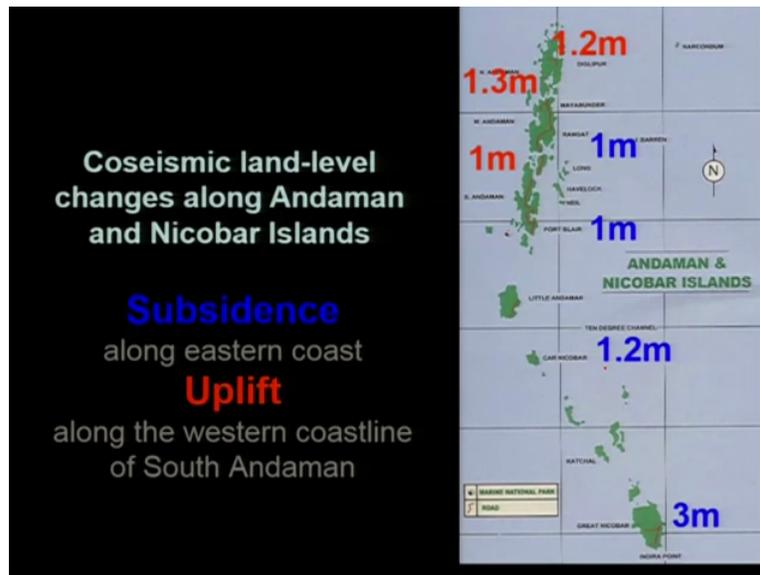


Earth Sciences for Civil Engineering Part-2
Professor Javed N Malik
Department of Earth Sciences, Indian Institute of Technology Kanpur
Tsunami and related hazard (Part-3)
Module 3
Lecture No 14

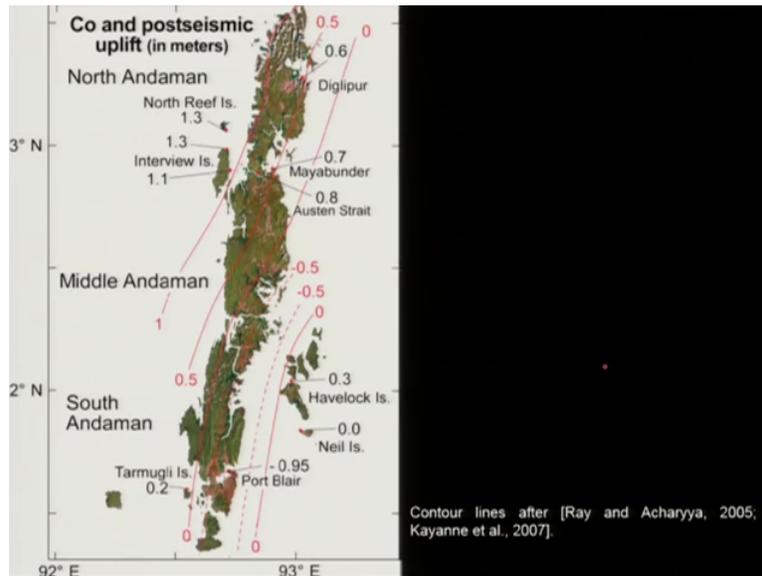
Welcome back.

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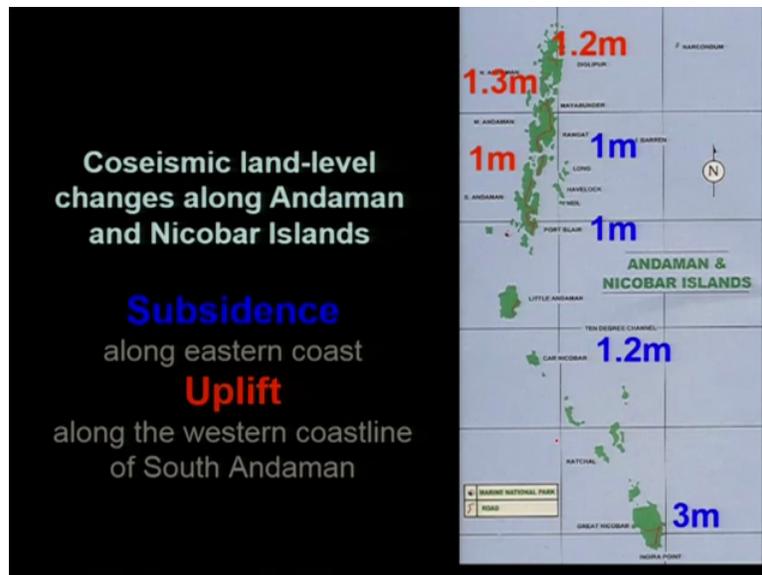
So this was the slide which we left during the last lecture and as I told that the blue ones are showing subsidence and the red ones are the uplift.

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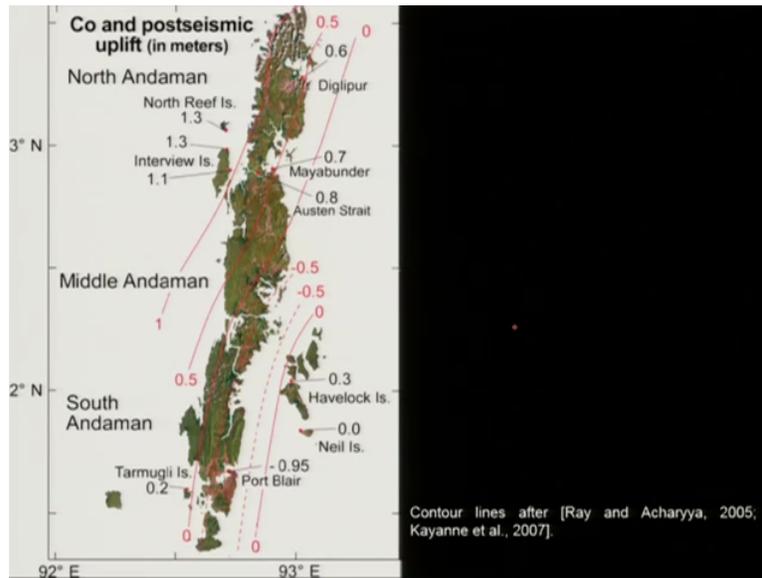
So very detailed observations which we made and particularly for portion okay Andaman islands.

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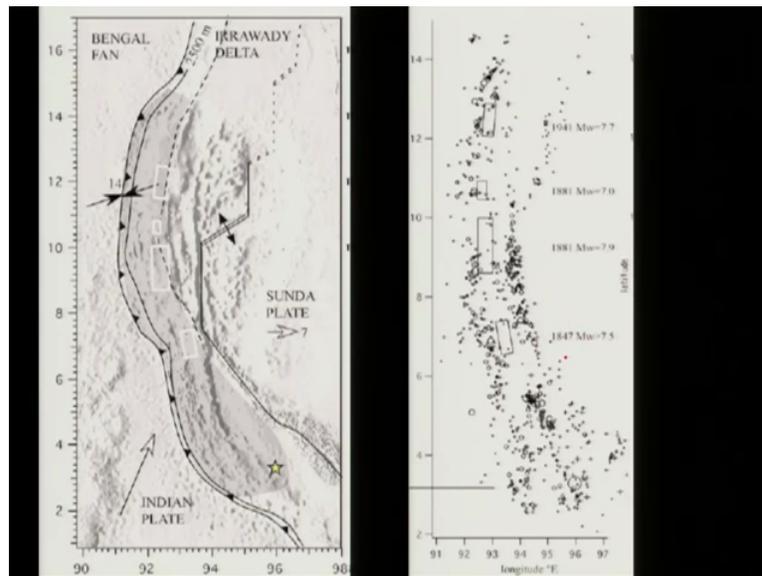
If you look at this one, these are termed as the Nicobar islands, this one here and this part is the Andaman island.

