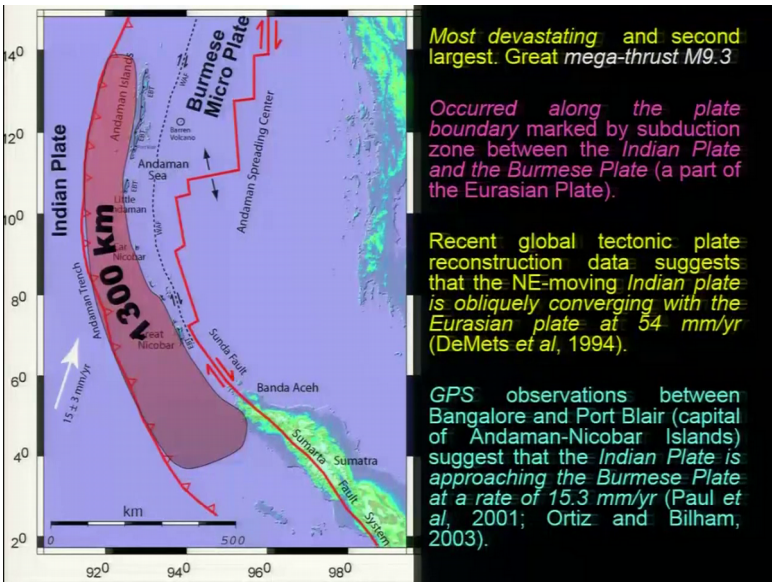

So, this is the configuration here. So, the Banda Aceh and the, or you can say the Sumatra area, Indonesia is sitting here the islands and then we have an very smaller islands. So, this is the southernmost step of India which goes when smaller islands (Refer Time: 17:32) then we have the bigger Andaman Island.

So, this is the whole island chain in 2004 earthquake was triggered here and start it started its journey in terms of the rupturing and it went right to the tip of this one. So, almost 1300 kilometer rupture was there and the effects which will we saw is was really traumatic.

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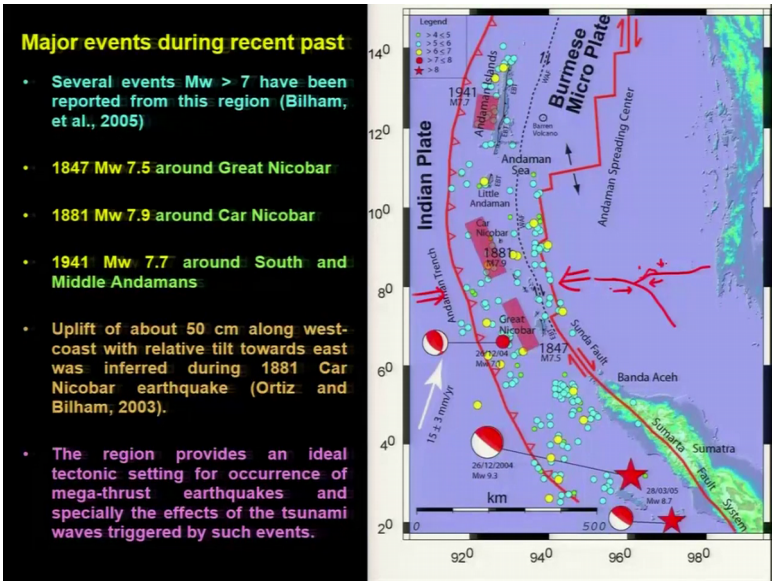

So, even in the past in this area, we there was the there were earthquakes which took this region are were 7.5 7.9 7.7 and they were in 1800 and 1941. Apart from this there was another event which was triggered here was in 1668 or so; so 1668 or maybe around 1672.

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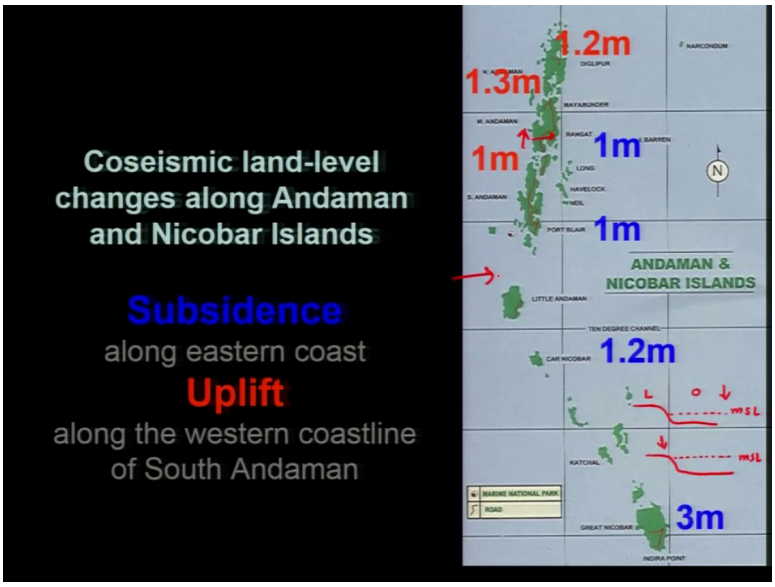

