**Natural Hazards**
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**Lecture - 40**
**Tsunami and Related Hazards Part III**

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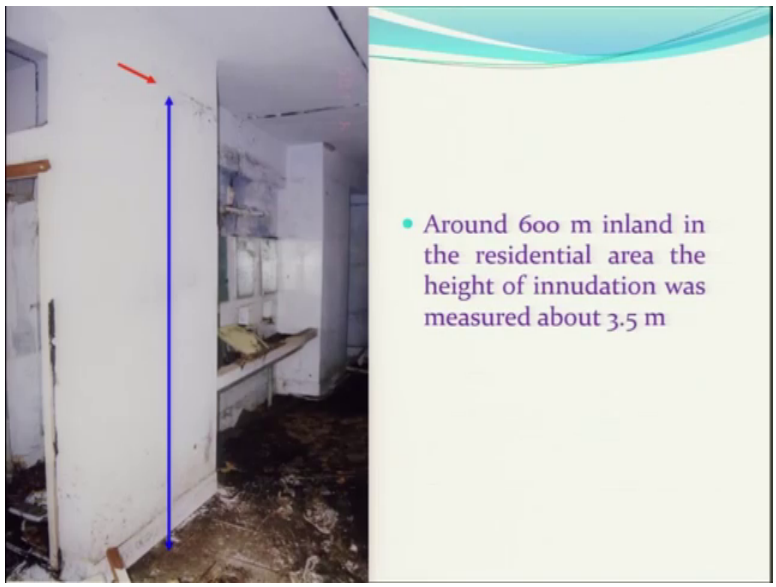


So, welcome back. So, we were discussing couple of example over the evidence or the signature which we identified from Andaman after 2004 Sumatra Andaman earthquake. So, this was a part I was discussing from car Nico bar where I should some photographs in ground photographs and reality which we observed after 2004 about the destruction pattern.

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This was the height so of the tsunami in previous one of the slide in previous lecture we saw that there was inundation was up to 7 meter that is height of the tsunami wave was up to 7 meters. And the event was after just of the Christmas eve.

So, people in the initial like when there was in flooding condition people thought of that it is a local flooding. So, they move to the first floor, but the height was much more above and this one. So, the most of them got killed in this one. Very few were have survived.

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And this was in signature of the return wave, when the water which came and pronging the wall here of the houses and when it return back it wing it bend the plates of the fan. Similar to what we will talk in terms of the run up, if we see the rebent wings then we can also take that is an at the height of the tsunami.

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Anyway so, this was because of the return wave. The water enter much more inland up to 2 kilometers from the coast and this was the scenario at the airport of car Nico bar.

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And even the very huge oil tanks very heavy oil tanks were will be lifted and moved inland by the tsunami water.

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So, this also helps us in understanding what energy condition this was as at hut bay.

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So, similar signatures first wave the height was around 1.5 meter second wave almost like 2 meters.

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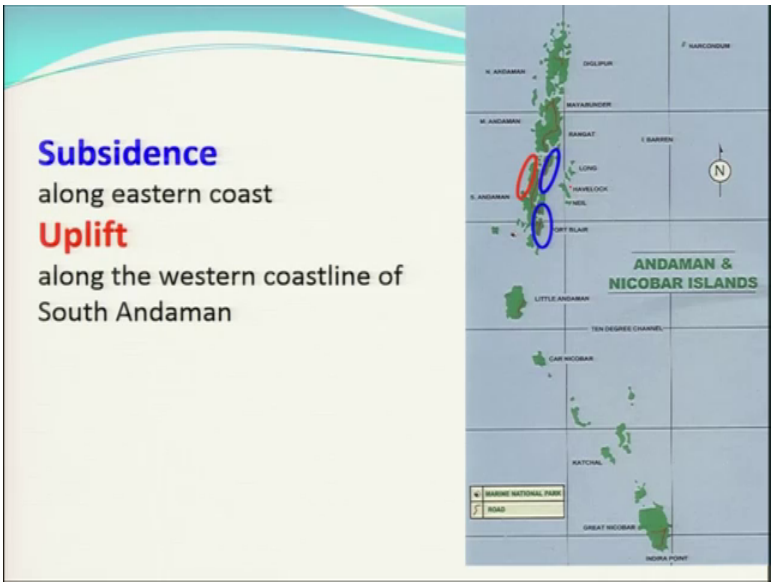


Now, coming to the another portion that is an uplift what we have served and the subsidence on the eastern side. So, uplift on the east along at the west and this uplift along the eastern side.

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So, this was before and this was after so, this island on the west coast of Andaman got uplifted. So now, the water comes up to this during the high tide and this area remains exposed.

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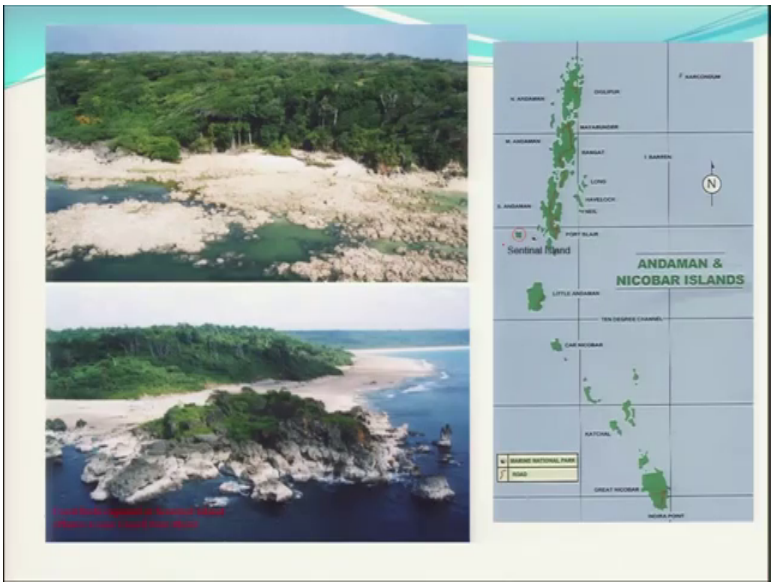


Similarly, things will been observed by at sentinel island, which is away from the main island towards the subdivision zone. And this photographs were been provided to us by coast guard.

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So, what we see a satire island this is we took photographs and this is the, it is signature of the emergence of the land after 2000.

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Nobody wants to go there because of the tribes. They are trying to and this photographs also been given us to us by the coast guard and they are trying to aim the helicopter.