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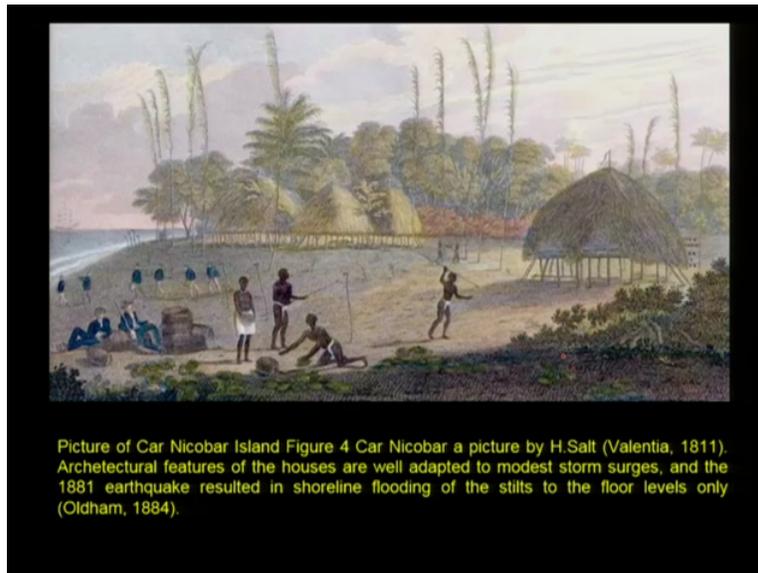
So what we found was there was a very clear cut pivotal line which passed through this area where on the west, we had an uplift on the (sou) in east, we had an subsidence okay. And this has been clearly observed on the on the surface also.

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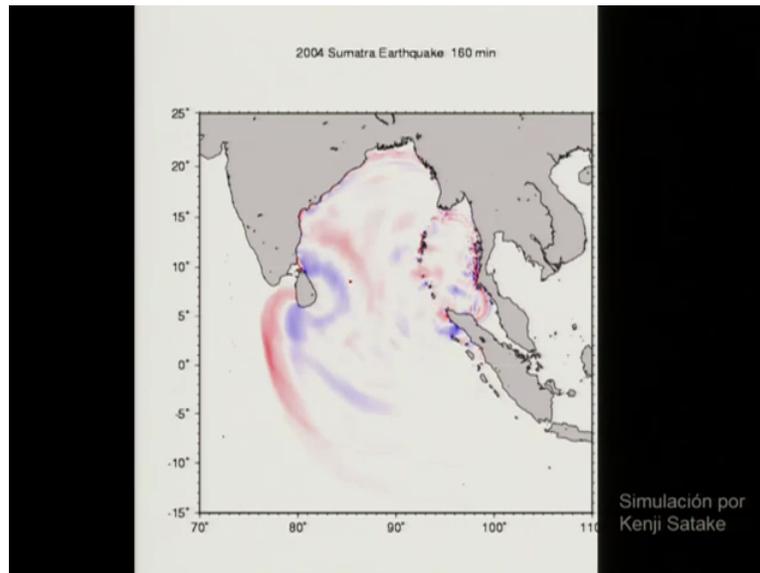
Let's see more signatures of that. Now the land level change was also been reported from the 19th century this was from 1847 earthquake in Nicobar area okay.

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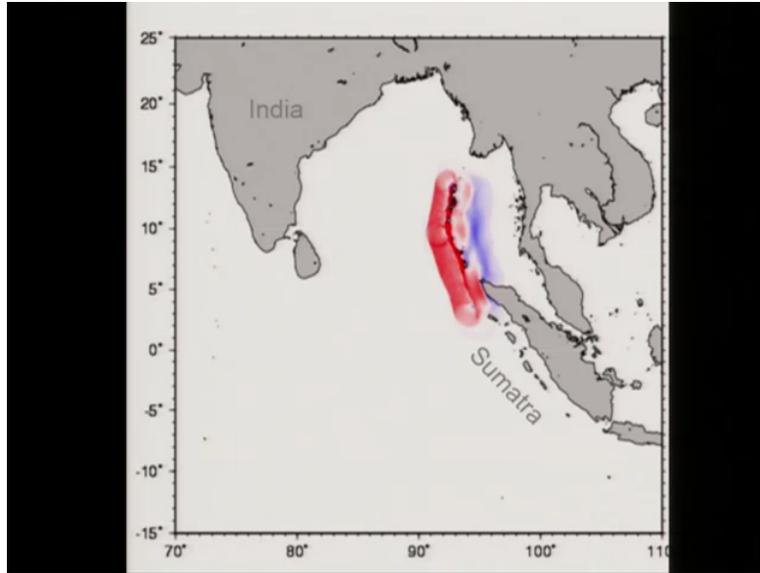
And this was the sketch which was been produced long back by Oldham in 1884 which shows that these are all Nicobaris okay, the tribal and they this area was been affected. Now, the most important observation if you carefully look at. These people very well understand the process and near the coast to save themselves from the inundation from the tidal waters, they construct their houses in a very typical pattern okay so the ground portion will be all open and then their floor will start, their house will be from the slightly elevated area okay so this elevation helps them to get protected from the the water inundating during high tides okay.

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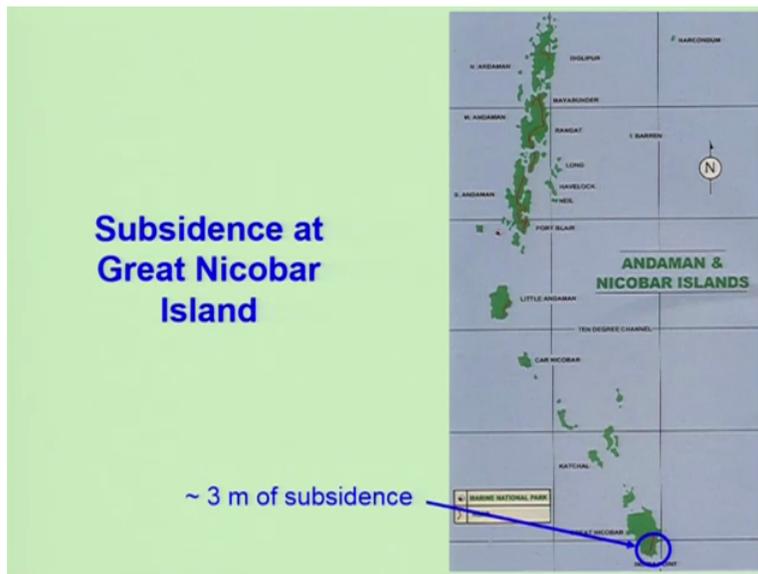
So this what happened in 2004 okay, the (who) whole area got ruptured here and then Tsunami triggered and it reached the coast. Please pay attention on the top of this one okay so how many, how much time it took to reach the Indian mainland coast okay. I will put this again and let's see if what what best we are able to see here again. So it took almost like 100 to 120 minutes to reach the the mainland coast that is the eastern side of the mainland India okay. So we had enough time to warn the people.

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So the west side uplifted and the eastern side subsided.

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So coming to this part that is the southernmost tip of India, what we call the Indira point or great Nicobar region, what we found was, the subsidence was around 3 meters.

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So this photograph was taken by coast guard before the earthquake and you see here, there are a lot of houses at the base of the watchtower okay and then this side, you have the beach so what happened after that okay.

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The whole area got inundated and this whole the the the region which was occupied by the houses (high) houses got wiped off. Now the beach has migrated towards the land so this is what it indicates that water level has gone up but this is not the case. The land has gone down okay.

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This was again another problem which was been faced in that region, in the great Nicobar.

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And this was at again at the great Nicobar. So we we had detailed discussion with the the army people there and they (eu) they told us that this is the boundary wall of their office at Campbell Bay, coast guard district headquarter so this is the boundary wall and after this, they had almost

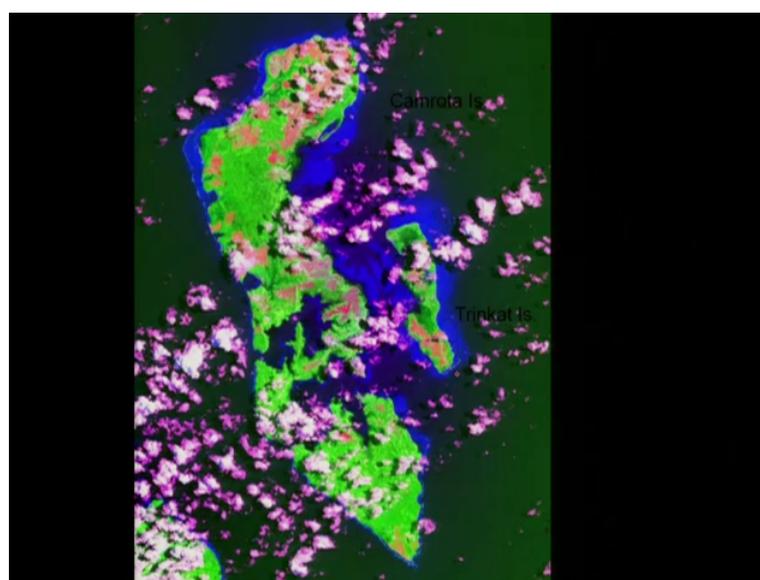
like 60 to 70 meter wide beach which now they did not see okay because this area got subsided and they are frequently facing face problem of inundation during high tide.