So, there was another event in this area. Now, talking particularly about the events related deformation, that is 2004 then what we observed was that the southernmost step of the India subsided by almost 3 meters. So, blue numbers which you see here is indicative of the land has gone down subsided. So, on if we see if I just put this here, so, this is an land area and there is an ocean area and the ocean water depth is around here. So, this we can say MSL.

Now when we say this area subsided then what is happening is that, you are subsiding this area I will draw the same profile here. So, here; so, water level has remained the same they may say they remain the same, but this area has gone down. So, it is subsided. So, an in ultimately what will happen that the this area that is the near coast area will get affected because this will start getting inundated and similar example I will discussed in for 1960 Chilean earthquake.

So, what we saw was the maximum subsidence here it reduced this side and went right up to 1 meter port Blair also subsided by 1 meter and the western side the west side got uplifted. So, basically it was like this got tilted ok. So, this area was uplifted this subsided. So, it was not pushed from this side and because if you see the configuration here, then, what we have? This is the trench area. So, the deformation is between those two plates. So, this is overriding

and this plate is going below at this junction. So, if I put the cross section then it will come like something like this actually. So, this is overriding. So, this portion slipped and this of course, moved towards it. So, push was so, this resulted into the tilt of the Andaman which is sitting over here.

So, it tilted this area subsided this got uplifted here. So, coming to this like what we see here is basically we have the subsidence and we have an uplift which we wind up to 1.3 meter.

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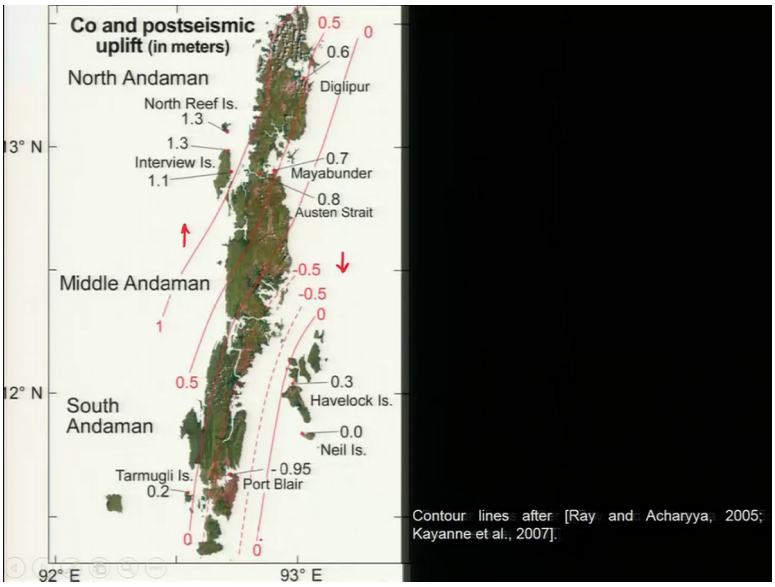

And just for the Andaman Island collecting all the information what we plotted was that therefore, this was then the 0 line here this is pivotal line along which the tilt was took place. So, this part went up and this part went down and they in this area there was no effect. So, it just rolled over ok. So, the rolling effect was been seen here. So, this side it was around 1.3 meters and then we have the displacement or what we can says this subsident related to displacement was almost like 1 meter.