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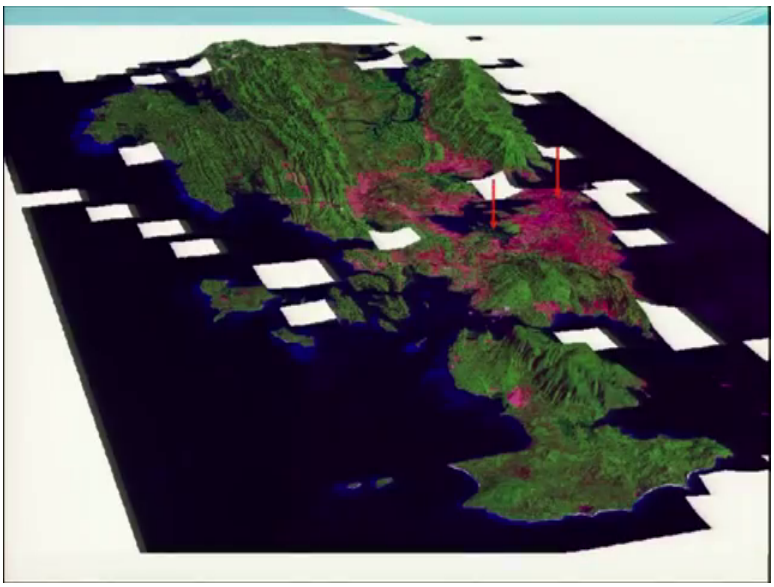

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Coming to the port Blair area. Port Blair area this area earlier was very much used for the paddy cultivation.

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But now sets an water. So, in 2004 before that this area was in demand in terms of the not only for the it is fertile region, but also for the housing purposes, but now nobody is interested in buying the house in this area because of the land level change which has occurred after 2004.

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So, this is the scenario what you can see the plantation sitting in water most of the agricultural field is are sitting in water even the residential areas they have been enforced to move from this because most of the time this area is under water. The administration has raised the road heights by almost like 2 meters.

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This is what was the construction which was been done, immediately after the event and this is the filling up of the roads the older road is sitting at the bottom here and now you have the new roads ok.

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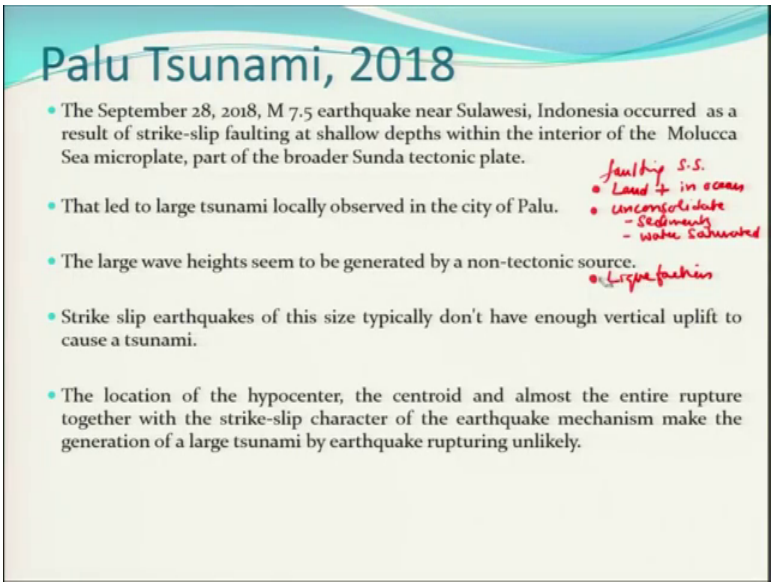


So, and then the event of palu tsunami in 2018 similar thing happened, but yes of course, this was little bit like difficult us for us to understand. Because the displacement took place on a strike slip fault, but then also and magnitude was not much high 7.5, but it resulted into devastating tsunami. So, what we learn from this is that even though the magnitude is less and if the faulting is taking place on the strike slip we should not underestimate the effect of the tsunami.

So, the whole palu city was of course, there was 2 folders have like affect, one was because of the faulting it was strike slip, but this was on land plus in ocean. And then another one was the affect was of because of the loose soil or we can say unconsolidated sediments water saturated. So, this resulted into an ideal side to prepare liquefaction. So, whole land mass in this area moved into the ocean. And you may find some videos on the social media which talks about that how the whole land mass moved and you can watch there, but we will try if we can put, but we can do that on your own.

So, this was an very devastating event again in the history of Indonesia. And at with an magnitude even 7.5 where most of us will not expected mega tsunami or major tsunami or devastating tsunami, but that happened ok.

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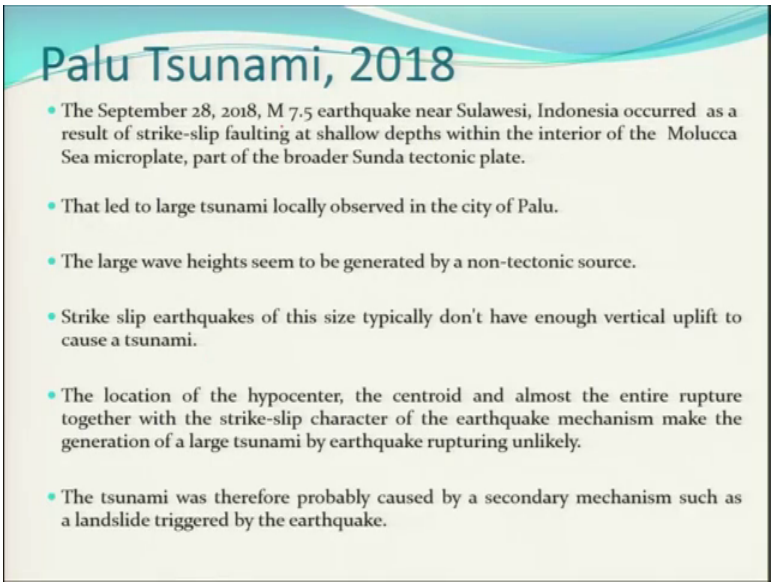


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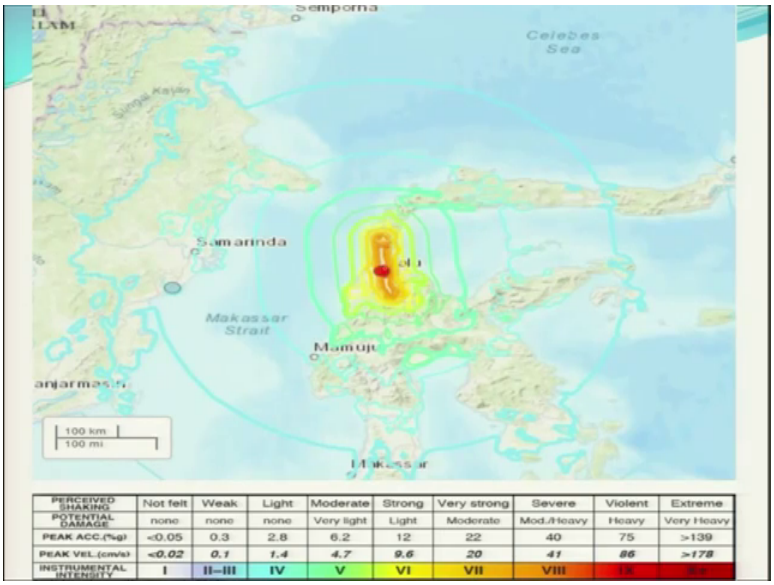


So, this was the rupture area and then it shows the intensity at how it moves. So, most of the huge ground shaking was in this region and that area got affected because of massive liquefaction as well.

