Geomorphic Processes: Landforms and Landscapes
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Lecture – 33
Coastal Processes and Landforms (Part III)

So, welcome back, in the previous picture we discussed few coastal land forms, we also saw signatures of marine terraces, how they will form and the sea notches and wave cut platforms and all that, so now I will try my best to show you some examples from Andaman and Nicobar and also some excellent features from Japan.

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So, let us move ahead the picture which you see here is the satellite or we can say this is the Google image Neil Islands which is located east of Port Blair, Andaman Island and this Island is excellent in terms of studying and understanding the coastal land forms, so if I just try to show you that with like you have barriers here, slightly like curved and some places, you see this type of the places locations which are the best to have the beach.

And right now, you will not be able to understand but this is what we have already mapped that this island has been going up because of the tectonic movement or the sea level has fallen down in recent geological past which has given rise to terrace like features on this island, so we have at least identified 5 steps on this and they are very identical on either side. So, central part is the flat

uplifted area and then we have steps like this and if you move, we have steps like on the other side also.

So, on the north side we have steps, on the southern side we have steps and that this is what we see the marine terraces.

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It looks something like this, let us see further detail.

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So, coming to the beautiful what we learn the arc, the sea arch and or the; we can say the gates also which because of the erosion and then we have what we see here is the beautiful sea

notches. Now, sea notches as we were discussed could be due to weathering effect and also because of the sea level rise or maybe we can say the sea level fall and this is because we learn in the previous slide that this point is your high sea or high tide level and this is the medial part.

And this is the low tide and this is present day wave cut platform, so we have what we identified is at least 4 notches here, so this small one is the present one and then we have the N2, N3 and N4, so at least 4 notches were been identified on this area, this is on the eastern side of the Neil Island. So, close up of that what we see is the notches and these notches are indicative of the paleo or the ancient sea level.

So, either you can say that the this sea was so high in during the geological past and now, what we see is the present seal level is this one, so nothing happened to the land level change or this is one interpretation and another interpretation is that you have the sea level which remain same which did not change but at the same time, the land moved continuously was uplifted, so the land or the area or the island kept emerging because of the tectonic movement.

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Now, along with that what we see is the terraces and these are the wave cut platforms finally uplifted and resulted in to the formation of marine terraces.

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So, further almost like few kilometres may be around 30, 40 kilometres from Port Blair, this sea notches, multiple sea notches we were able to observe or identify from the west coast of Andaman island. What do you see here is again, multiple notches.

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So, and this is the recent and multiple platforms also with you can see here, so this type of features are indicative of the ancient sea level which remained at similar to what we learn in the fulwell landscape, the abundant fulwell terraces and all that, so similarly these are all also, so you have a sea notch here and then the older platform, the present day the platform; the erosional platform is wave cut platform is this one.

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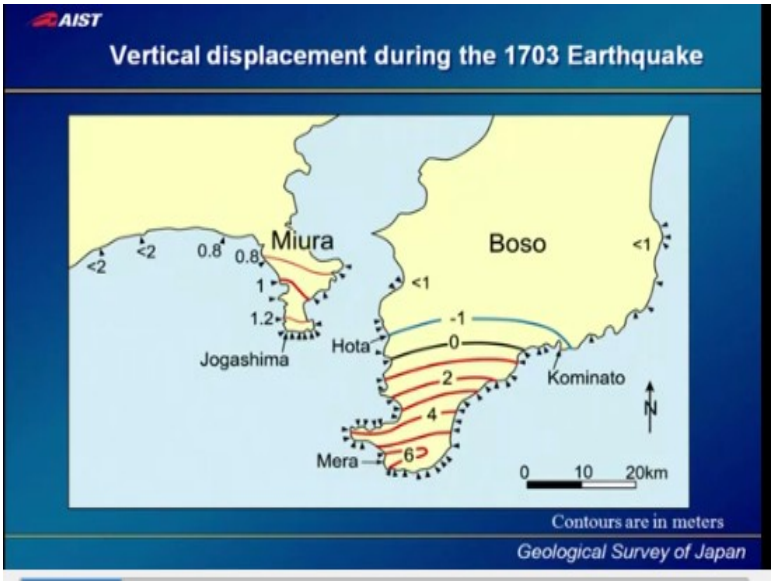

Now, coming to the other part of the terraces, if you try to see this is from Japan and this signatures are related to the vertical uplift during particular earthquake, so 1703 earthquake and similar signatures we have; we see from Andaman but we still we have not been able to date the events which event was responsible for the uplift.

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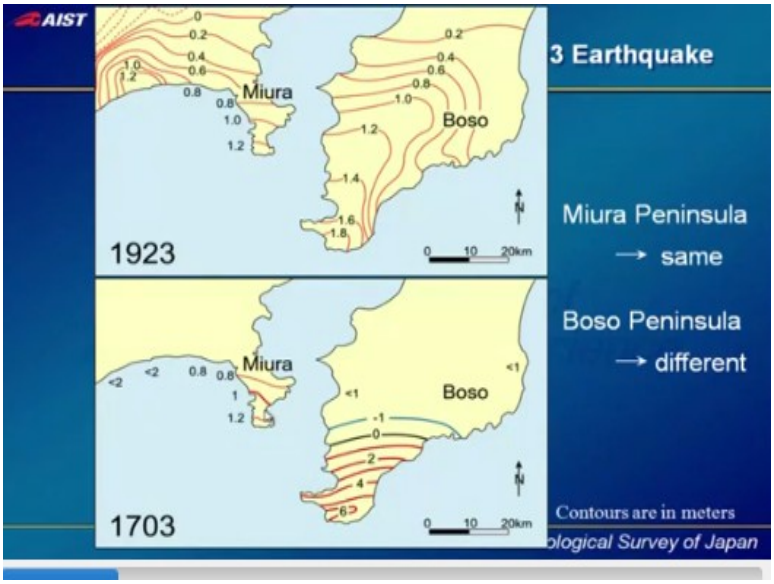

So, this is from the Boso and the Miura island were what you see is that in Miura Peninsula is this one here and then we have the Boso Peninsula on this side, so what we found was the here are the formation of the terraces or maybe you can see the notches; sea notches and the wave cut platform because of the vertical uplift.