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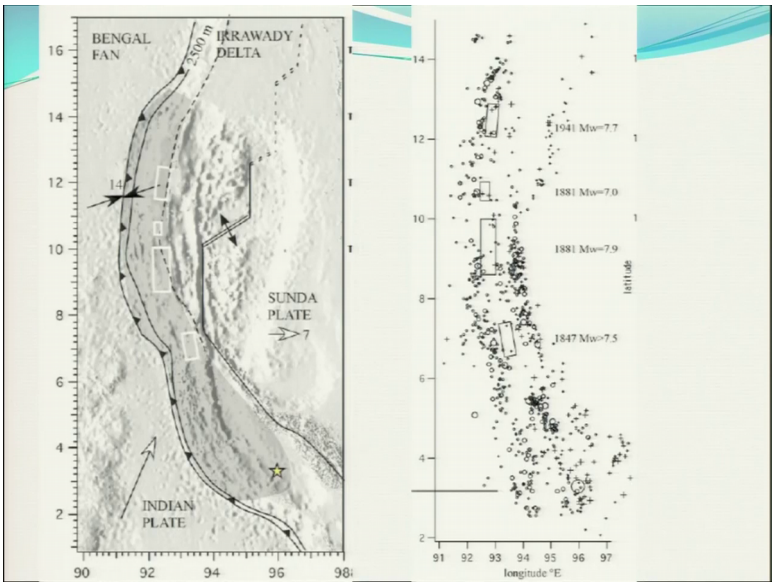

So, this is the past records, we are having like couple of earthquakes, which were been reported by the Britishers that this period the Britishers occupied this area and of course, in 1940 or 45 Japanese also occupied this region.

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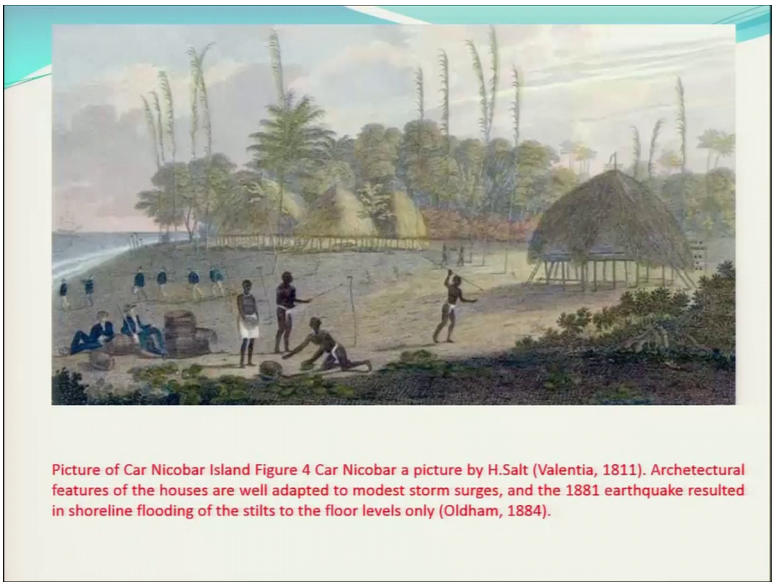
Picture of Car Nicobar Island Figure 4 Car Nicobar a picture by H.Salt (Valentia, 1811). Archetectural features of the houses are well adapted to modest storm surges, and the 1881 earthquake resulted in shoreline flooding of the stilts to the floor levels only (Oldham, 1884).

And this picture again the sketch it comes from the one of the publication which was done in 1884 by Oldham, which talks about that the local tribe in that area which survived. Even during 2004 this tribe the people from this tribe survived and because they understood well about the what we can say the storm surge. But this was not storm surge, but this was in

Tsunami, but they understand that what best you they can do at the time of any surge either it is a Tsunami wave or it is in storm surge.

So their construction is typical that they the construct their houses the circular house here, and then floor sets at the few meter above the water level. So, if there is an Tsunami and they understand that what will be the height, then the Tsunami waves pass through this one and if since you are having this circular columns here of wooden columns, then it will disseminate the energy also. So, they are safely sitting above the water. So, this is another very important aspect that how people who understand the phenomena or the process makes themselves safe or they reduce the risk from and particular hazard.

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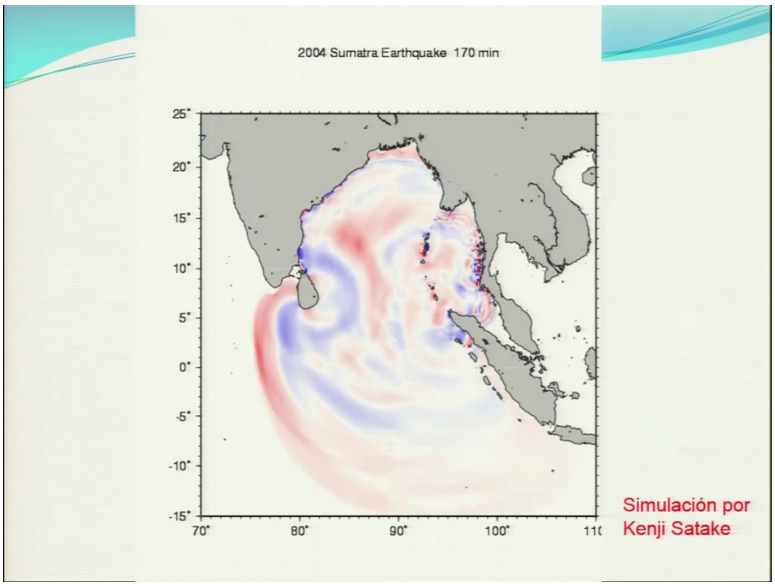