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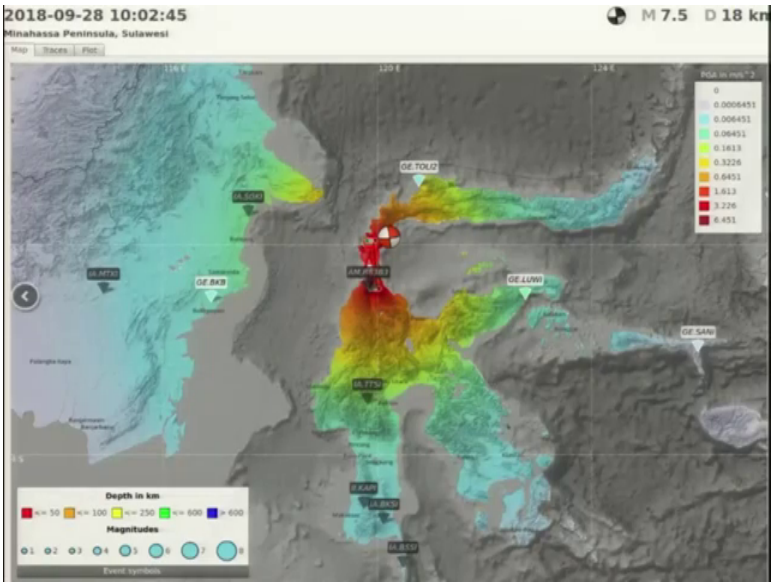


So, rupture was on land as well as in ocean and the landslide which was been triggered here was the cause for having an unusual tsunami wave heights.

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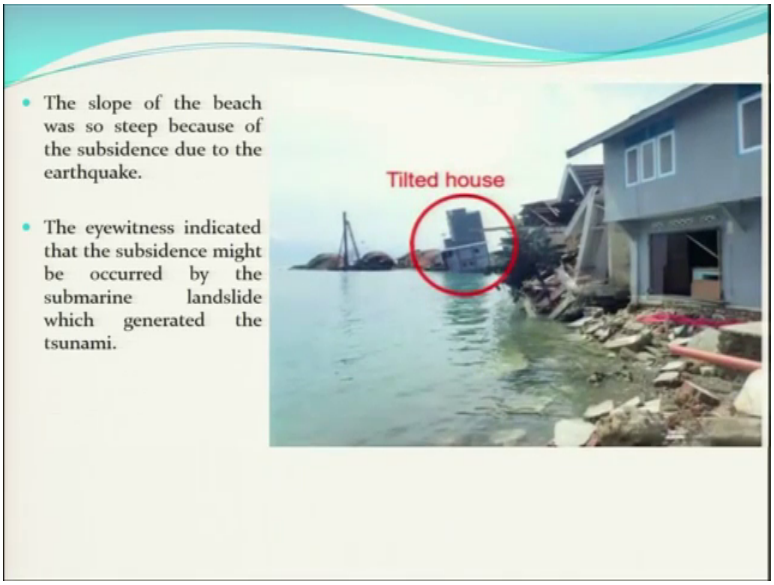


So, these are few photographs which talks about subsidence of the area and the land slide which took place close to the coast.

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Now, coming to the past earthquake signature in the sediment. So, I will quickly look at and what we can do is that those who are interested can refer our publications which appeared in different journals and then try to gather more information for that because reason part of an complete huge course or large course where we discussed about more about the deposits how to identify and what are all parameters we should consider to say that this is tsunami and differentiate the tsunami from the storm and all that.

I am not going to discuss here, but we will still share that what best locations at which we can look at for the preservation or the preserved past tsunami signatures that I will discuss and then one or 2 slides, I will talk about at what we got as an signature of the past land level change in port Blair area. And then I have couple of slides which I borrowed from professor kanji satake from earthquake research institute where they have talked about the jogan earthquake which cause in predecessor of 2011. And they knew that the event which they experienced in 2011 is going to occur. So, they very well knew about it. So, I will discuss that that will be more interesting and similar type of studies we are also stepping in to do for the Indian side.

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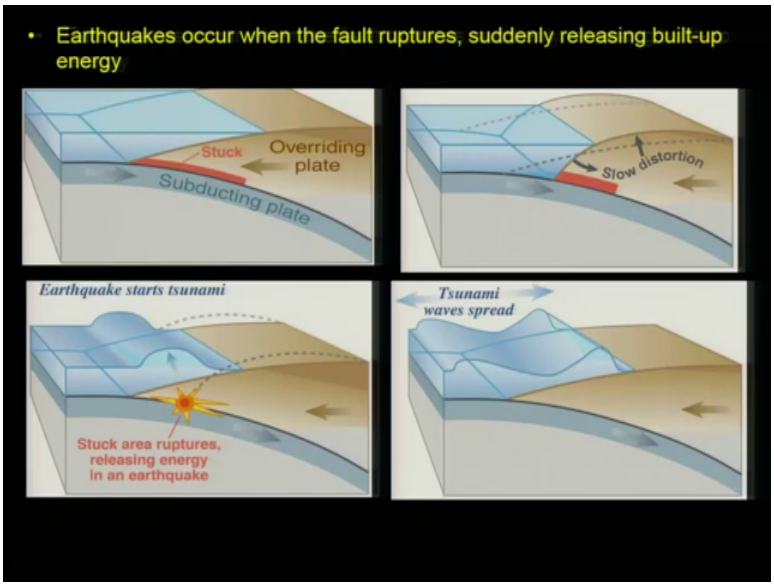


So, this part we discuss that usually what happen before the mega tsunami and the or mega earthquake along the subdivision zone that over the time the strain is been developed and at the time when the strain is released is slips. And then land level change take place as well as the tsunami will be triggered.