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The Tsunami wave reached almost like 2 to 3 kilometer inland in the Car Nicobar, Great Nicobar area and then impact of the wave and because of the ground shaking, there was lot of damage which was been observed in this or experienced in this region okay.

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The another beautiful part which we came across was the some of some people from this region, they informed us that 2, this (a) this island, that is Trinket island was splitted in 2 parts okay because of an earthquake.

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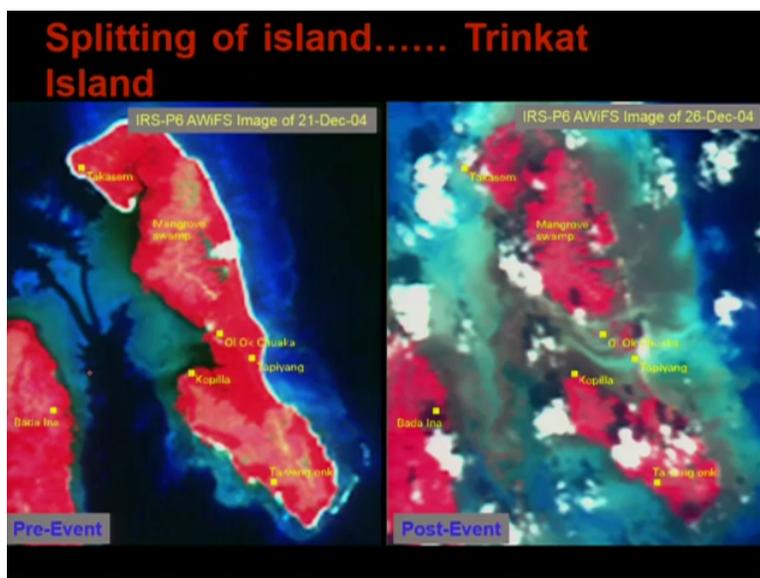
But when we flew on this region, what we observed was was not exactly the same because it was what happened was that this area subsided and now the water has been passing through and through from this region. So there was an because of the subsidence it happened. We also looked at some beautiful signatures here. The next photograph which I am showing was the aerial photograph which taken from this place looking to this side and what we saw was that there are signatures on some drowned shorelines okay so this clearly indicates that this area experienced subsidence in the past also but not always there will an subsidence. In some earthquakes, there be an uplift also and that has been by the flat surfaces here so one flat surface is there here, another flat surface is here so this indicates that there was an uplift also experienced by this area in the past okay.

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So drowned beaches if you or drowned shorelines sorry, if you look at this configuration here, the coastal configuration, it clearly indicates that there was shoreline which existed before which is underwater now and this portion is submerged because of the 2004 earthquake. So this area again got subsided in 2004 so this is a drowned shoreline and this was the submergence after 2004 earthquake.

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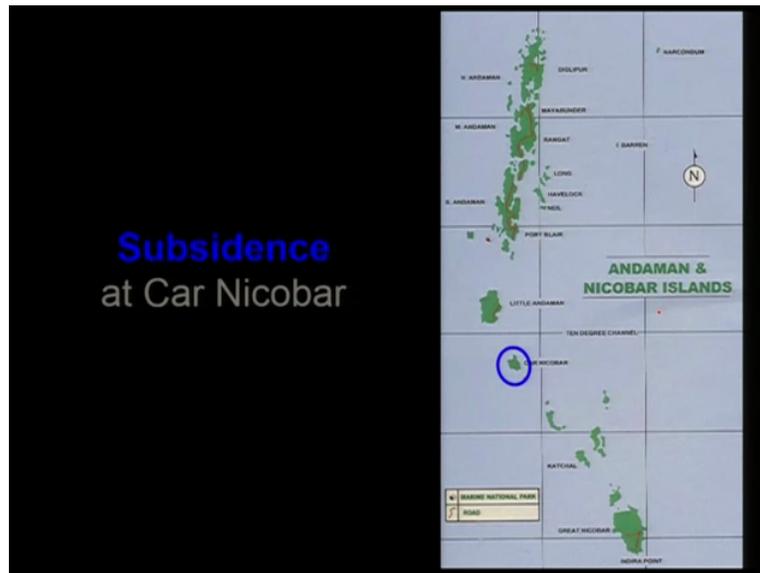
This is what the story I was talking about. The splitting of the islands okay. This image was been taken by NRSA before the event and this was after the event okay so you clearly see that this area, this of course it looks like that this was been splitted in 2 islands because this happened because of the subsidence and the water getting inland okay along the coastlines. So this area is over here compared with.

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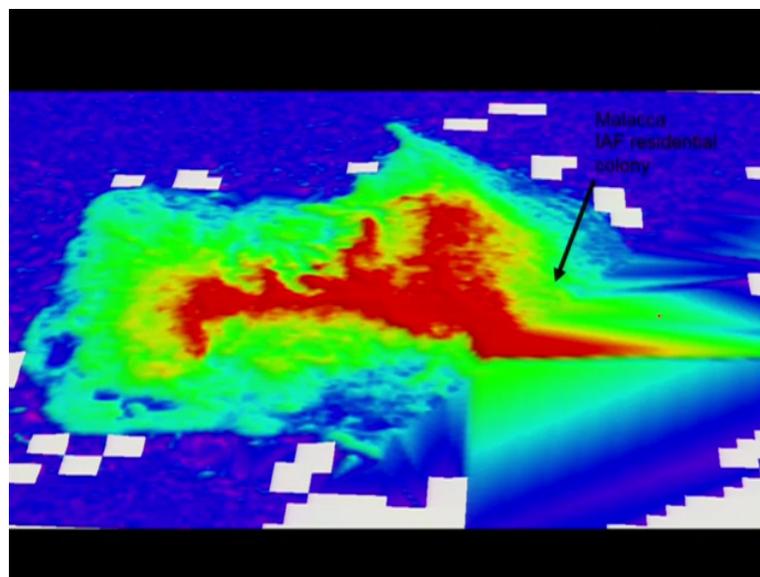
And this is what we took the flight and we observed okay so there was the splitting over here but this was because of the subsidence.

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Now coming to this part, again it was dramatic and very sad experience.

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This is one of the most beautiful small island and where this side, this is in eastern side of the island and the height of the maximum height in this region of the hills, which goes maximum up to 70 to 80 meters okay this is not very well developed or elevated island okay. So relative height is very less here and we have most of the areas are and here are having flat land and then we are

having a very beautiful beach here okay so this portion is the portion which is when utilized by Indian Air Force Residential colony and they have the runway here so this is the best place which they found that can be used for the stay and all that okay.

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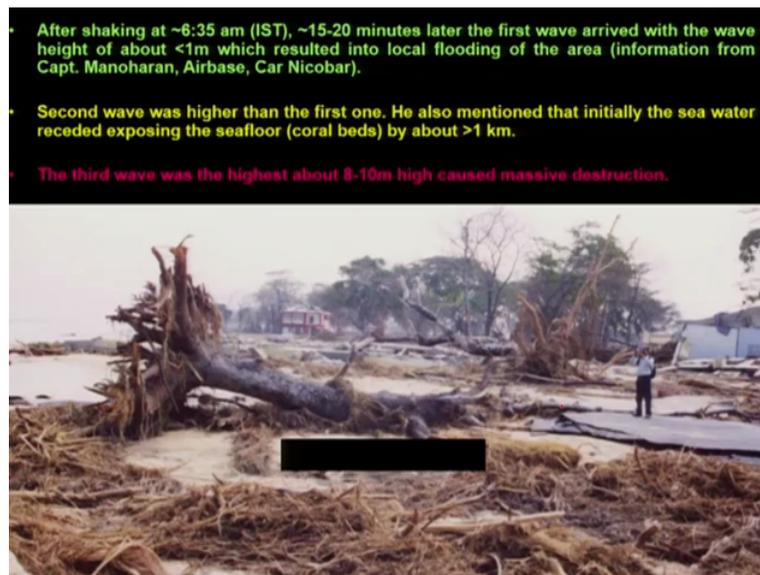
So this strip you see here is your the airbase and this area was been occupied by the Indian Air Force people okay so what happened after during the earthquake.