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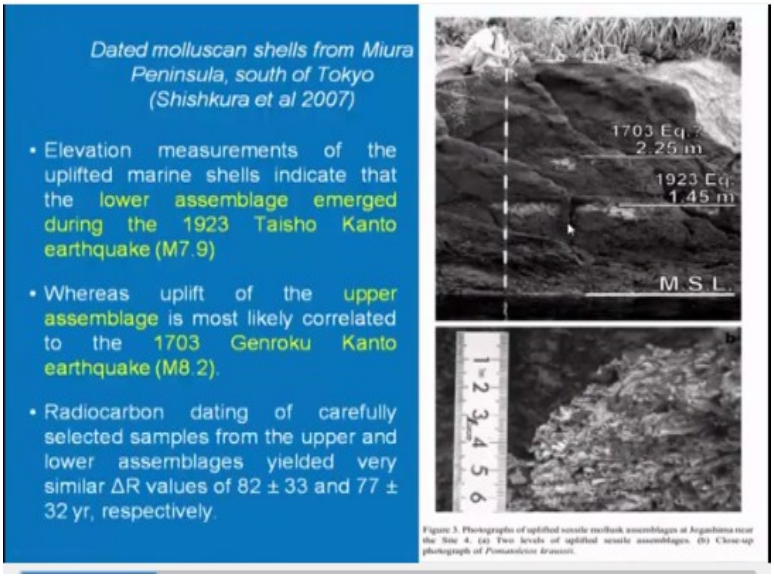

So, what they did was; they also try to date the molluscan shells which also because this organism here, molluscan shells were will survive at a particular level of survival and that is related to your the tidal levels. Now, if they are exposed above the mean sea level or the tidal levels, then they will die and this is what has been shown here that these are the dead shells of molluscan shells which now remain above the mean sea level.

So, this indicate that this and this has been proved that this indicators or the previous mean sea levels which finally was more like the land was uplifted during 1703 earthquake and 1923 earthquake and which has been like noticed and based on the or you can prove based on the molluscan; dead molluscan shells, so these are the signatures of 2 earthquakes which are preserved in the coastal areas.

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And further details, if you can see is from here actually, so you have like the uplifted rock terraces and this terrace was formed during the due to the uplift in 1923 event. So, 1923 event was; which also affected in the other coast of Boso peninsula, which uplifted almost the area by 1.5 metre, so what we see is the erosion which has started taking place now, this was the previous wave cut platform but now, it is; it appears like a rocky terrace.

And this is the portion which is under the erosion, so sea notch will form here and this is the present day erosion or the wave cut platform.

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So, this is the close up of that again, the you can see the dead or the indication of the paleo shore line and now it remains the water remains here actually, so this was; this area was uplifted during 1923.

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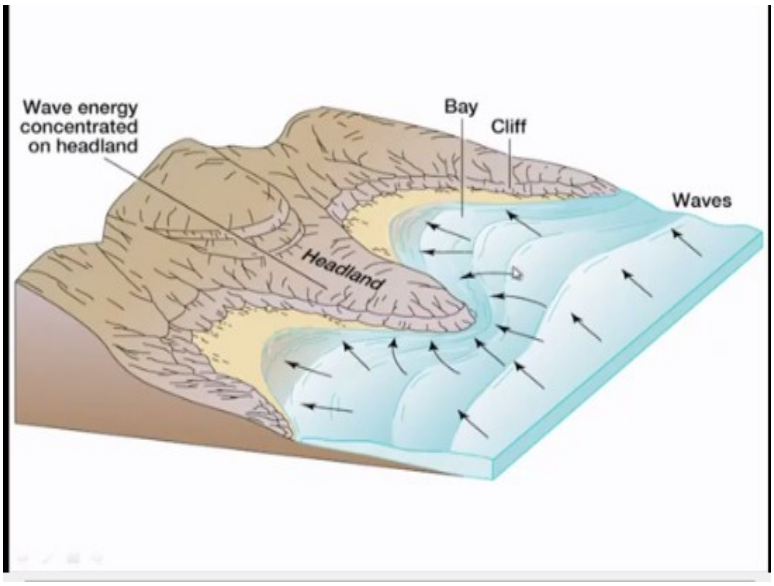

So, terraces and the erosions will take place in the region could be related to 2 ways; like it can be either because of the uplift or because of the eustatic sea level change.

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So, these are few samples we have seen from Andaman.

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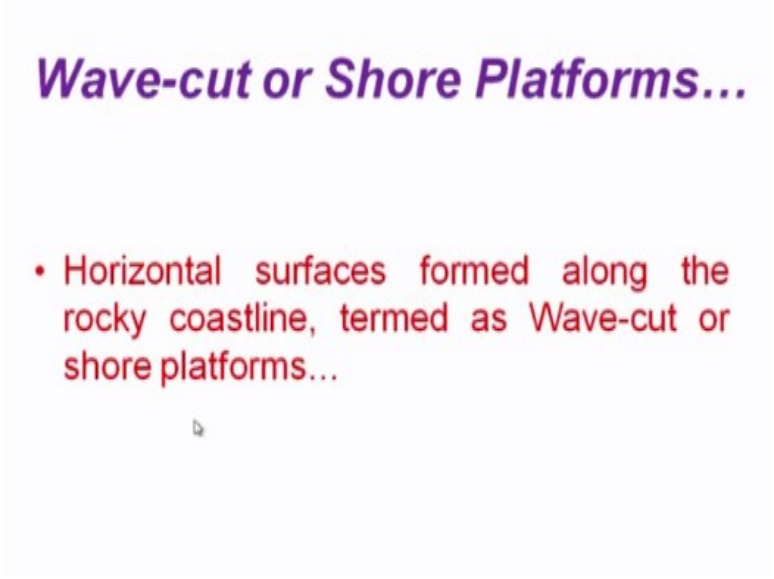

Now, wave cut shore platforms or the shore platforms of the horizontal surfaces formed along the rocky coastline termed as wave cut or shore platforms.

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So, this again from Andaman, so this shore platform or wave cut platform what you see here, so present the erosion is taking place in this area and this what is you see is the rock cliff, so wave cut platform or shore platform from Andaman.

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And this one I was previously shown in this example of sea notches, so you have multiple sea notches, so this; its posture or the coastline gives a clue of different level of sea which remained in the past, so sea level was definitely at this level once upon a time but now, it has moved to this present day location if you see here, so this is the present day wave cut platform, then you have another one wave cut platform here and then we have the sea notches.

So, notch 1, notch 2, this is the oldest and the youngest one is sitting here and then you have the last one. Now, what we saw here was this notch was like an cumulative notch, so 2 notches merged because of the erosion and giving rise to a larger one or we can say that this was the single notch because this gives us an complete idea about the tidal levels what we are having that is the tidal range in Andaman is around 2 metres.

So, this is; this notch, so 2 metres means the main at the centre because this portion will be the mean sea level and the high tide and the low tide were here.

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This is an another example of the shore platform or the wave cut platform.

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So, usually, what we see is that very much similar to what the marine terraces are similar to the formation, we can at least correlate with the fulwell terraces which mark the abundant floodplains, so similarly the erosion of the cause of the ocean water will also be reflected here so, what it says is that this is the; these are all ancient sea cliffs, so water used to come up to this place and erode this area, so we can see the marine terraces.

So, at present what we see is the sea is eroding this younger sea cliff, so such features are very common in the coastal regions and this is what I was talking about that this type of steps we were able to see in the Neil Island.