Now, if you look at this is a model which was been prepared by Kenji Satake from Earthquake Research Institute University of Tokyo, which shows that this was the whole front which got ruptured and then the Tsunami waves got generated and what probably the height but it was not very particular, but one thing which is which came out very interesting was that we got enough time for this portion to receive the Tsunami waves. It is almost like around 300 minutes or so.

So if I play it again you just watch it that how it originated and it was not just that this area got affected, but the region surrounding the Indian Ocean were affected. And that is what you must have watched the some videos which are available on social media that what was the

effect on the Thailand side and watch for the effect of course, in the Indonesian side and the cities which were sitting close to the east along the east coast.

So, the another worry which is coming of course, is that we need to and of course so, far I know that INCOIS has already generated the inundation maps along this coast in the east side, and also taken care that what will be the inundate inundation the inundation of the area during in particular event of the particular energy of the and then what will be the effect of that to the local people.

And as well as to the nuclear power plants which exists today and which are supposed to come in near future. So, if you take this then you will understand that how much time it more almost took to teach at almost 1.1 20 minutes it took to reach the Indian coast.

So, we had enough time to announce and we had enough time to issue an early warning system and enough time to implement the evacuation plan, but none of this way with us we will not having any early warning system with us we were not even aware of that what will be the effect, to the coastal region and how we should have plant the evacuation. So, nothing was there with us because we did not even thought of that this type of event will occur.

Still we try to underestimate most of the things, but I hope that whatever the research we have been doing and what are the information we have generated, the higher authorities or we can say the organizations or the institutions or the ministry should take this in they should consider seriously and they should reevaluate if there is something missing out of this ok. And recent research we identified almost 7 Tsunamis from one single location and also we are pretty sure that they will be having different effect if similar type of events have been triggered in this region.

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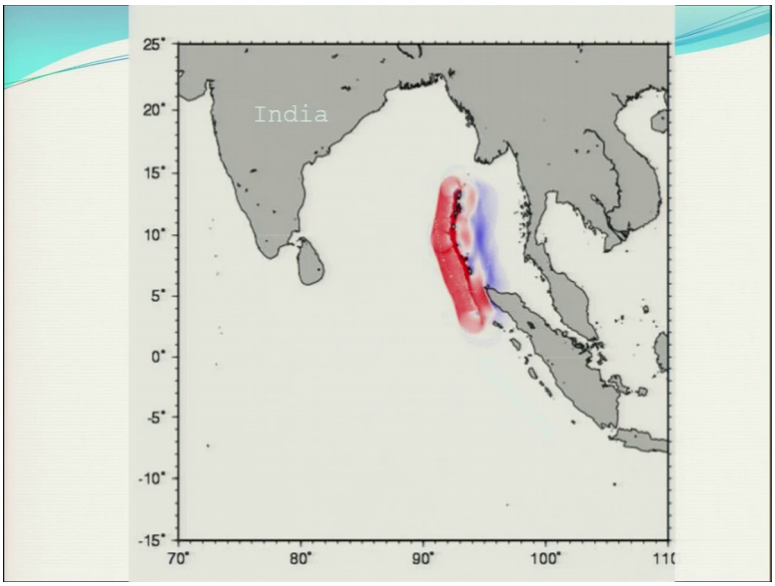

So, let us see quickly the uplift and subsidence from this region related to 2004.