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Everything was been wiped off okay. All the houses were been completely wiped off. Only one structure, that is water tank it remained okay and the reason for this because it is circular and the thrust was been like the forces were been distributed or the energy was disaffected okay, so you don't see much of the damage occurred on the circular structures okay but the houses were been wiped off and then there was an very huge scouring of the the land because of the ground shaking as well as because of the the Tsunami.

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So if you look at this one what we we discussed with these people because this is one of the the deadliest event they experienced in their life okay so we spoke with some of the survivors and one person was from the airbase was Captain Manoharan okay. What he informed us that this event occurred on 26th okay and 25th was the Christmas Eve, so they had like big parties going on and they slept very late so in the morning when this earthquake took place around 6:35 AM okay so after 15 to 20 minutes what they have reported us okay.

They experienced the first wave arrived but this first wave was not powerful as as what they informed us okay and the height was less than a meter or so. So what we evaluated based on this that this was the, this was not the Tsunami waves but this was the inundation which took place because of the subsidence because the land subsided and the area was been, the water came in okay, the ocean water.

Second wave was higher than the first one. That was the first Tsunami wave, that what we interpreted and they said the third wave was much much more powerful and the height was almost like 8 to 10 meters okay and that caused the massive damage and this is what I we were talking about that in Japan, how people were been evacuated and then people experienced first wave, second wave and third wave so here also, they have multiple waves which came in which were triggered by the 2004 Sumatra Andaman earthquake okay. So the the last wave what they say as per their understanding third wave was much more powerful and the height was almost like 8 to 10 meters okay so 8 to 10 meters means you are crossing the the ground floor and the first floor okay, the top of the first floor. Giant trees were been uprooted which you can see here and then you can imagine with the height of the person here standing.

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So lot of huge destruction took place on this okay and then corals, the courser deposits were been carried. Sand was deposited huge thick sand was been deposited after the event.

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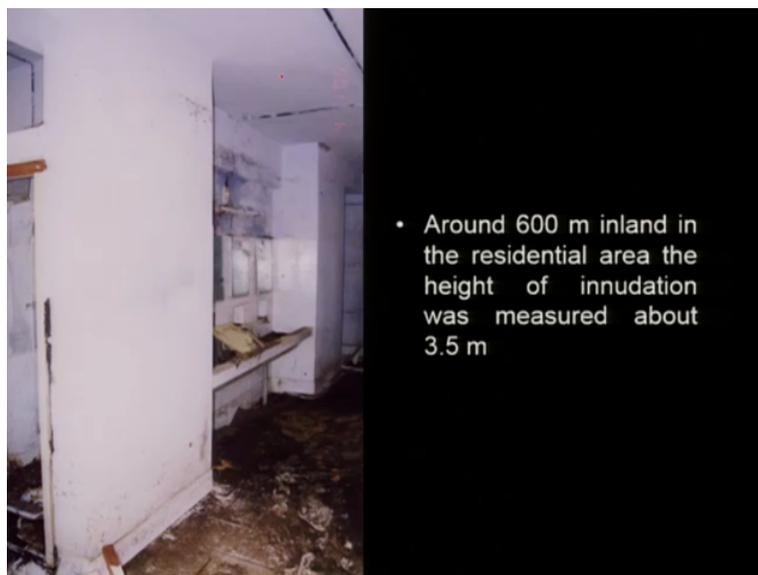
And this is the picture of the inspection bungalow of the Indian Air Force base which is right now sitting in the in the ocean okay closed to bay and they had like very beautiful beach which used to extend for almost like 100 meters, further lift here okay but now they don't see that okay so this is sitting in water now because nobody will construct an house or an inspection bungalow where you have the problems of inundations okay. So this is what clearly indicated that this area got subsided during 2004 earthquake okay.

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And as I told the third wave was almost like 8 to 10 meters high which you can see from the the clothes which are hanging round the window and the the top of the roof is been destroyed okay.

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And this is the indication again of the the inundated watermarks okay or the watermarks formed because of the inundation and stagnation of water for some time which reach right up to this one okay, so it was almost like more than 3 meters okay. So this is within the house we we were able to see.

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And then this was another story which was been told to us that since the first wave came in or first wave which they interpreted had the the water level of 1 meter so the people who used who stayed on the ground floor, they moved to the first floor to save themselves okay but they never understood and they never knew that the third wave or second wave will be much much more powerful they will engulf, it will engulf all the even the second, the first floor also okay and that what happened okay. So few of them, the person who survived with his family, he ran to the high ground but these people, they stayed here with an understanding that nothing will happen and we are moving on the higher floors but this whole area been inundated okay, so water level reached up to this which can be seen with the mark of the debris which has been left out but in the previous one, we even saw much higher up to this one okay.

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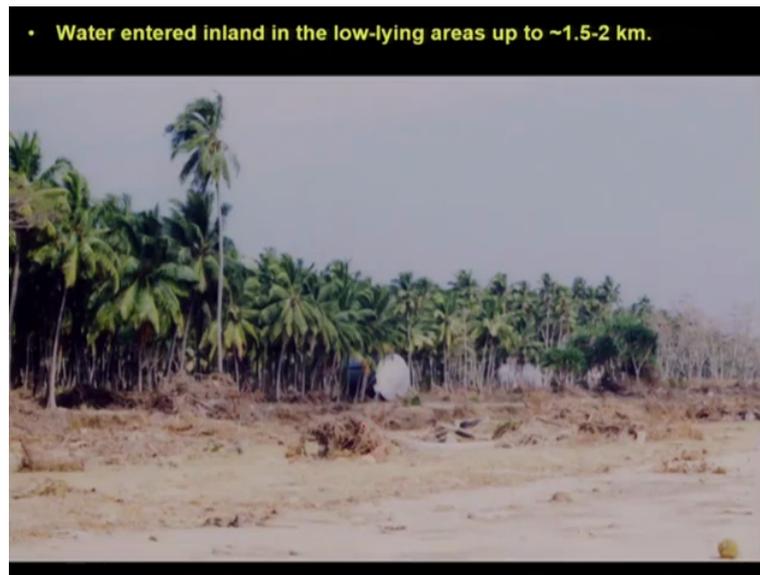
And this is what it indicates that the return wave okay so it came in broke in this wall and when it and this is the inundation limit over here and it went back folded the wings of the fan okay and you can even see the debris which is laying here at the top okay so water was quite deep like the depth was quite high here. So this is because of the return wave.

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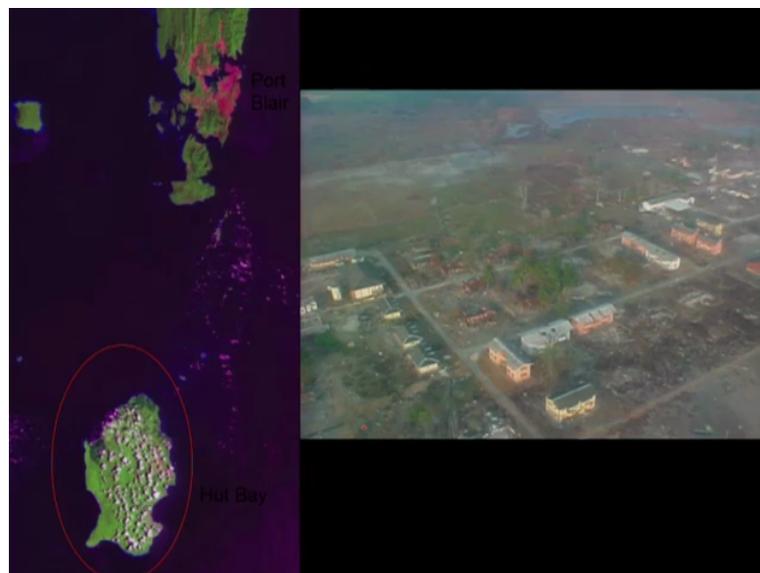
The energy was so high that it lifted and moved the oil tanks okay. You can see here the oil tanks which were been moved on the on the runway okay of the airbase and you can see some debris which is small television here and then there is a refrigerator here and all that okay.

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So tanks were moved inland by almost 1 kilometer and these are huge oil tanks okay.

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Then coming to this part that is further north if you move. We have an Hut Bay, we call this as an part of the Andaman island. Similar damage was been observed.

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And there was again an massive damage. Everything was been wiped off okay.