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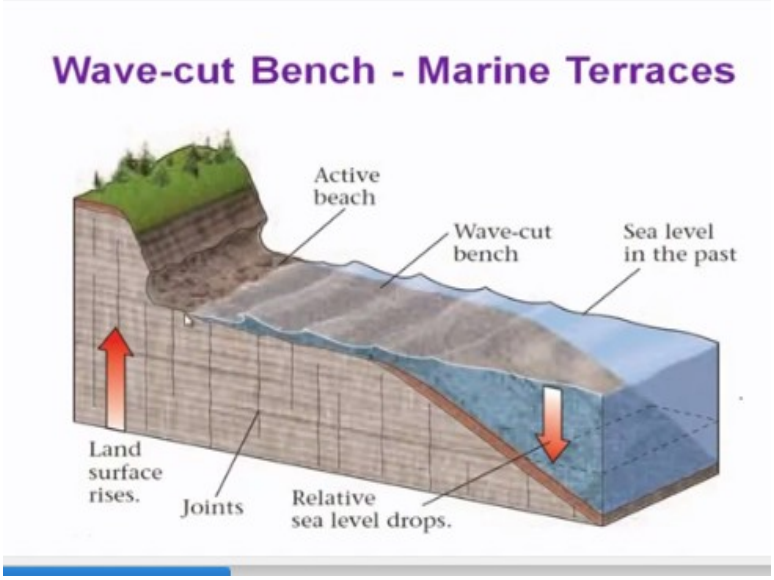

So, wave cut benches and terraces usually are been formed, when there is an erosion or the and subsequently followed by the sea level change.

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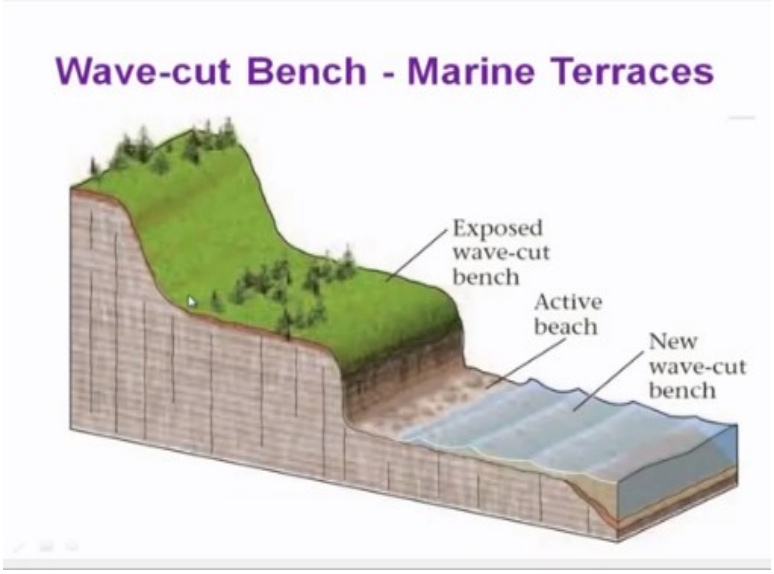

So, this shows that the; this was the previous level of the sea and that this was the previous wave cut platform which now is exposed as an terrace but now and then present one is this one, so

further next will be, this will be the terrace and similarly, multiple terraces are formed, so these are the examples of marine terraces.

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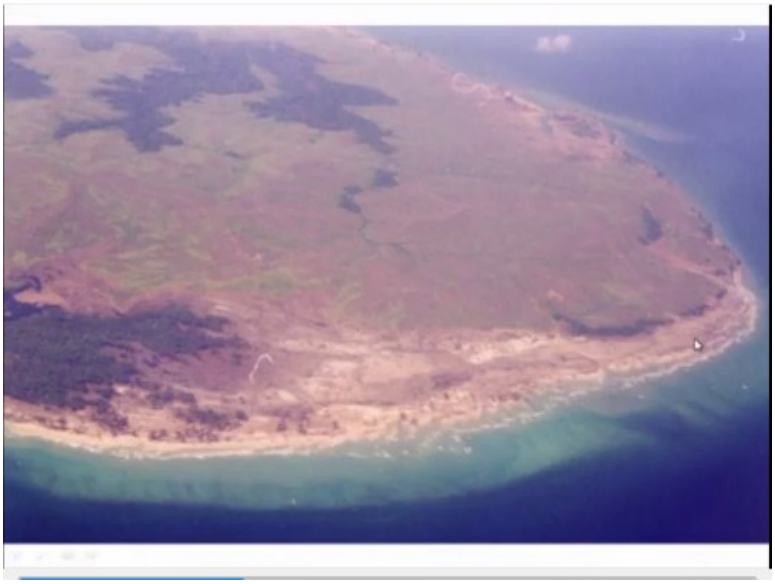

And the example from Andaman would be sea as the flat surface here and then another flat surface over here, so these are the clear example of the marine terraces.

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Another example of marine terrace and sea cliff.

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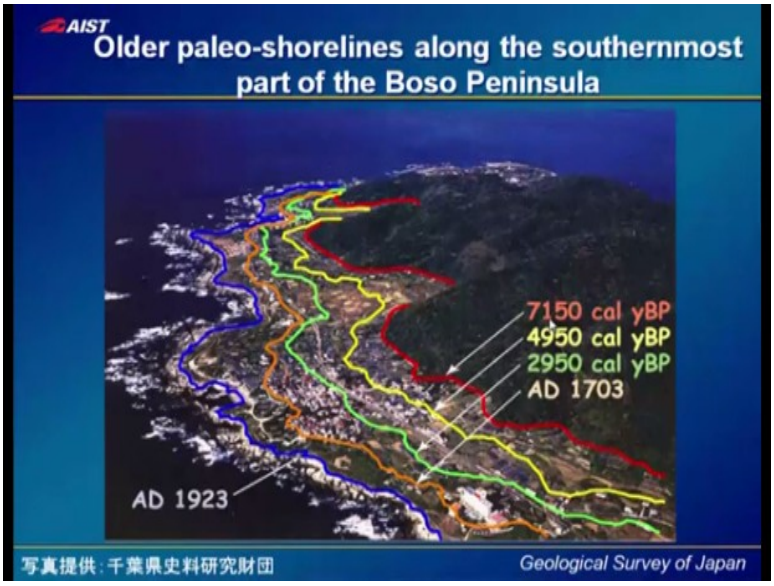

Now, going to be the ocean from Boso peninsula from Japan, this experience that almost like this area which is occupied by thickly populated area in the region or have settled on the terraces; multiple terraces. So, if and this terraces are correlated with the events, so 1703 earthquake and the 1923; 1923 earthquake we were looking at the Boso at 1.5 metre of uplift which I was showing this sea notch and the wave cut platform.