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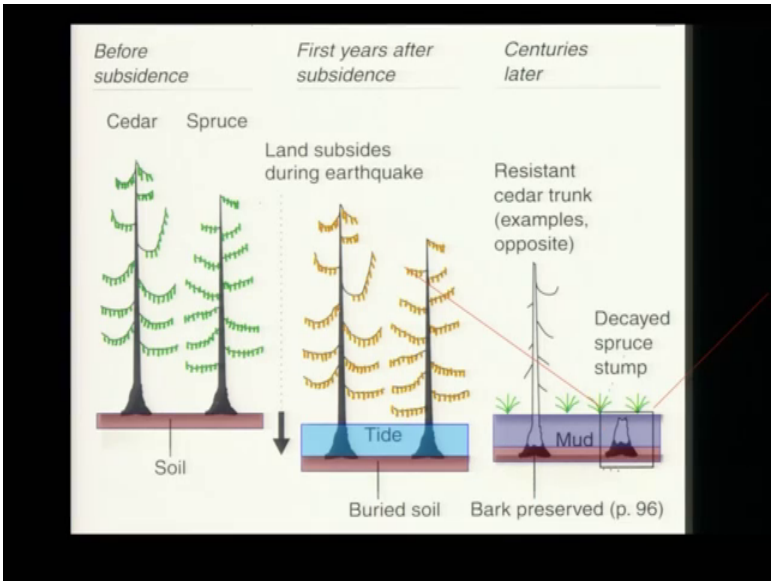


So, as one of the example we talked about a book from the chili 1960 that how we identified the ancient tsunami deposits. So, this is very much similar to that. So, if you are having soil here or the forest close to the coastal region and during the subsidence

initially it will, of course, in and at the area and then you will have slowly this forest will die off ok.

And so, mostly in such regions what we expect is that we will have the formation of wetlands. So, soil covered by it remains even dated and slowly the mud deposits will take place. And some signatures of this tree trunks if there is a forest which will be preserved within the sediment cover.

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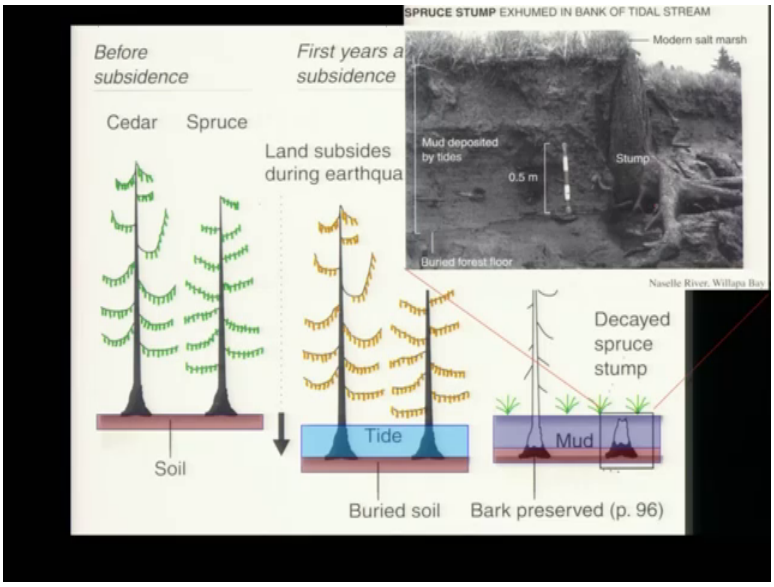


And this was very clearly observed from one of the example at willapa bay from US, where you can see easily the tree trunks which are sitting dead trees and this is your (Refer Time: 11:43) salt marsh. So, we slowly get into the formation of the salt marsh.

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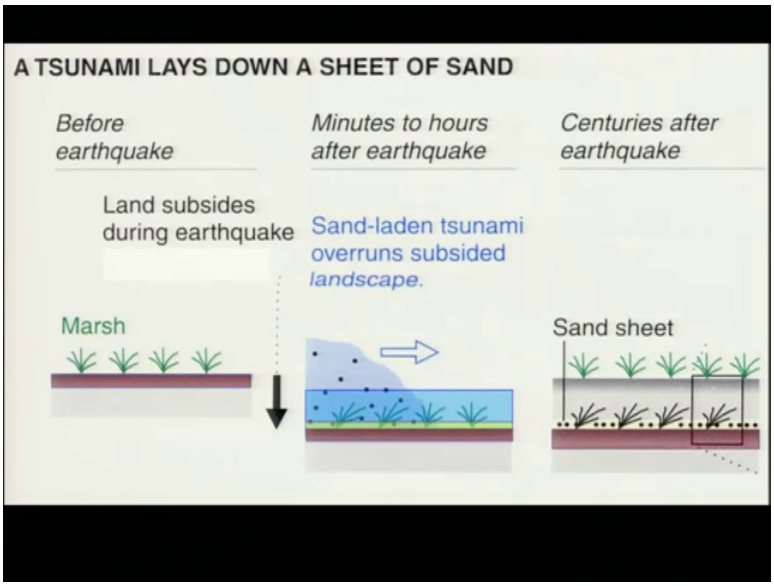


And this was the another evidence which we discussed in the previous slides at that we having in the land which got subsided and then we have some preservation of the sand which will be left out and then we have this one.

So, one is the evidence of the land level change. And land level change plus the tsunami deposits which we try to identify or locate in sections.

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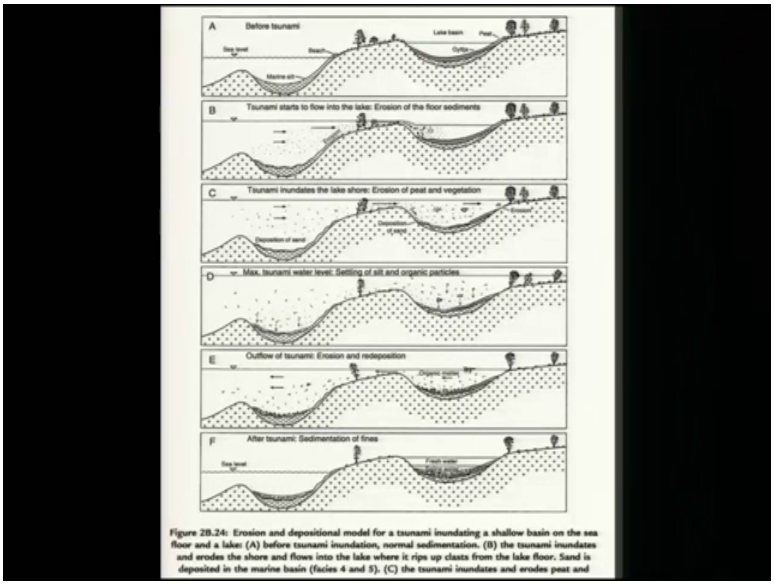

And the best locations are at for the shallow or the trough regions behind the beach ways that is what we call back marsh. So, in back marsh areas you will always find that there the tsunamis will remain preserved.