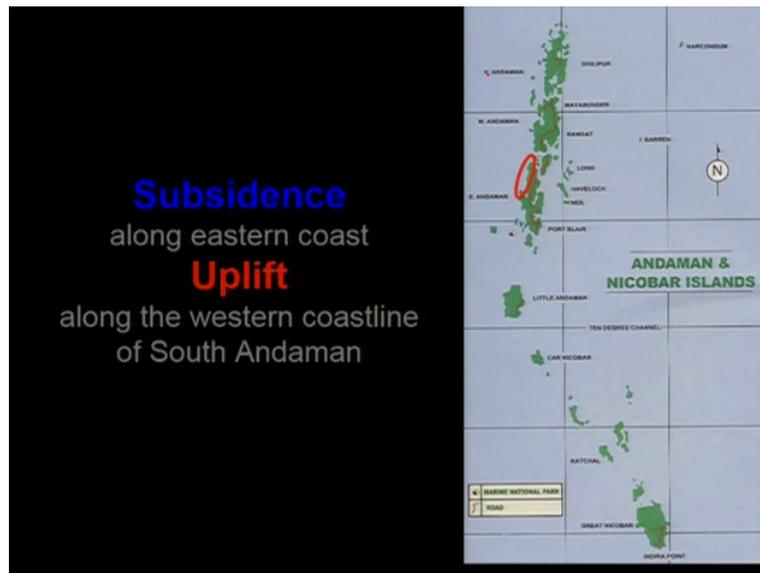
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Some locations were very much similar which we observed in in Car Nicobar and this is from the Hut Bay area. The whole walls were been broken by the water and then water went back so

you can imagine the height here okay because of the return wave. This person told us that we can see the stagnation of water which left out the water marks on the wall of the their houses okay so this was one, almost 9.5 meter and then moving up okay and having almost like 2 meters or so.

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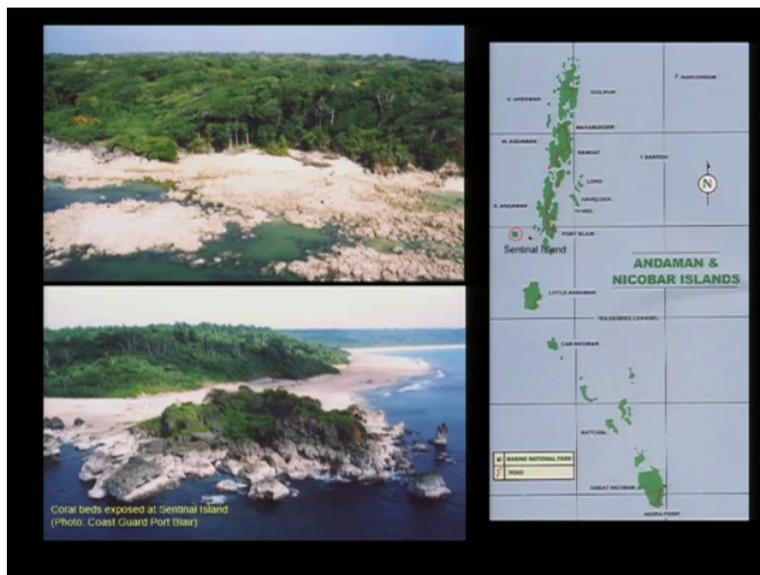
Then coming to the other part which where we see so what we were looking until now was the subsidence okay at Great Nicobar here and then subsidence at Car Nicobar and we saw some signatures of the Trinket island and Cumrot island here okay. Now we are going to the Andaman part here so we saw an clear cut uplift and subsidence which occurred on the western side and subsidence on the eastern side respectively and of course the subsidence on the Port Blair part okay.

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So this is an uplift in the northern side of the Andaman islands so this is before and this is after okay. So area um emerged in that region okay.

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And this is from the Sentinel island over here okay in the western side of the, so this area got uplifted, nobody (wan) goes here but this because of because this area is still occupied by the tribes.

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So this photograph was been given by coast guard people so this shows clear cut uplift while this area got emerged so island got uplifted here okay.

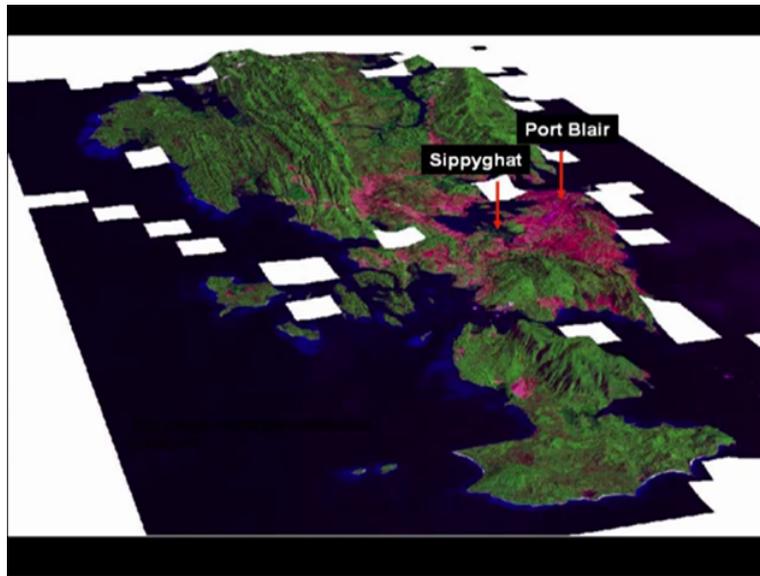
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So this was an very interesting photograph which we got. A tribal person, a tribe with an bow and arrow, he is aiming the helicopter of the coast guard okay so no one dare to go in this region. But

of course these people, couple of people were been saved here because of their understanding about the process okay.

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This area is the Port Blair Sippighat which again experiences subsidence.

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Now, if you carefully look at this photograph here, you have a very beautiful marks of the agricultural field okay and this area was extensively used for paddy cultivation.

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And this was an very interesting photograph which we had okay so it says house site for sale but nobody is interested now to buy land in this area because this area is frequently getting inundated (ev) even today okay, we experience that this area is (hav) facing the problems okay so what they done is, they have raised the wall. This is this the road which connects the um the different villages, they have raised the the portion here okay almost by 1.5 to 2 meters.

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So you can clearly see this here here. This whole this in coconut plantation so it take now it is sitting under water and all agricultural fields are getting inundated so they have lost the land in this sands okay so this area subsided.

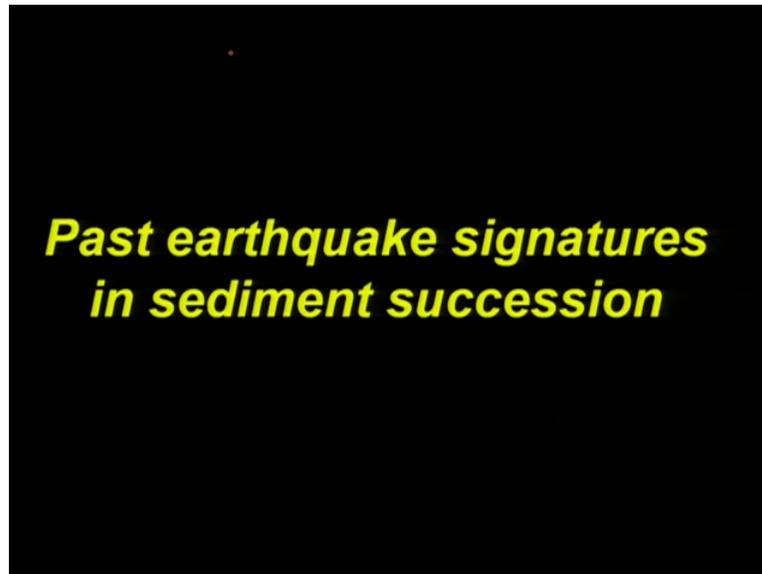
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So if you look at the close up of this, this (a) the the the level of the water road was raised because to because there is no other place available to put the road so the best way was to elevate

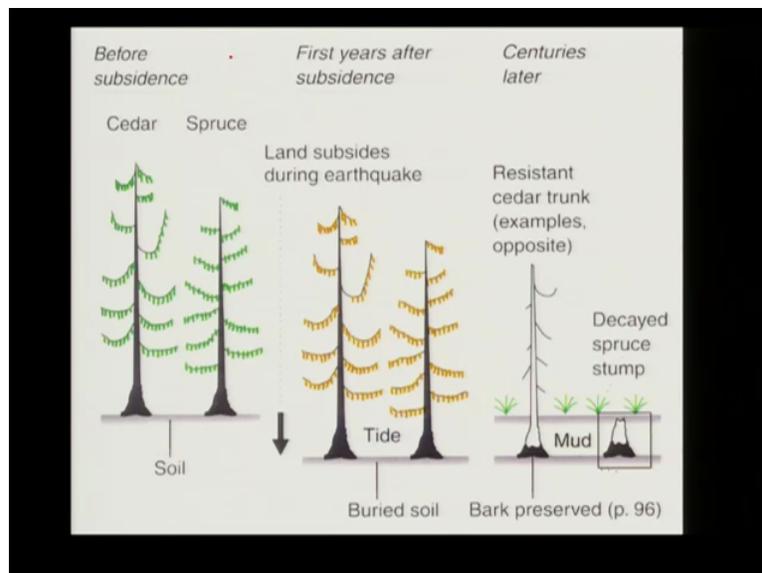
the road level okay. So that what they have done almost by 1.5 to 2 meters they have raised the road.