So, this uplift and this was almost like the; lift was around what it was been shown based on the measurements around 2.2 metres or 3 metres something like that so, different level of terraces are there, so suppose next earthquake, then there will be another terrace which will be formed in this region. So, this if you want to see here further, what you have is that other than this 2, there are few more terraces which are been identified and which have been correlated with the different earthquake.

So, the blue line shows the terrace which was formed was the latest one during 1923 earthquake, then this orange line shows 1703 and green line shows the 2950 years before present, that is an uplift during that period and this 4950 and 7150, so they have almost like 1, 2, 3, 4, and 5 terraces and this is and all are occupied, so if you move from this place to this place, you will be able to see the steps here.

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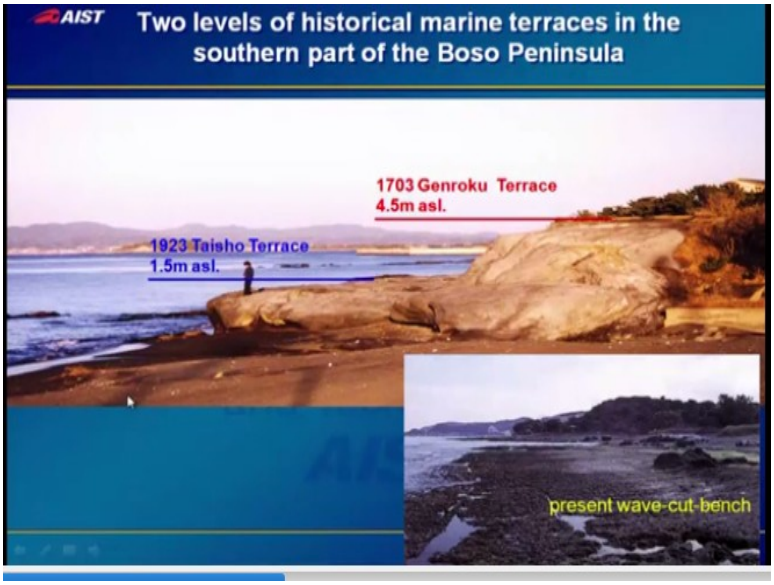

So, this is this side is like up down, up down and all that, so example here of two recent terraces, so this is what you will be able to see the platform like features, so this is this one is almost like a sitting above of 4.5 m above mean sea level and this is also above mean sea level and this is correlated with the Genroku earthquake of 1703 and this is Taisho earthquake of 1923 and this shows the present day, so terraces are sitting here and this is a present day wave cut platform.

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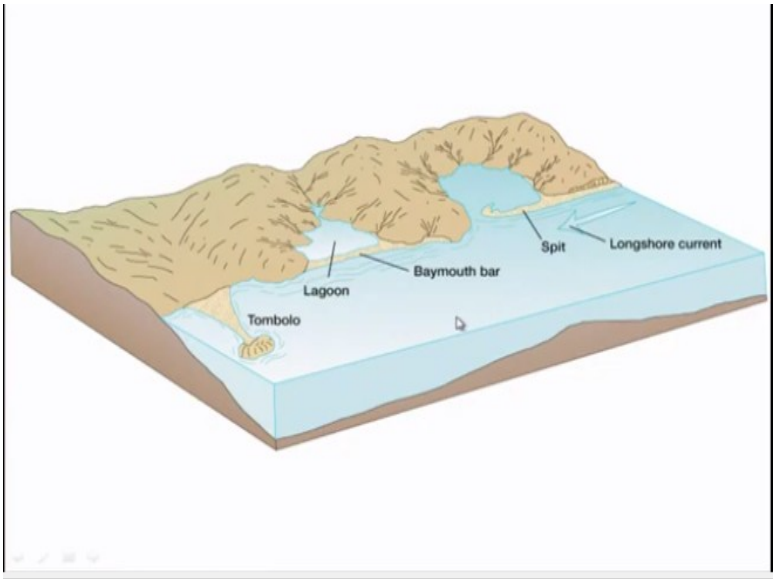

Now, other features which are commonly seen along the coast other than the terraces, the wave cut platform, so sea notches, sea archs, tombolos and the; so we will see tombolo; what is tombolo and but we talked about this stacks and the gate ways and all that, so lagoons are very common in the region and mostly we see this in the behind the beach ridges or the dunes and

then these are basically, an enclosed body where you will have an input of the freshwater as well as the marine saline water which also will spill over the bars.

Or you can say the dune areas and the formation of spit, we talked about the littoral drift and all that where which help in formation of this split and finally, when it covers this whole area, it will result into the formation of lagoons or the marsh area.

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So, coastal land forms, so those all what we have seen sea notches, wave cut platforms, terraces and all that these are all erosional landforms and this now what we are going to talk about the depositional landforms, so depositional landforms basically what we have are the beach, tidal flats, coastal dunes, salt marshes, spit, bars, beach ridges, barrier islands and mangroves, tombolo's, natural bridge, so these are all depositional features.

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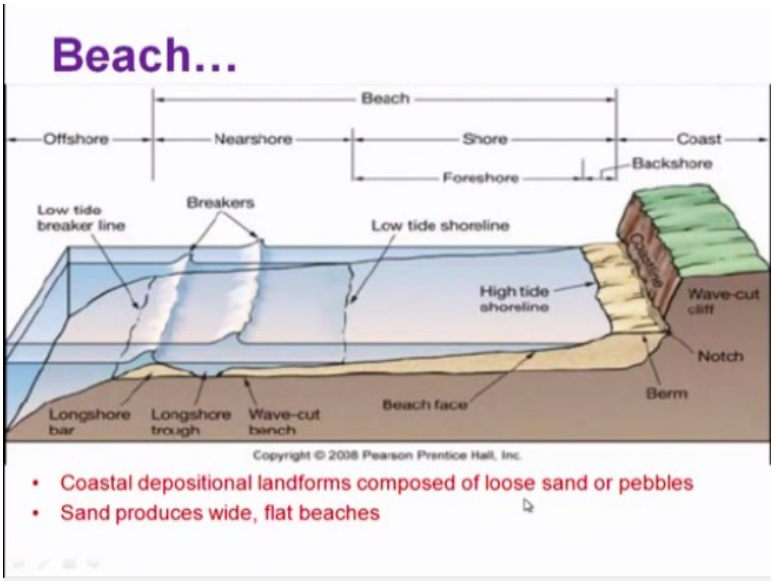

So, in short if you see the variation from the offshore to the coast, then you will come across all the features here, including the depositional one and this few are which have been shown as the erosion ones. So, coastal deposition landforms composed loose sand or pebbles, sand produces wide and flat beaches. So most common features which you will come across in the coastal zone is the beach was again, it should have an ideal condition to form a beach.

They form the beach will not form everywhere, so it needs an ideal condition and the configuration of the currents or in the direction of the currents, the waves coming in carrying the sediments and the coast line, the configuration of the coastline, the geomorphology of coastline is extremely important for the formation.