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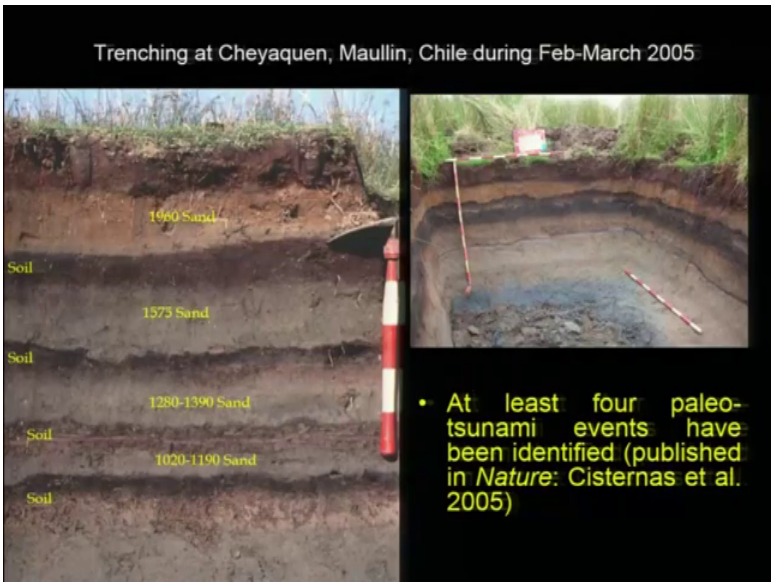


So, this was the sequence which I have shown in the previous slide that that slowly the after the every event they will be in deposition or the formation of soil or peat and then you have another tsunami if at all it comes then get preserved and finally, it will create a sort of an sequence which has been seen here. So, you have sand soil sand soil couplets in the region.

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So, this situation prevailed after the event of 2004 in car Nico bar. So, you having this pool this side is the beach area that is the ocean front. And then you have a beach ridge. So, elevation reduces here and then we have in back mursh. This is the ideal place for us to look for the previous tsunami deposits.

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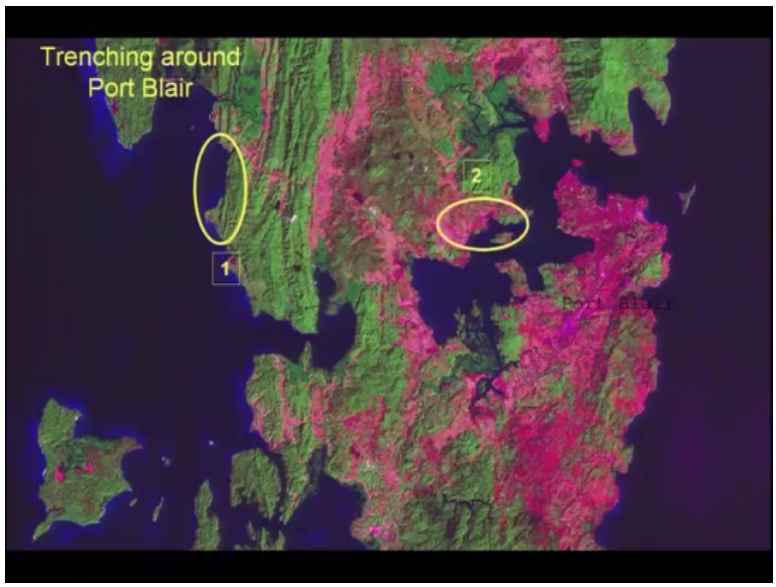


So, how to hunt for the past earthquakes what we did we carried out some quenching as. I have shown from the Chilean Chile area mouren and similar things with or similar mythology we adopted here.

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In Andaman some signatures which we gathered from this 2 locations over here; so, one the location which I am showing is next one is this one. So, you found some tree logs, but could be due to the coastal erosion. So, we are not very sure about it this was our first field, but of course, what we saw is the older bunkers this a Japanese bunkers which has sitting right in waters, but it should not it should not have been sitting here because bunkers will be always created in the area in the hidden side. So, this is one of this nature of course, if we look at the close up here this is what is the trees vegetation level at the time of 2004.

So, the definitely the height over here was up to this one in 2004 you can see this. And this similar signatures we found from the 2011 Tohoku earthquake site also.

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So, this is 2004 tsunami sitting on the soil of 2004 soil and then tsunami coming in and then previous tsunami even signatures are over here which is sitting on the previous soil.

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So, such things which we try to identify and try to date study in detail the microfossils and try to differentiate between the storm and the. Because if the over the water is coming from the deeper side it use cover or bring the sediments and the forums or microfossils from the bottom area or the bottom and deposits in such material. So, that also helps us in identifying whether it is tsunami or it is related to storm.

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So, this area we visited again very much similar to the Chilean areas. So, this people used to use this so a region for agricultural purposes. So, we have taken this photograph from the high ground, but now it remains underwater.

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So, this was the tsunami direction we open up.

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So, what about the sand you see has been brought by all during the 2004 tsunami and we also were been able to identify some sand deposit over here which indicates the value tsunami signature, ancient tsunami signatures.

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These are the type of trenches and the details which we try to gather when we are hunting for the past signature of the tsunamis and all that. Whereas, this one is in clear cut indication than this area remained and deeper environment for longer time and then got a back to the normal what we see from the comparatively course at deposits.

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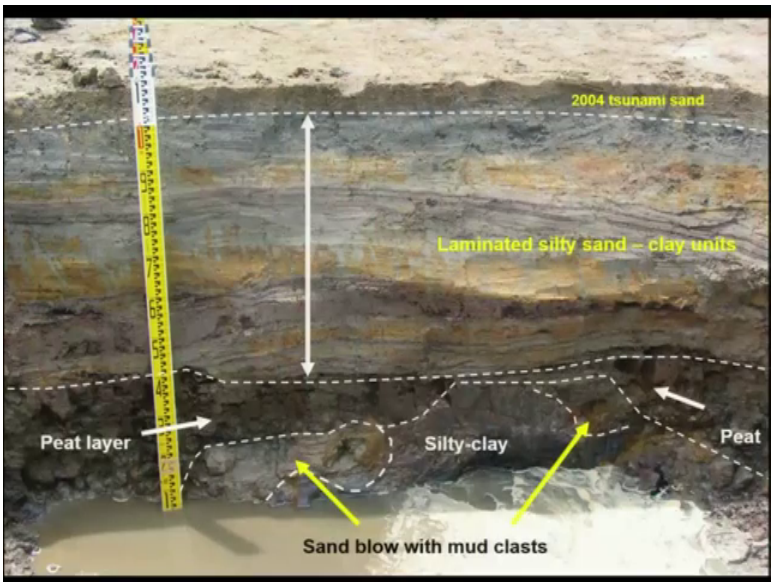


And very sharp signatures were been identified between the 2 sediments a layer which also indicate as at this where because of the sudden change in the clan level now. So, next slide we will showing that ok.