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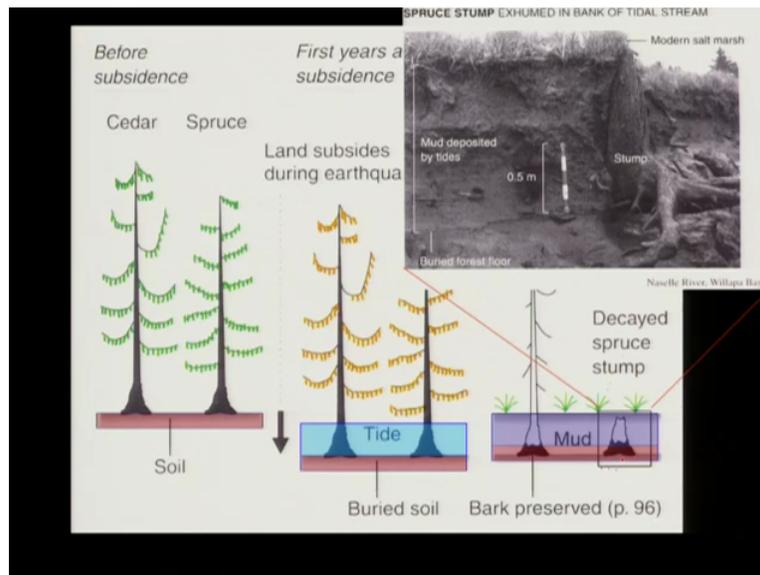
And then like coming to the past earthquake signatures in the sediments if you look at okay, this we have already discussed to I will just move.

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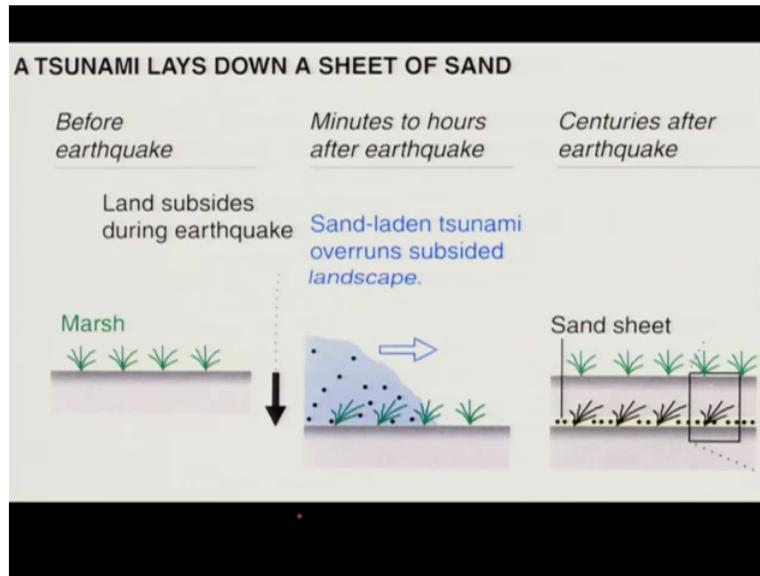
This is what I was explaining there also in the first couple of slides in the beginning that if you are having subsidence then you will have the preservation of the dead trees as we have seen in the Chilean from the Chilean (a) Chilean earthquake also and then you will have the formation of another soil layer okay. So in some locations along with the Tsunami sand, you will have the signatures of the dead forest okay. So that this what it shows that this was the level, it subsided and then it got preserved in this sediment succession okay.

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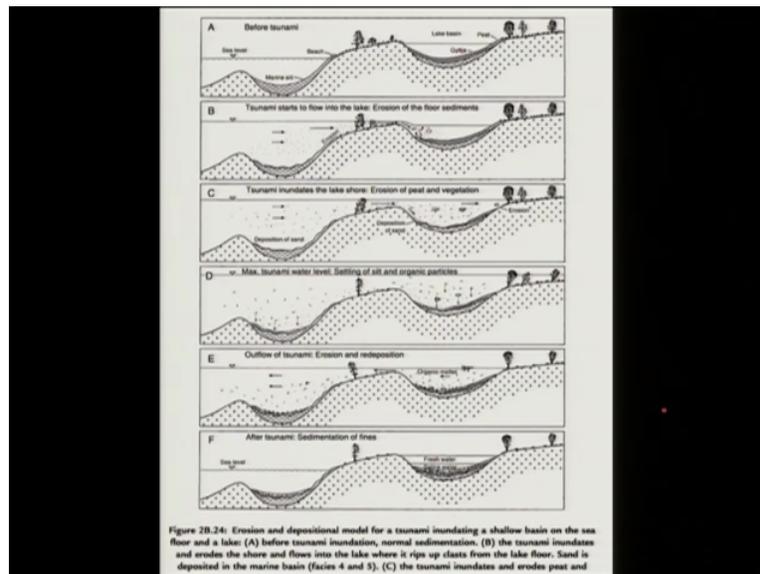
So this is an example Willapa Bay from US which shows the dead trees, the trunk of the dead trees okay over here so this surface existed like this before the major earthquake okay. Then the area got subsided.

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This is also we have talked about so I will just move. So in some locations, you will have the preservation of sand but if in some, there is no no preservation but at least you will have some signatures of the subsidence which took place during an earthquake okay.

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Best locations to look for such deposits are the behind the beach ridges, we will always see the preservation of the Tsunami deposits okay because these areas will not will not be much affected because of the coastal erosions from the tidal.

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So this we have talked about that we (s) we can see these sections and we can try to identify the signatures of the old Tsunamis which triggered in the past okay so similar example what we were looking at here like the if the area is subsided then we will have the formation of to some extent, we will have the formations of lagoons okay behind the beach ridges.

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And this is an example from Car Nicobar, this is what we see that there is a formation of lagoon behind the beach ridge that this happened because of the 2004 earthquake,

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So what we did was I will just quickly show some signatures what we found from the Andaman area.

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So this is the area which is sitting somewhere here okay, probably in this part and then we moved to this area okay here okay. What we saw is that there are few Japanese bunkers because Japanese, they occupied this region during 1991 to 1945 if I am not wrong okay so they constructed few bunkers here but now this bunker is sitting in the (o) open to ocean okay because no bunkers will be constructed looking for enemies okay which indicated us that area experience the subsidence in the past also. And in 2004 from the local people we also came to know this area was affected by the Tsunami and then we have some examples of the old dead tress also here.

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So we opened up similar what we call trench to see the near subsurface sediment succession, stratigraphy and you can see clearly this blackish part and the sand sitting on the top here okay so this is 2004 Tsunami sand and this is 2004 soil which existed before the earthquake okay. And then if you go down we see very clear indication of another sand layer here and then we are having soil here okay.

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And then further below, we see some signatures of gravel cast and then we have some buried tree roots okay and this buried tree root is along with the peat deposit okay so this peat deposit clearly indicates that this area was subsided during past events okay. And we see here very thick sand layer again, very much similar to what we are having here okay so we had the earthquakes in the past also and this was not the only one which was experienced in 2004.

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So this area looks very similar to what I was showing from photographs from the Chile so on this, we have taken from the high grounds, this whole area got inundated again. We can see very clearly the the boundaries of the agricultural fields. Now they cannot grow anything over here okay so Tsunami wave direction was from this side.