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So, this is the again, like a very beautiful beach from Andaman slightly a bay area which has facilitated formation of beach here.

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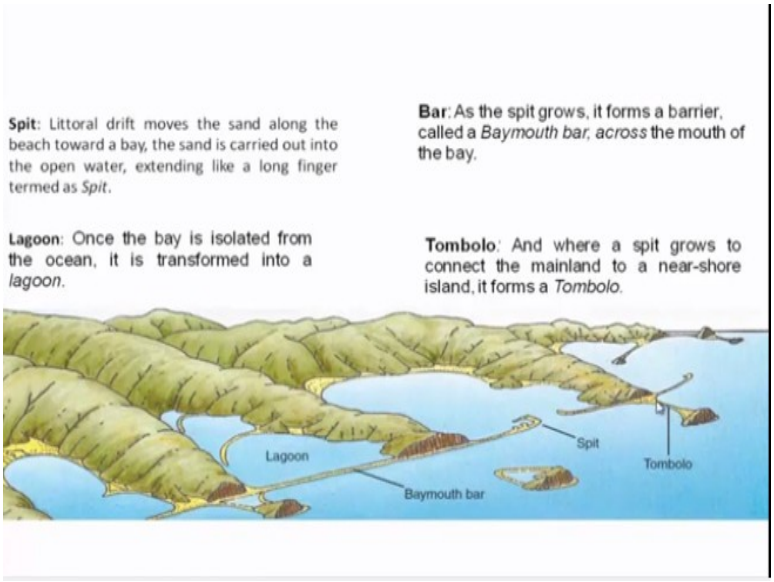

So, now if you look at the few depositional features, so mainly as we discussed in the previous slide also that what we see is the formation of bar or you can see the formation and development of the spit and joining the spit here on the other side and resulting into the formation of an enclosure and which will result into the formation of lagoon. Now, these are the common features which are related to the depositional landforms.

So, spit mainly if you take is as we discussed earlier also that it is the littoral drift will and the long shore currents will help in formation of the spit in the coastal region, so littoral drifts moves the sand along the beach towards the bay, the he sand is carried out into open water, so it is carried out in an open water and extent like a long finger termed as spit, then comes your bars, so bars are also like as the spit grows, it forms a barrier called the bay mouth bar.

So, it result into the enclosure, so it forms across the mouth of the bay and that will result into the formation of lagoon, once the baby is isolated from the ocean, it is transformed into a lagoon, and then we have a tombolo; tombolo, where a spit grows to connect the main land to a near shore island, it is termed as; so there is an island here and a spit is formed or developed which connects this 2 islands.

So, now this one is the main land and the island which is sitting here and that feature is termed as tombolo.

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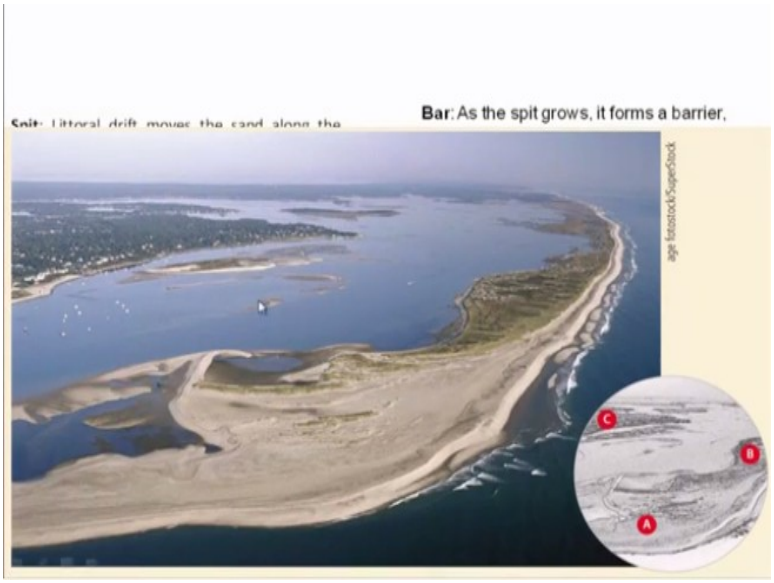

So, the signature of spit or mouth bar; bay mouth bar enclosing resulting into the formation of lagoon here.

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And then another one is the tombolo, which is connecting the island here and the mainland over here, so this is an example of tombolo.

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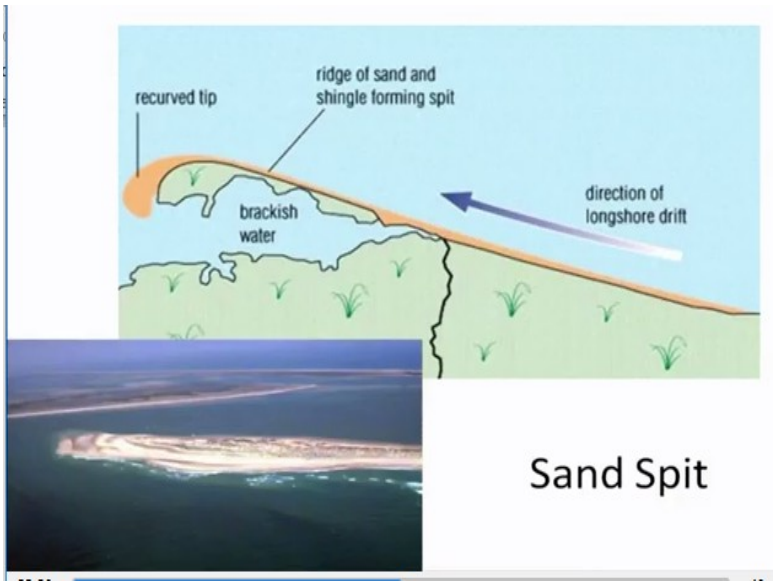

Now, coming to the spit, beach and beach ridge, so this what we were talking about the beach, so mostly the long drift; long shore drift out of the littoral drift will result into the formation of spit or carries the sand into the ocean side and result into the formation of the lagoon finally, when it closes this portion, so this area will be the brackish water area.