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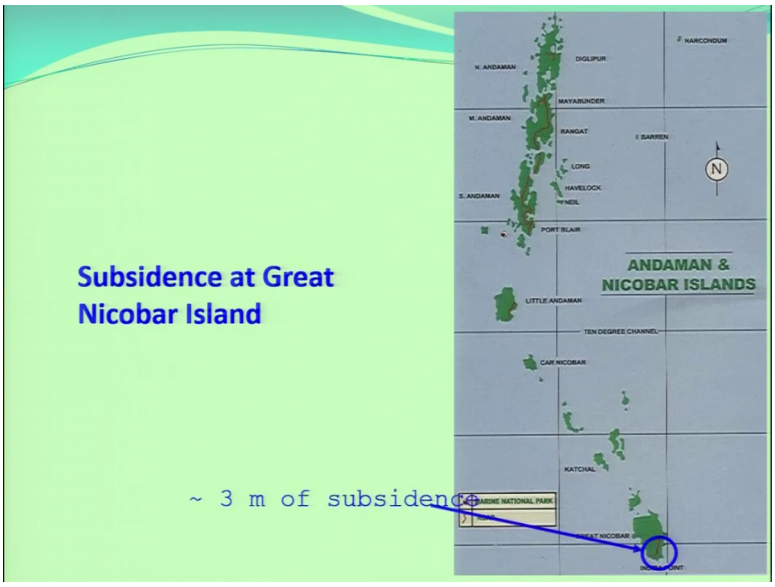

So, I will quickly go through. So, you had only the great Nicobar the Subsidence was around 3 meters.

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So, this was the photograph which was been taken before by coast guard where you can see the hut sitting here.

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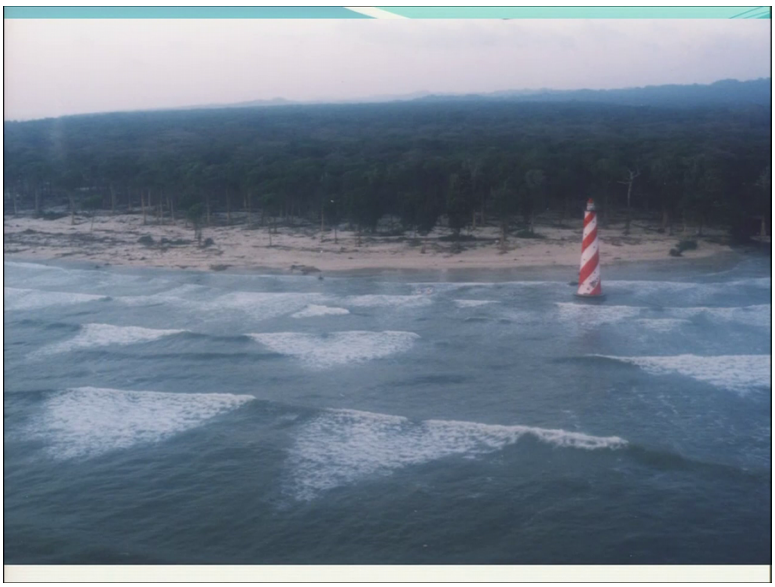

But immediately after that that is 2004 Tsunami, it is a completely wiped off the beach has moved inside. So, this is because of the land subsidence, but the whole area was completely wiped off and eroded this means. So, you are having now the beach which was sitting here it is now sitting at the back.

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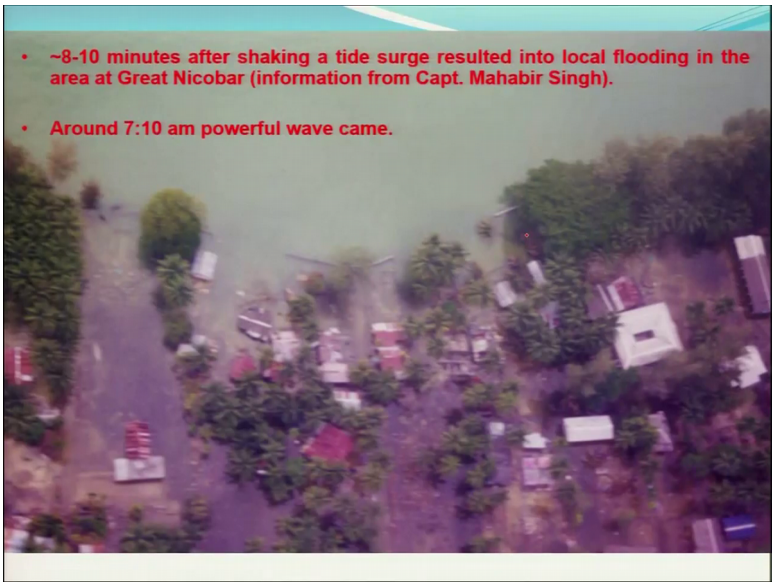

Similarly, was the case in the Car Nicobar and Great Nicobar only. In another region the area remained under water because of the subsidence.

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So, these are the photographs of the coast guard office, which are the headquarter in Campbell Bay and its Great Nicobar, where they have the experience not they water in never use to enter into their premises, but now it enters during the two during high tides.