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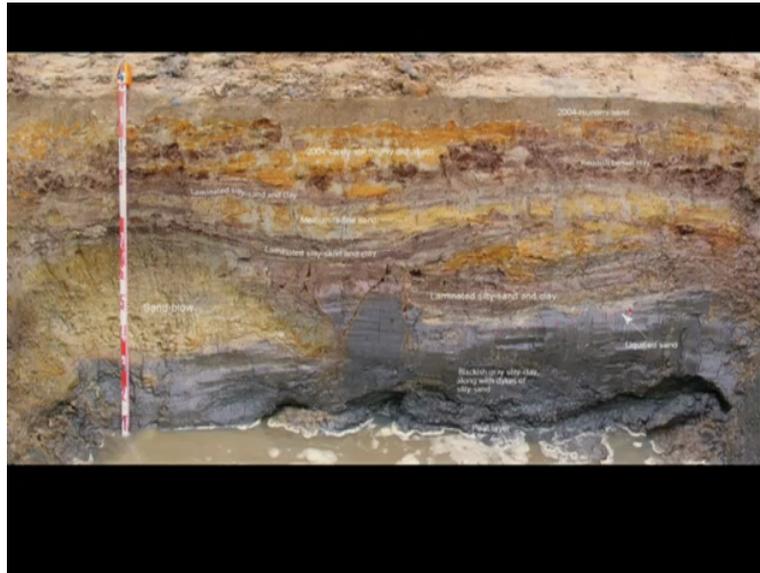
So again it deposited lot of sand on the surface.

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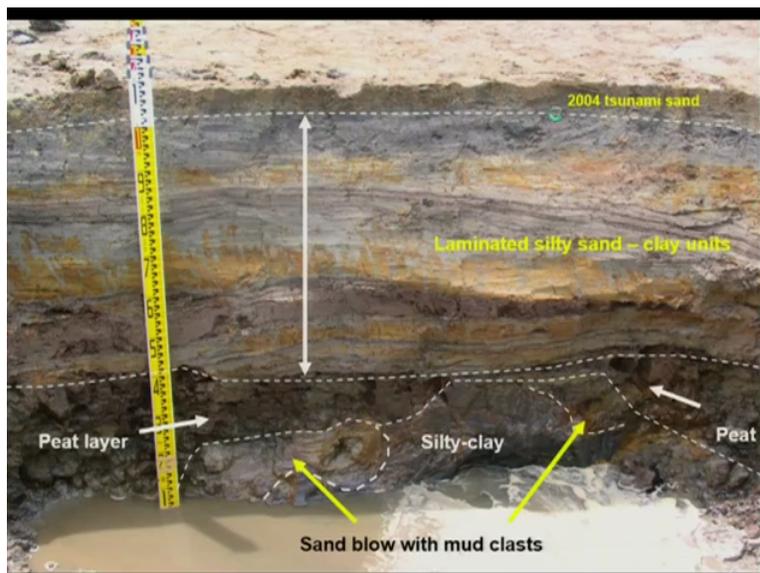
So we opened up the trench again and then we saw some very beautiful signature of the old Tsunami deposits here okay. So these are the Tsunami deposits and then peat layer, thick peat layer clearly indicate that this was this area was at high ground before the past events okay.

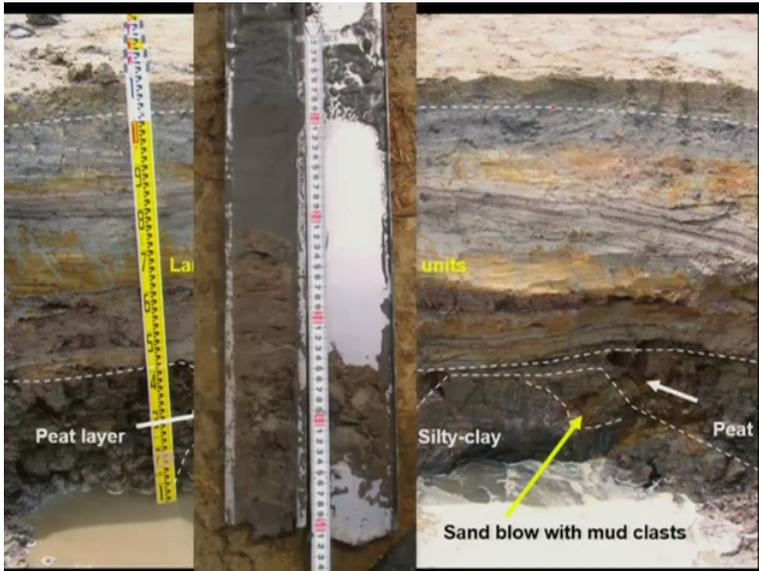
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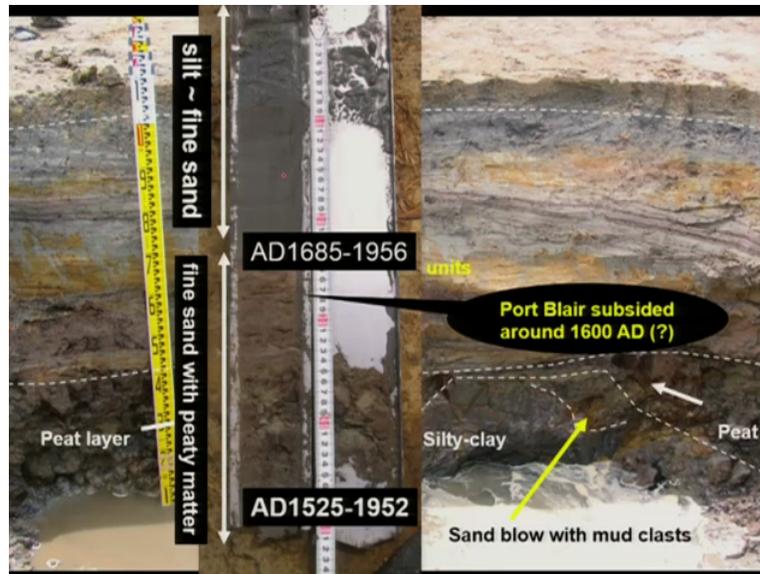


So we have the blackish peat layers and we have some liquefied sand here and then we are having the this chaotic nature of the deposits here which again indicates the old Tsunami events okay and then we are having on the top is the 2004 Tsunami sand.

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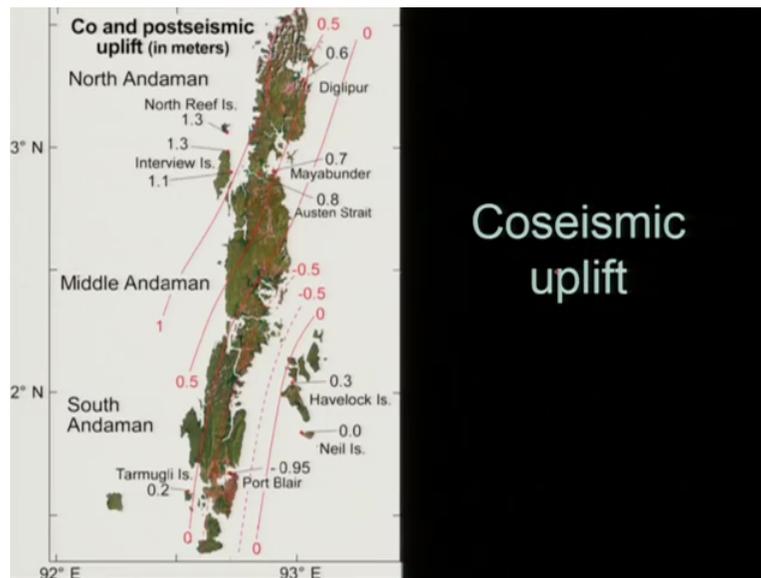




So further deeper part we took, using a and then what we found was this one okay now we have a very fine deposit over here sitting okay. There is an clay bed and then you see a very sharp contact between the so this deposit is very much similar to what we usually come across in tidal areas okay and then we are having a very sharp boundary and then we are having a finer clay deposit so this clearly indicates sharp boundary clearly indicate that there was a sudden change in the land level and the environment changed okay.

So this was, this indicates the deeper environment and this indicates this a lower environment where you are having the tidal waters coming in and getting deposited. So mostly you will a laminations which are seen in the tidal deposits okay so this we we classify it as in peaty and these layers and then we have the edges which indicates that this event okay which we say that this was an the event here so we have the edges from this layer which suggest that there was an event in 1600 A.D. okay close to that so this is an very good indication of the past Tsunamis from this region so Port Blair subsided even in 1600 A.D. and then in 2004 also, it subsided almost by 1 meter and our studies suggest that in 1600, the subsidence was very much similar as we experienced in 2004.

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So about the coseismic uplift, we are talking until with coseismic subsidence and uplift also was been observed in this area. This is the area from here, this is the Interview island and then another one is North Reef okay so the uplift was almost like (1) 1.1 to 1.3 meters okay.