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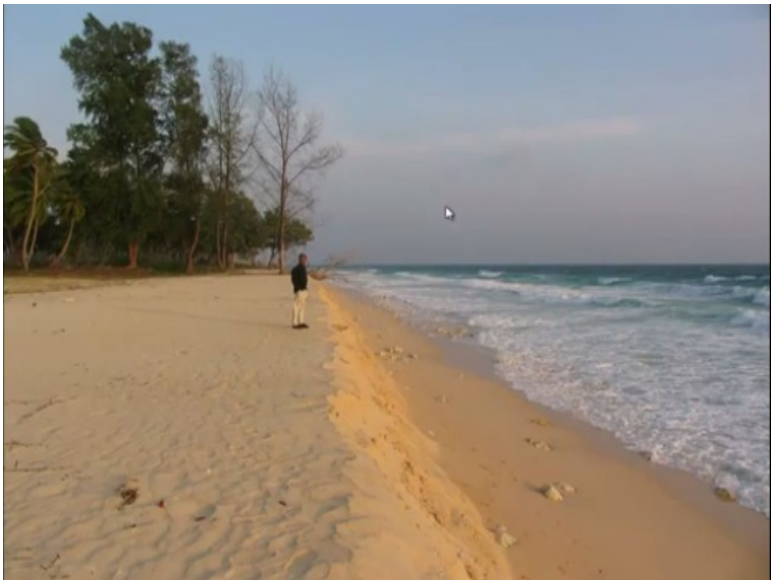

So, this sand spit and this is very much similar to this one here, a thick pile of sand.

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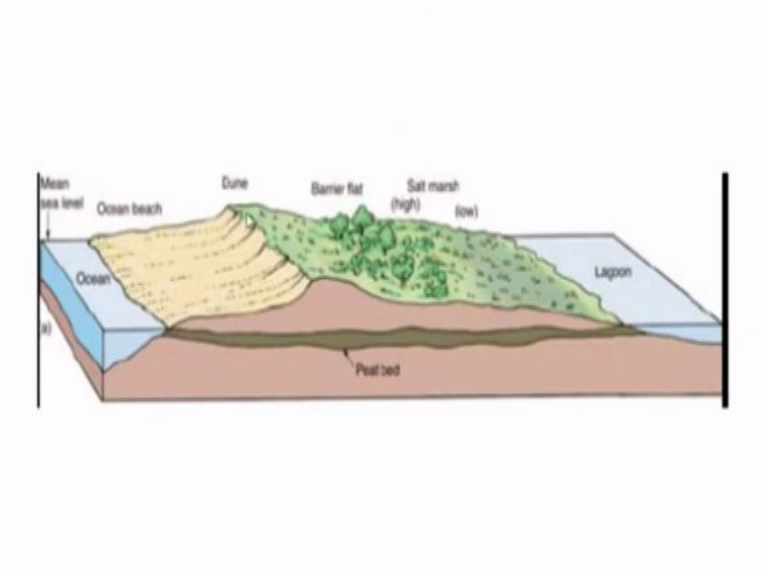

The beach ridge or the dunes are also an important feature which have been in so, in or developed in the coastal zones, so you have the beach and then dune or the beach ridge and behind the beach ridge, you will have the lagoon, so this is again a back marsh area which is a brackish water region, so you have and in sense of situations because of suppose, the next phase comes in and this is buried, then you will have the formation of bed here.

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So, this is an example what you see is from Car Nicobar from Andaman Islands, so this side is sea and the portion you see here from this point where I am putting the cursor, if you move further this side, then it is a sloping surface, so this is a beach ridge what we have and behind the

beach ridge may have the formation of lagoon. So, lagoons will look something like this, so it is enclosed and protected by barrier beaches.

So, we have barrier beach, in the front we have the beach and the beach ridge, so freshwater river draining into them and develop into the wetland marshes, so marshy lands will developed behind the behind the beach ridges or the barrier beaches.

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Then, we have the mangroves, which are again will grow close to the coast and most of the regions.

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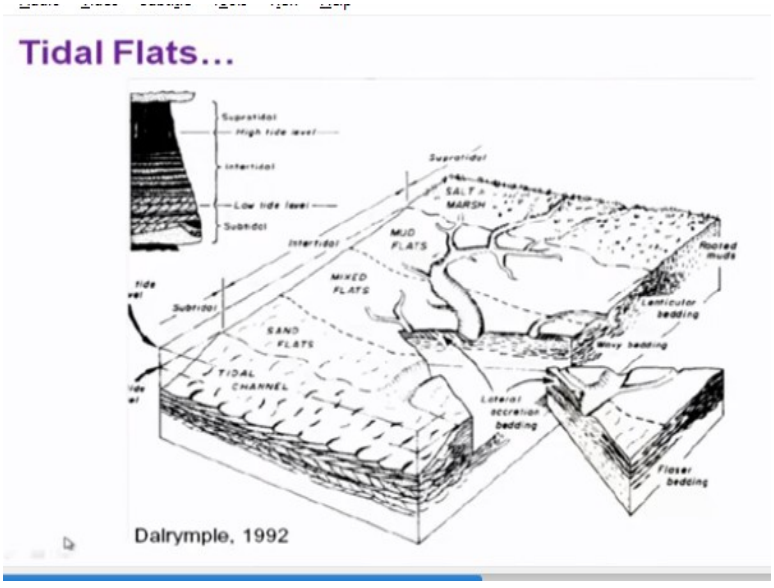

So, other than mangroves, another most common landforms which you see along the coast is the tidal flats, now if you see this and tidal flats mainly are formed along the coast because of the tidal fluctuation, the high tide and the low tide and it is comprise of mainly the fine sediments or maybe at least the coarse and the alternate sequence of or we can say the intercalated sequence of sand and silt and all that.

So, you will have all horizontally laminations or stratified sequence, so if you see this section here, what we find is; now, we have toward the coarse, we classify this as an supra tidal area and intertidal area and sub tidal area, so what we see here is that if you move from the supra tidal area to sub tidal area, the gradient decreases and you enter into the deeper environment, see you have mostly close to the in the intertidal areas, you have the sand flats.

And then you will have intertidal, you will have mixed deposits, so we will have sand silt and then further in land if you move, you will have mud flats and then you have salt marsh, so this section and further in the deeper part that is in the sub tidal region, you will have mostly the tidal channel, so when there is an the low tide and this tidal channels will we see in the exposed. So, what we see here is different environment across the topography here from the land towards the ocean.

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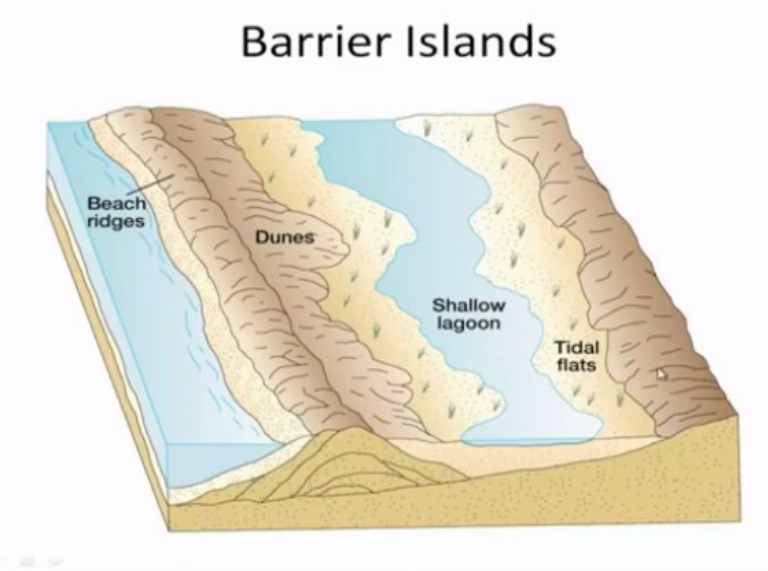

So, these are very common features, the landforms which you come across in the coastal regions. So, you have like the beach, beach ridges and dunes and the tidal flats and all that in the regions.