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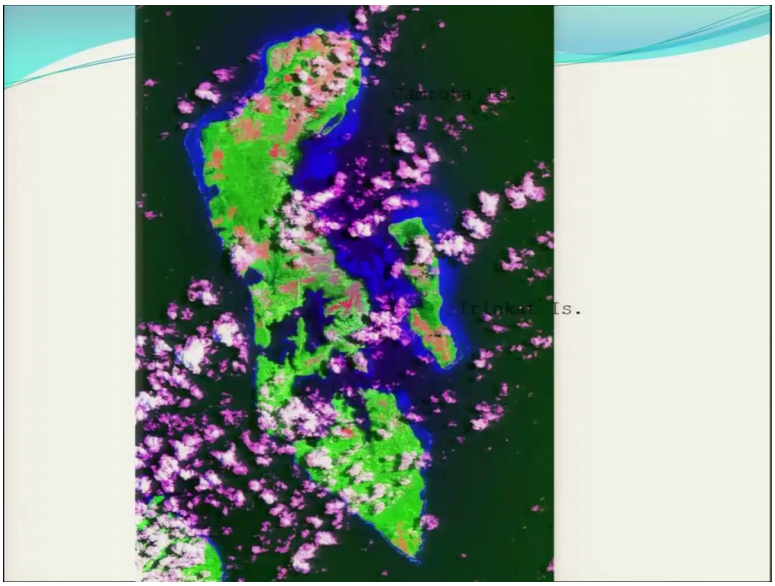

And this is the photograph or the as with I want to show that this island also got subsided and because of that because the height is not so much what we see now is that these are divided into two different islands.

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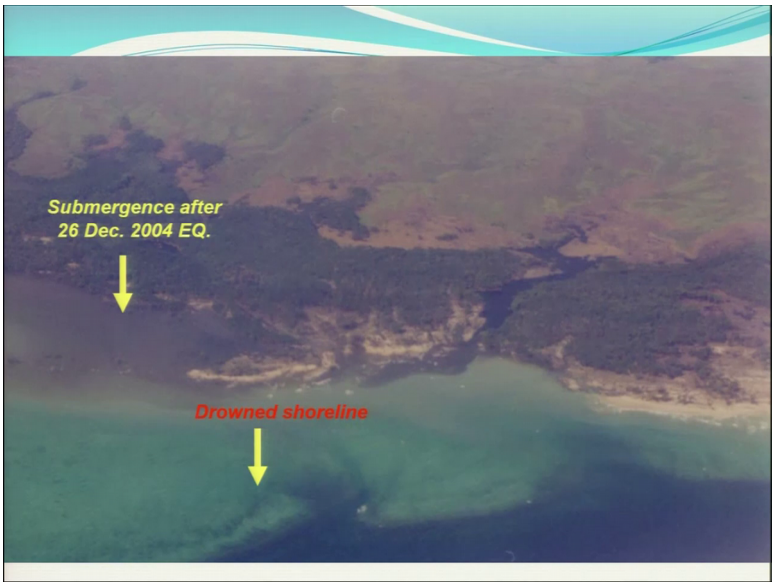

And that was because of and this area, we also if we were able to see some drowned coast lines which were like this is an older coastline here ok. Drowned shoreline and this and here social language got subsided in 2004.

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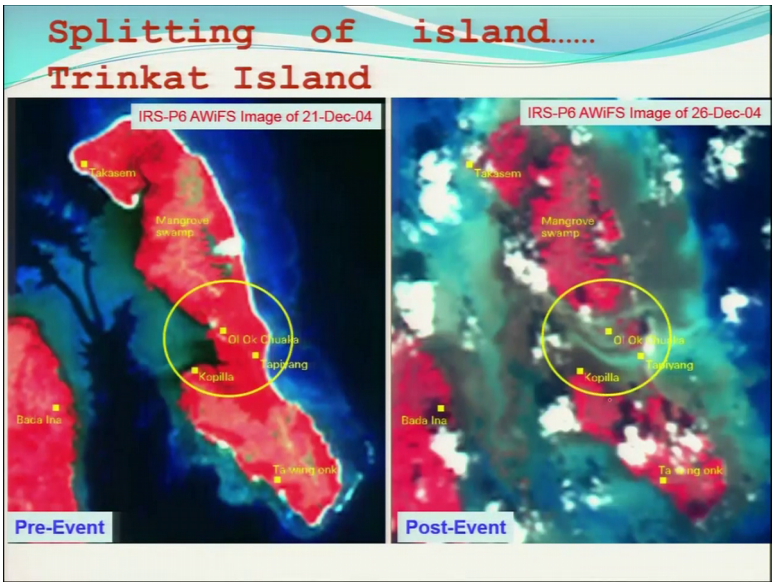

Trinkat Island and these are the pictures the images IRS images, which were been taken before and after so, pre event post event. So, this what happened, but we got this images later on.