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So, what we did was not now we opened up the trench and then we took this section. So, these are the tools which we are using is from Japan. And they use very commonly, but now we also have similar thing.

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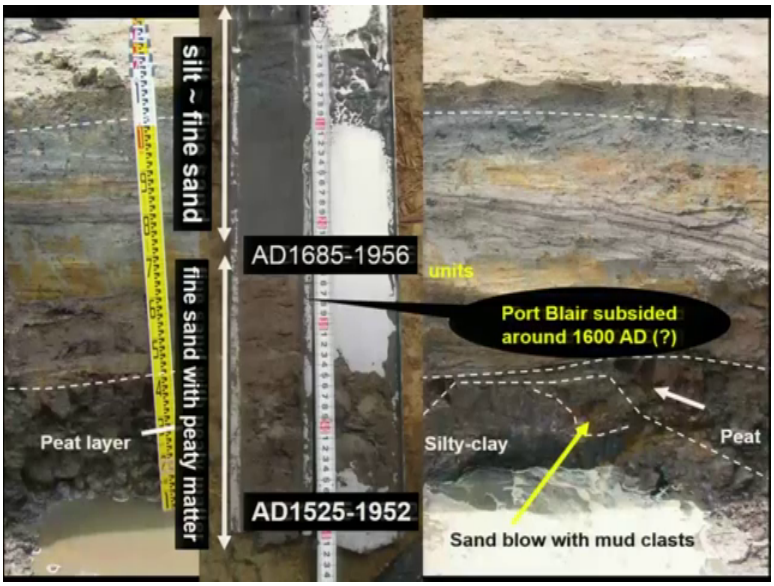


So, what we did was deeper part we found a very thick this was the reporting say the peaty unit. And then below peat we are having in very sharp contact and we are having the (Refer Time: 17:21) paddle sequence.

So, this sharp contact being suggest and this event or the environment; this environment was suddenly changed and then you have deposition of this one. So, deeper parts of this are been indicators that this area at the time of before the earthquake was under intertidal region, but then went into the deeper environment. So, this was in sudden change ok.

So, what we have fine sand with peaty material. So, in tidal intertidal area or sub tidal area and then we are getting into the fine sand deposits or will fine silt. And the ages what we have is from like around 1690 years older. So, what we suggest that around 1600 this event occurred so this again indicate that this was an peak event similar to 2004 itself. But the effect was different in the sense it was not. So, close to Banda Aceh, but very much been Andaman region.

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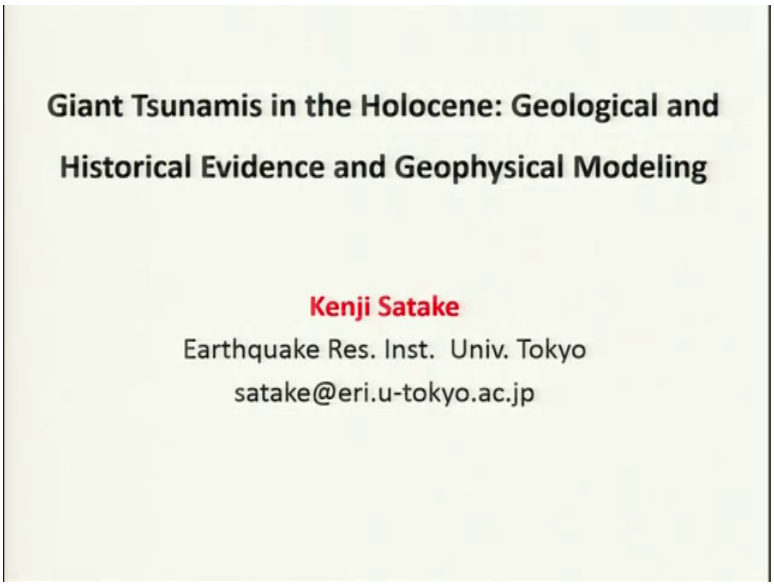


So, coming to this part this is bit interesting, that gathering all the information how best we can we can study or how best we can try the mitigation plan and reduce the risk ok. So, I will come to this one. So, this is giant tsunami in Holocene that is in last 10 thousand years geological and historical evidence and geophysical methods.

So, process from Kanji Satake he is one of the pioneer worker on the on tsunamis. And the one of the model which I was showing in my lecture was given by professor Kanji Satake from his lab ok.

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So, he that what I was telling that the new about that similar like 2011 type of earthquake will occur anytime in that is region. So, this is slide which shows about the wave height at the time of 2011 Tohoku tsunami in Sendai area.

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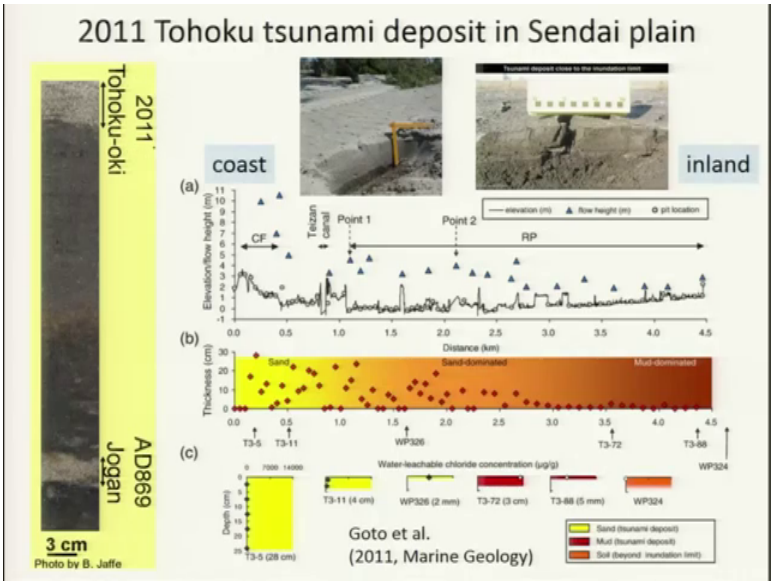


And what they found was this again they have done after the 2000 2011 event they have also look at this similar signatures what we will showing in my above slides. They have look for the tsunami deposits this shows the condition of the tsunami and deposition of the tsunami fine.

The what we another interesting thing which they identified usually what we used to do and of course, they were also doing that and other palu tsunami scientist used to do is that they used to identify the Tohoku he find until which point in the coastal region the this cores where deposits have been seen ok. And after that we will say that fine this was the inundation limit. And, but what they found was that even this tsunami that is to of 2011 inundated much more inland as compared to that what the cores of deposits were been left out.