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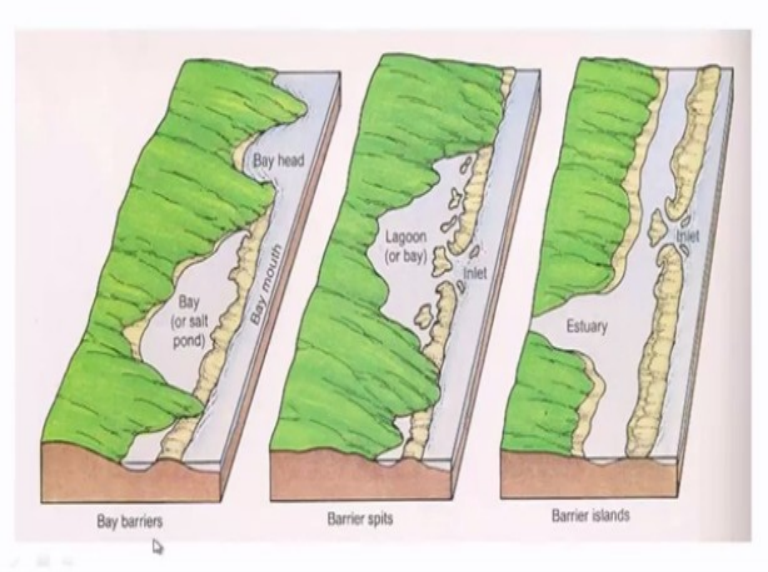

So, barrier islands and this shows the different barriers, so Bay barriers and barrier spits and barrier islands.

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Now, another important portion which we come across in the coastal regions is the formation of corals, so other than mangroves in tropical coast, you will come across the formation of corals.

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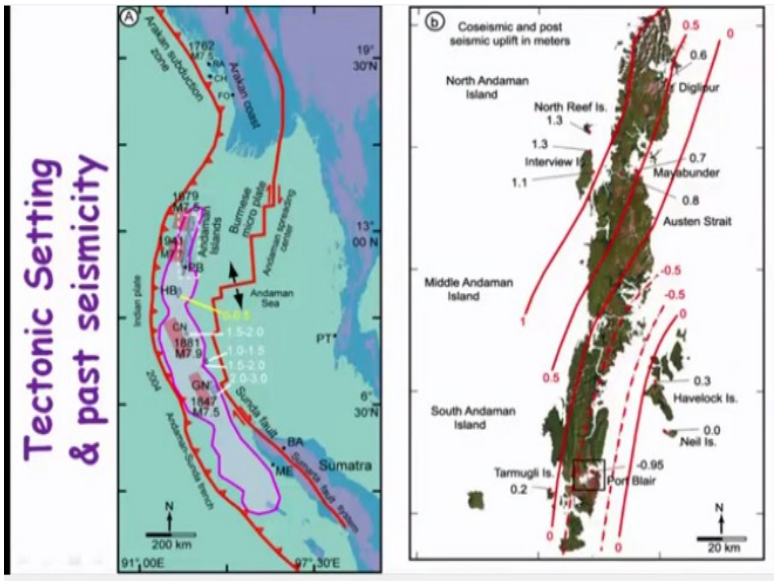

And the corals in Andaman basically what we studied was related to the tectonic movements so, I will quickly show you some examples of what studies we did in Andaman using the understanding of the coastal landforms as well as coastal terraces we can say or maybe the corals which we formed and corals are very good indicators of the sea level fluctuation and either the sea level fluctuation is because of the tectonic movement.

And when we say tectonic movement, then it is a sudden change in the land level, so sea level remains the same but the land goes up or down with respect to the movement which has occurred in that region, so as I discussed earlier that this was the situation or which was experienced of may be the land level change which was experienced during 2004 earthquake, so zero line known to formation, whereas this side that is the eastern side subsided by almost 50 centimetre.

And the western side got uplifted maximum of up to 1.3 metres, so we did some survey in this region, try to identified and look that the marine terraces or we can say coral terraces and then I will show some example of this region where what was the landscape before 2001 and what happened, before 2004 and what happened, during 2004, what is the situation at present.

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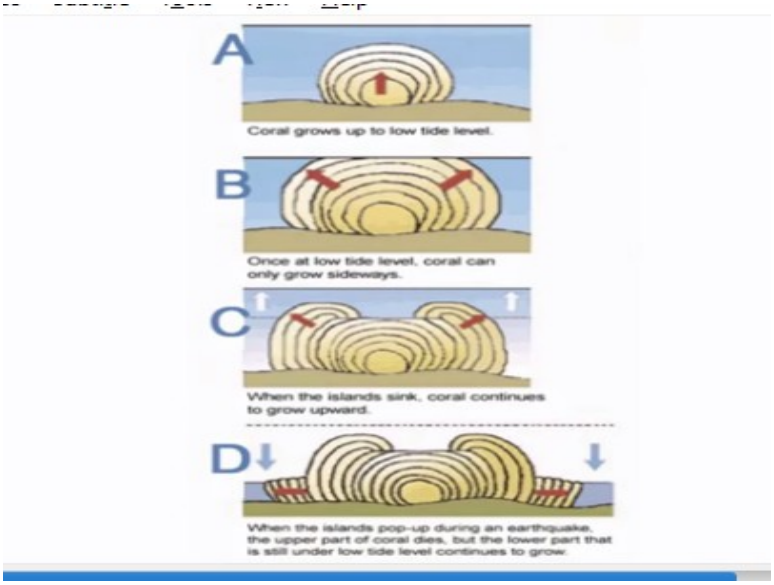

So, these are few sketches which talks about the coral growth getting affected because of the tectonic movement, so what happens is that corals usually grows vertically as well as laterally, so this rings which are seen or shown here on this sketch, similar rings will add up every year and the growth of the coral will be normally in the vertical as well as lateral direction, provided it remains within the range of the tidal levels.

So, coral grows up to low tide levels, so that is the survival line, so if low tide, if you expose it, then the top portion will die. Now, once at low tide level, the coral grows sideways also, so it will grow vertically, it will grow sideways, now but in this figure; figure C, what it has been shown is that this is the level which was available for this coral and there was some disturbance which did not allow the coral to grow vertically here.