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But when we few across this area what we found was that yes of course, this area got subsided and because of its less height now the water is flowing through and through across this one.

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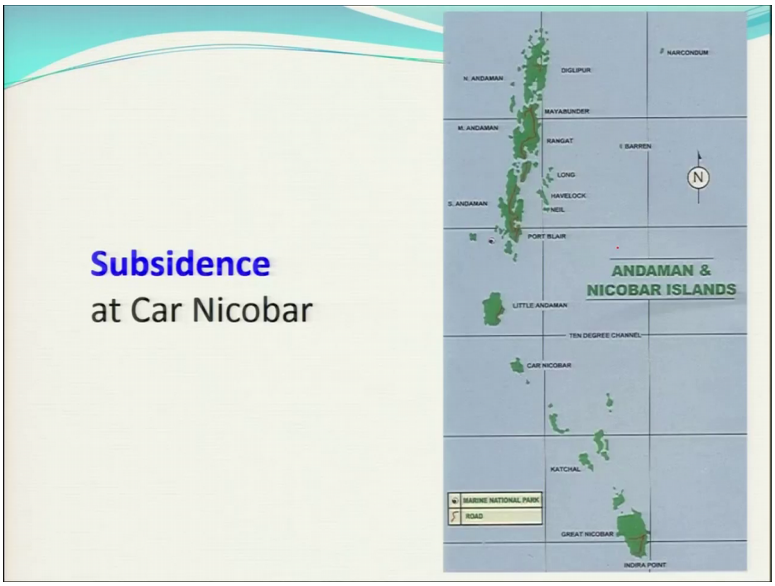

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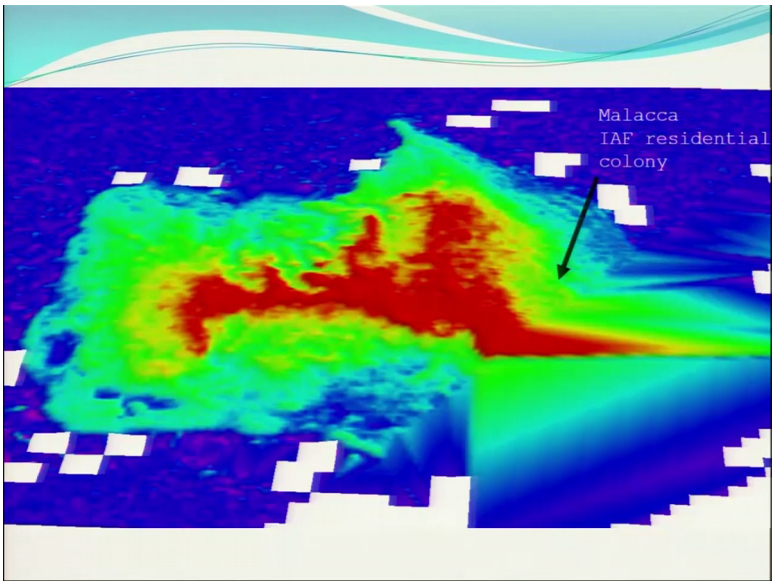

Coming to car Nicobar the height of the say this island the elevation maximum goes up to 70 to 80 meters. So, it is an very flat almost flat island and beautiful beach areas and the coastal environment. So, this whole area got affected and this was the residential area of the army and Indian air force.

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So, you have the runway which was long back constructed by Japanese people, but now it is with us.

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So, this area was occupied by the Indian Air Force and the Army people which was completely wiped off, because of the 2004 Tsunami and the earthquake.