So, even the mud dominated and deposits they were able to find out which went up to almost like more than 4.5 kilometers and the cores were deposits they ended something over here. So, that was not only. So, they have sand stopped here and then this whole sand dominated of course. But beyond this almost like one 1.5 kilometer inundation was mud dominated. So, giving this has come up as a very important parameter that not

always we should rely that saying that they until where the sand was deposited was the inundation limit, but it probably the mud also can indicate the inundation of by the tsunami.

So, this is the sequence which they found above sand this was what the earthquake of Jogan 869 was the predecessor of 2011 Tohoku earthquake. So, they knew not similar this event was the devastating event and similar to devastating event can occur any time.

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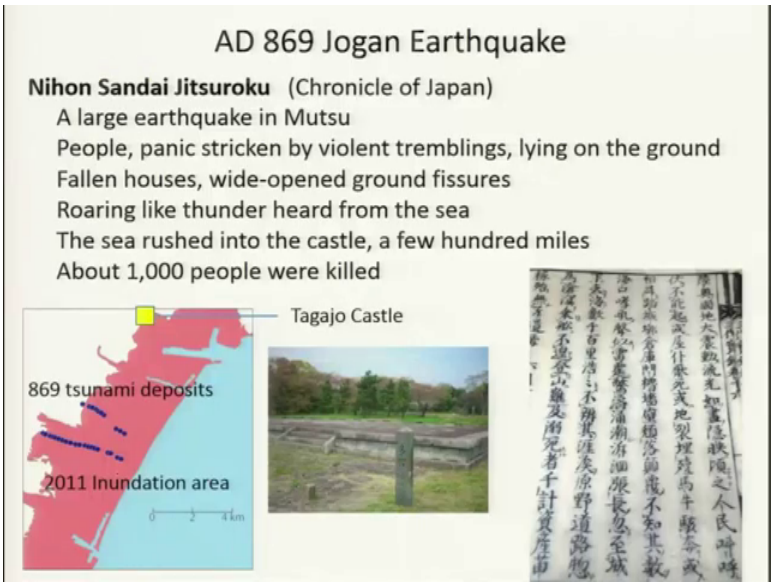


They are well equipped in terms of the ancient literature and they have the records, but in India we do not have this because of we have been rule many invaders and the records were been destroyed or no matter nobody (Refer Time: 22:10) to save or put those historical chronicles in place.

So, this was one of the; this is one of the drawback which we have and this people are having advantage, but of course, and then they are a better position to save their people or reduce the risk part. So, the text which has been translated we have translated here what it shows about a large earthquake in Mutsu people panic stricken by violent trembling lying on grounds fallen houses and so on ok. And it says that about thousand people were been killed. So, if this is from for about the 869 Jogan earthquake the record is available within.

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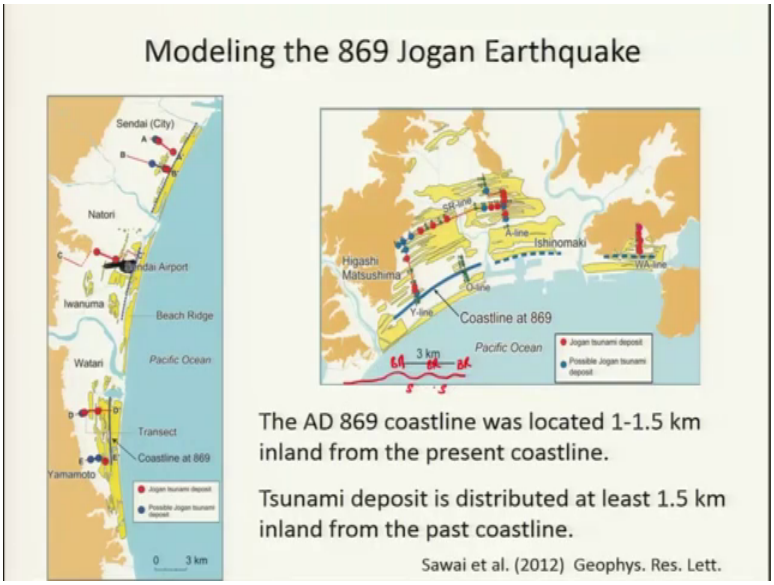


So, what basically I will quickly move, I will not going to the detail of each and every slide, but what they did was, they have taken the details these are all along the coast, they have taken the detail or collected the details of subsurface or near surface study graphic. Sub surface sediment succession and not very deep, but shallow and, but then they have identified and dated at the events ok. So, what they say is that jogan tsunami deposit possible jogan tsunami deposits. So, wherever they are doubtful they have put the blue dot at the blue, but where they are certain they have put with the red dot. So, they with it they took the transits and this yellow and whitish part is nothing but the beach ridge swell topography.

So, if you take the cross section across this one, if you able to see something like this ok. So, these are all beach ridge; these are beach ridge and may be considered as a cost and these are all swell region. So, beach ridge swell beach ridge swell. So, they were able to identify the preserved tsunami. So, it can deposits will this one.

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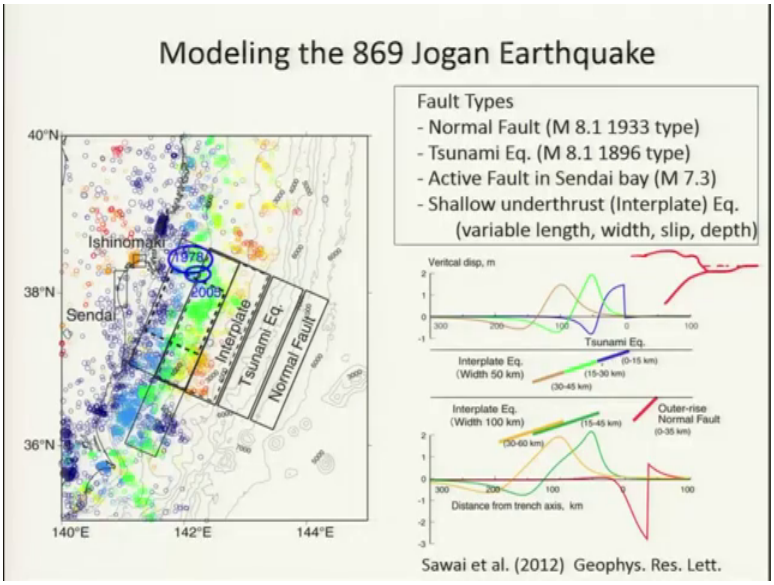


They also tried to model different earthquakes with different fault mechanism and they have also try to understand that what will be the effect of different earthquakes, which are occurring at different depth, and with the different slip. So, that what they have done suppose for example, if you are having this event which ruptures the blue part here this is what we call so, this you are having.