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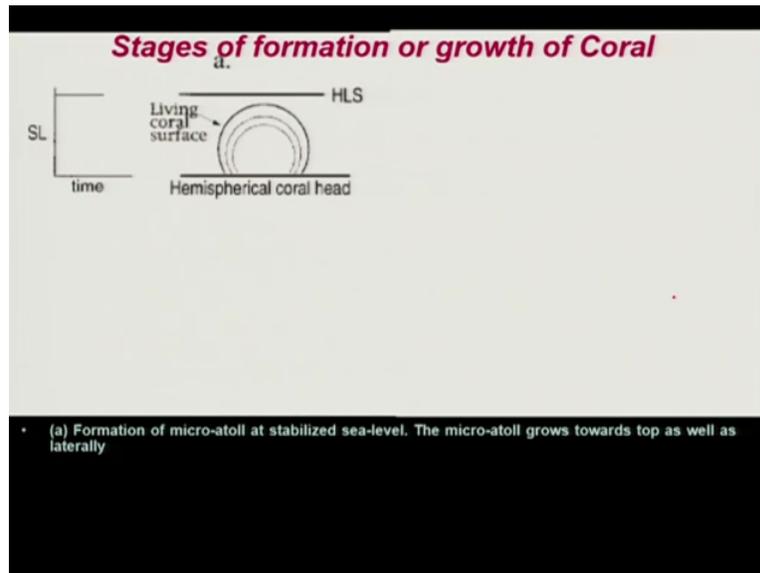
Now this is what has been seen here okay. This is before, this is before and this one is after okay so tip of the Interview island, you can see the this is uplifted here so coral reefs got uplifted and it was exposed to the the environment okay.

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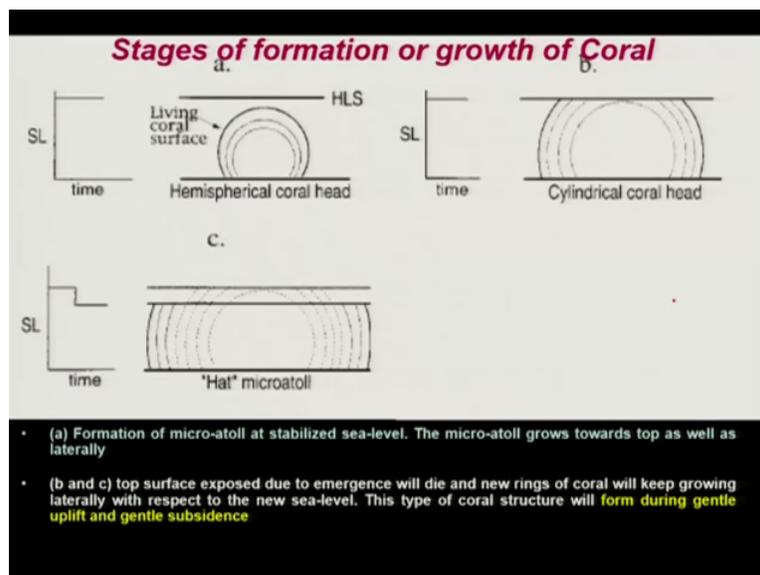
Now if the corals are uplifted and they are been projected to the surface, it will die okay. Apart from this, what we observed was that this is the barnacle level of the barnacle survivors, survival where where they survive in the the highest high water line. Now they are exposed so this clearly indicates that this area got uplifted during 2004 event.

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Now as we see the signatures of the past earthquakes or the Tsunamis in the sediments, we also see very beautiful signatures which are usually preserved in growth of corals okay.

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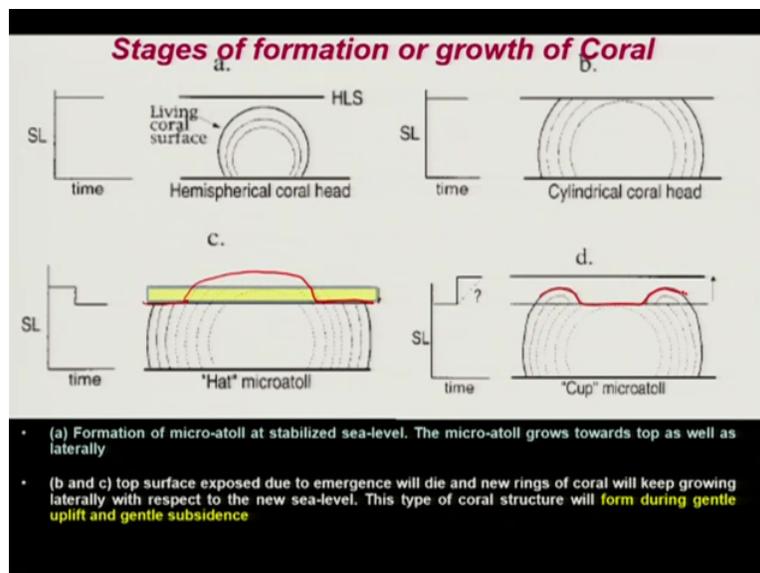
Now the from here what has been shown in the sketches okay like corals will always grow under a particular level of survival okay, like level of water okay. If it is exposed more of the the the atmosphere, it will die and since we these corals are seen mostly in the the coastal zones and if

those coastal zones are close to the subduction zones, they will be definitely affected by the uplift or the (sus) subsidence process during an earthquake okay.

So now if you look at this part okay. If suppose this area is uplifted or we can say the area is getting subsided then what will happen okay. So if the area is uplifted okay so B (a) the B part here, this one. This you can see this is the the top expose during the emergence will die and the new rings will keep on adding up on the lateral side okay so usually the corals will grow laterally as well as vertically okay so it will keep on developing in form of the rains okay.

So this type of coral structures will form during gentle uplift and then you what you have the gentle subsidnace okay, so you have an uplift here and then slowly you are having the subsidence here okay. So this area during an uplift, this portion got exposed so this remained okay but (du) then later on the subsidence, it again allowed the corals to form on the either side okay so you have an subsidence here and then another one which shows here is, this is an abrupt uplift and then gradual subsidence so during an abrupt uplift this was exposed but during the subsidence next event, this again starts growing okay so it grow (lat) vertically as well as laterally. So these type of features one can easily look at and the (())(33:24) so this is what we call the hat type so in hat type you will have this will be exposed okay.

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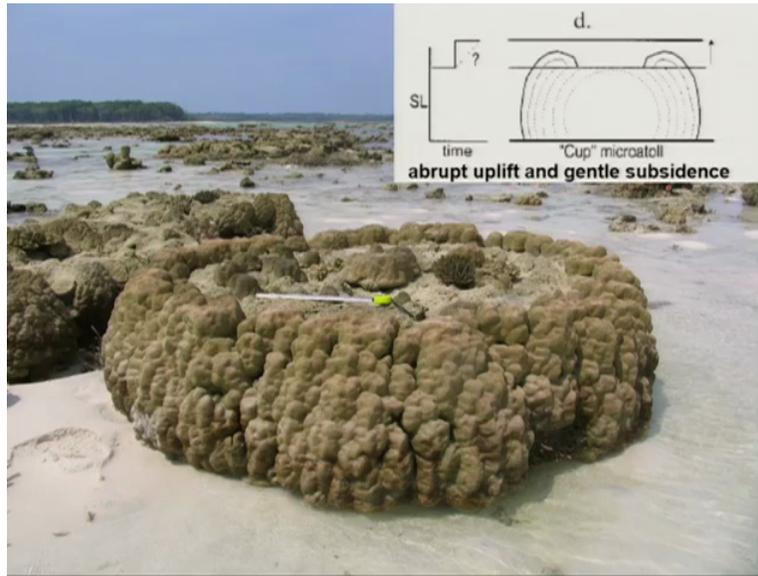
So this remain and then this will grow so this is what we call hat type and this is cup type so you are having the the cup shape here.

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So this one what we call is the cup shaped so you are having the the growth here of the coral and then you are having a flat area here and then you are going up here. So this is in typical of the the cup type of but in 2004, this got uplifted so now what will happen, this remain exposed, this will remain exposed and then the corals will start growing from here okay so they will have the growth on either side here okay, they will keep on growing like this. So this will be now exposed so this will be like what we see is the the hat type will remain on the top okay but here, we are having a cup type. So I will stop here and then we will see you in the next lecture where we are going to talk about the this the landslides and other part okay.

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So this indicates the abrupt uplift and general subsidence okay. Thank you so much.