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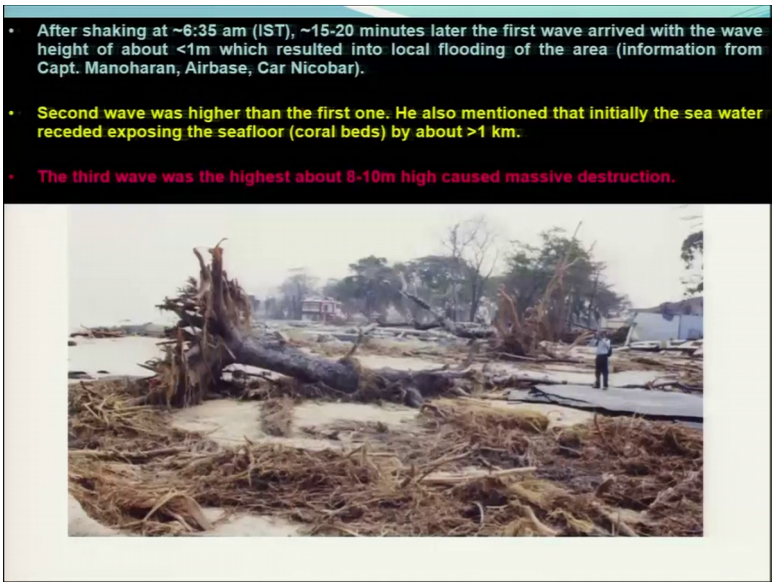

There is what happened and most sad part was that this event was on 26th morning and 25th was the Christmas Eve. So, everybody enjoy it late night and the in morning they face this event.

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So, many people got killed from this region because of their unawareness maybe.

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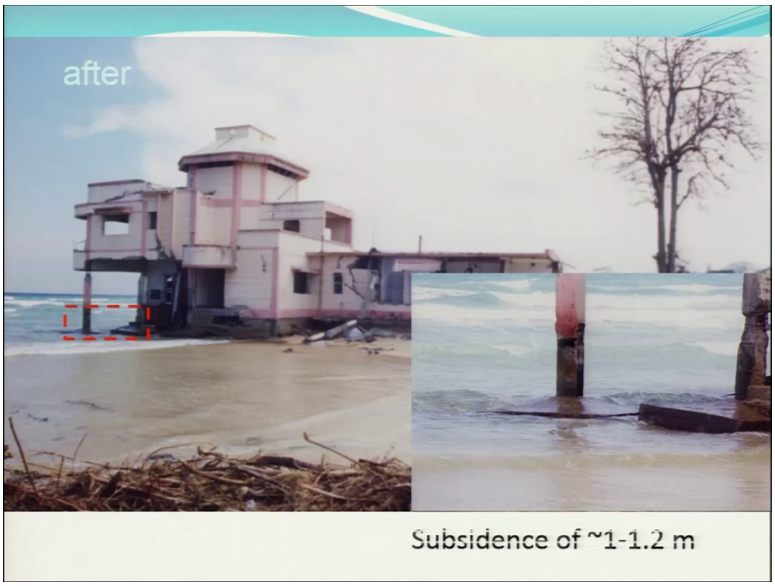

This again it showing the inspection bungalow which used to have almost 100 meter wide beach, but now it is in water during high tide that is because of the subsidence.

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So, you can look at that this was the height almost like 7 meter which topper most of the top of the houses and the return waves you can see with the hanging close and the on the window grill.

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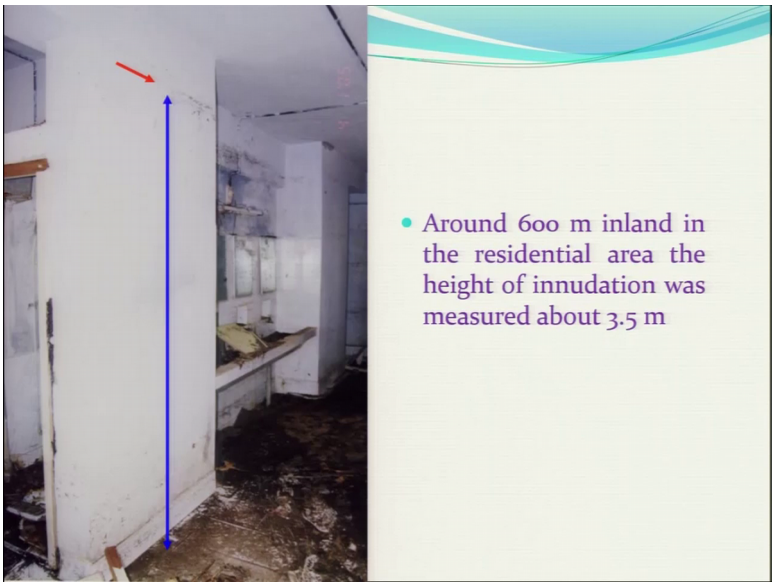

So, and then the inundation of the water, which was almost around 600 meters inland from the boundary coast was around 3.5 meter. So, I will stop here and then we will continue in the next lecture.

Thank you.