Subtraction zone or the overriding plate and this is the plate which is subtracting below so along that plane. So, one is overriding over here and another is subtracting like that ok so if the upped part of the area ruptures then the effect will be at this portion on the top also suppose I put a cross section here. So, you have an overriding plate and then you are having the area then with the ocean this is you are the subsiding plates of this portion is been shown over here. So, if this breaks this portion breaks then the area which is sitting here with will get uplifted and then the area sitting with tip the down tip of the rupture will subside and that what happened in Andaman also.

So, depending on which a ocean is going to get displaced or the lock portion is going to slip, the affect will be different suppose this portion at the deeper part. For example, which has been shown here with a light green if this ruptures then this area will get uplifted and the down dip tip of this one will be subside. So, tip of this one will be uplifted and similarly for this case also. So, this is very simple model which has been

created and which helps in understanding that what will be the effect of land level change if different fault portion of the lock fault slips actually.

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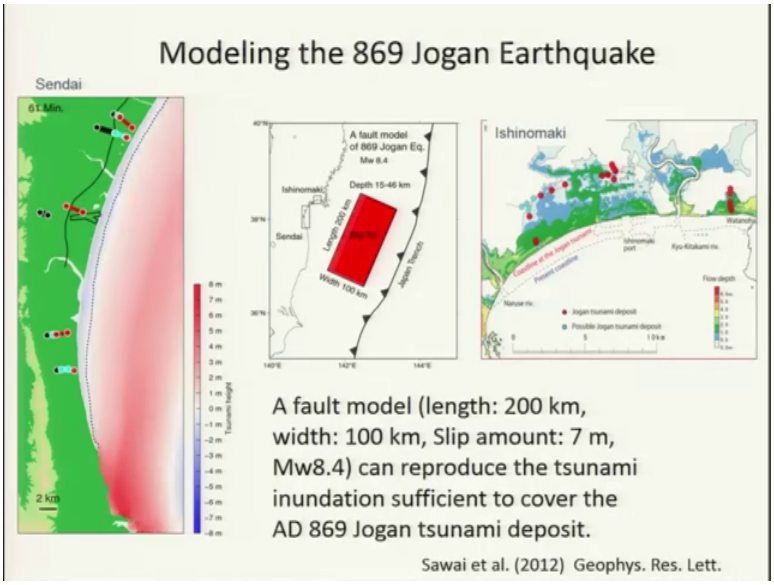


So, and this what they found was that if you carefully look at then we are having the jogan tsunami deposits and then possible tsunami deposits of jogan. So, they have prepared an inundation map so which also helps us in understanding that how much area will be affected if such event will take place ok. So, this of course, included the portion which got affected in 2011 Tohoku earthquake also.

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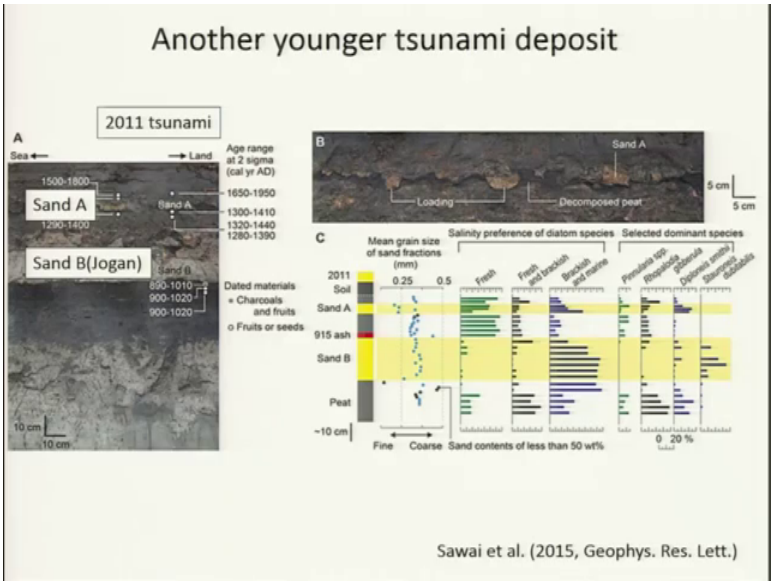

These are the signatures gained from this depend which shows about the older events and the younger events. So, this is 2000 the sand layer is younger of course, but then the jogan one. So, what this helped this information helped them was that they wanted to see that fine whether they have similar events in the past and what will be the recurrence interval and the future and of course, what 2011 and what we it helped ok. So, B layer is your jogan layer and then there is another one over here which is again around 15 00 ad or so and then they had in 2011.

So, this is jogan in sand B and sand A. So, if you look at that then what they have is around 1400 1500 AD they were they had another event after the jogan 869 and then they had in 2011.

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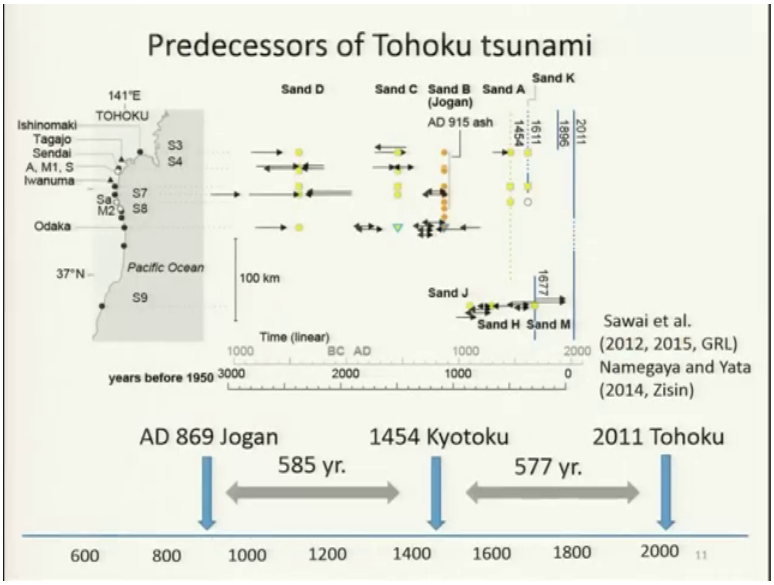


So, if they believe and what they have based on the signatures, what one can see as than the recurrence interval is almost 580 years between such events.

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So, anyway thank you so much for being with us in this course. I will stop here and I hope you enjoyed. And if you have any questions or any query do write to us and feel free be in touch with us ok. And we will try our best to help you and whatever we were unable to cover in this course will be we will keep offering different courses and we will try to keep you updated with the work which we are doing at IIT Kanpur and with other institutions in India, to give you the better environment in terms of the safety from such hazards.

Thank you so much [FL].