So, when the island's sink, the coral continues to grow, so the sink of the island that means the water level has gone up, so the level; the top level of the this which was the level of your the low tide has changed, so now it has become this one. So, again the coral will start growing towards the low tide. So, low tide level has changed because the land has sinked or subsided. See what you will find is this similar growth, this will start vertically growing as well as laterally.

Now, suppose the island pops up, so suppose this goes up, so the coral will be exposed, so this coral portion which has been shown here is now dead coral and this is the new tidal level because

the land has moved up and the sea level remain the same, so this is the new tidal level. So, this portion will die and remain preserve whereas, this portion will have the formation of lateral growth as well as the vertical also which will touch up to this level.

Now, whether we see such signatures in the coral which we found from Andaman, now this can also indicate the eustatic sea level change if but the eustatic sea level change is gradual, it is not sudden.

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So, what you see here is that you have a surface which is a dead surface and between over here and then top has been covered over here so, this indicate again the land subsided and the corals grow laterally, so in 2004 what we saw is that when we visited this was the low tide levels. So, now what we are experiencing is this whole coral is exposed almost like more than half a metre thick, coral is exposed and this is the level of the present day sea level after the uplift

Because the land in the western side got uplifted or the island got uplifted in the western side, now the growth of the coral will be along this one, at this level, so lateral growth will be seen and this will be exposed as we were looking in the previous slide. So, this will be the situation, so this will; because this portion has exposed and now the bottom of the coral over here is the tidal level.

So, this is because of the pop-up of the island because of earthquake, so the upper part of the coral is dead, so this is now will be; is dead and new coral growth will be seen laterally along this line. So, this happened in 2004 and this is an example from Car Nicobar and this is the along the west coast of Andaman and this is again from the interview island, north reef island, and interview island this example and this is from Car Nicobar.

So, Car Nicobar the area subsided now, what we saw is that there was a beach which existed here in the front of this inspection bungalow but now, since this area got subsided whereas, the upper 2 photographs are showing the uplift whereas, this one, this area subsided, so this subsidence now like force the ocean waters to come further in land, so whatever the process which were occurring here, the formation of beach water coming and going back resulting into the deposition and the formation of the land forming the beach and the beach ridge will start developing in this area.

And this is what we saw here, in 2009 when we visited, we found that this in beach ridge which are started forming in this area, so the coastal processes will get affected because of the change in the sea level, so this is an important lesson which we will learn from this event that every change which occurs on earth's surface are preserved and for example, the sea level change if it is occurs either it is because of the land level change or because of the eustatic sea level, climatic fluctuation, the landscape along the coastal region will also be affected.

So, this was in 2009, 10 and the previous photograph was of 2005, after the earthquake we took and this is the 2009, 10, so again this area is from Port Blair which subsided and this was situation in Port Blair area, so this region was very like high priced lands because of the paddy cultivation, very fertile area but now, this sits in water.

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Again another example of the erosion of the coastline because of the subsidence, so what you see here is that all coconut plants are affected by the present day erosion and this happened after the 2004 earthquake, so this was the previous beach which extended up to this portion but because of the subsidence, the water started entering inland and this was the high water level, there is a high tide level.

So, beach before 2004, the high tide level before 2004, whereas this one is present day high water line, so now the high water line that the high tide comes up to this portion and erode, so this erosion is because of that and the present day beach has moved further inland and the earlier beach was here and then height, water level used to come up to this and this was a protected area not in terms of like fencing but at least it was protected from the erosion.

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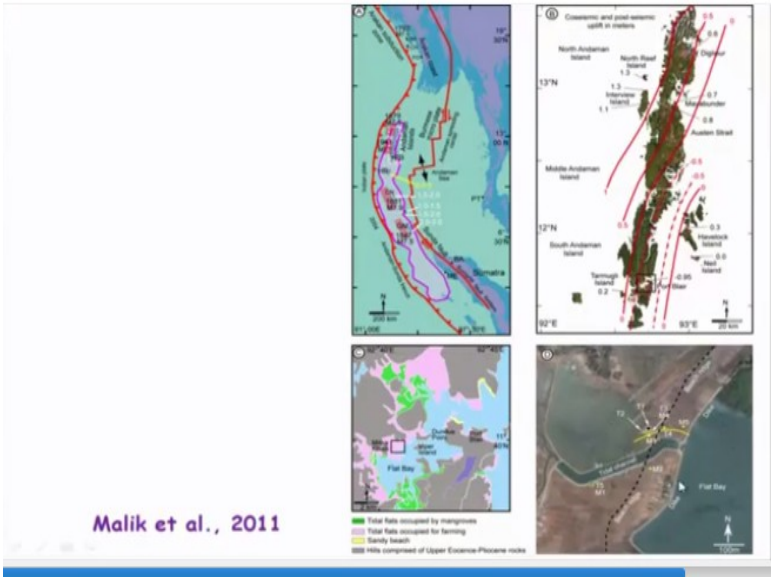

And this is what we have the present day beach ridge, so we did some exercise in terms of identifying the old Tsunami deposits and all that I will quickly move or may be discuss in the next course about this all details.

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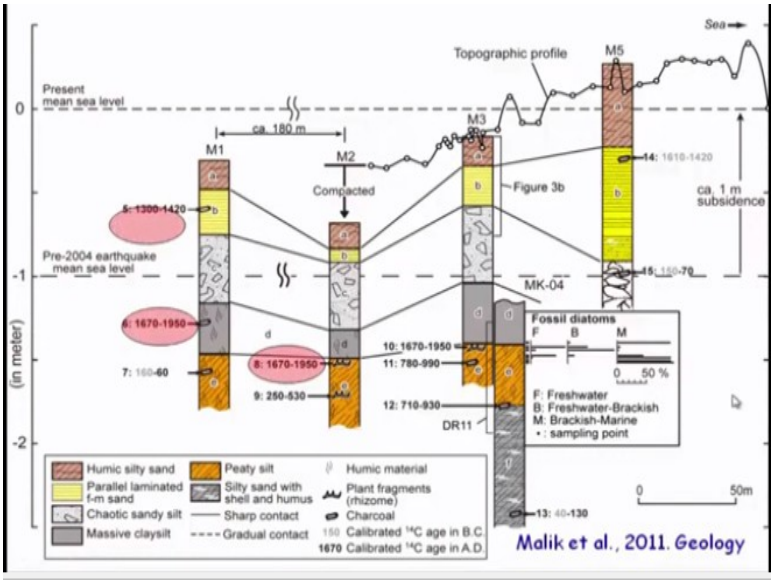

So, but this also helped us an understanding that the landforms or the landscape kept changing during the geological past and this evidence what we identified was of the marshy or the peat which we found and that was the signature of subsidence, so there was an big earthquake in 1680 which resulted into similar effect in terms of subsidence what we have identified in 2004 or what we experience in 2004.

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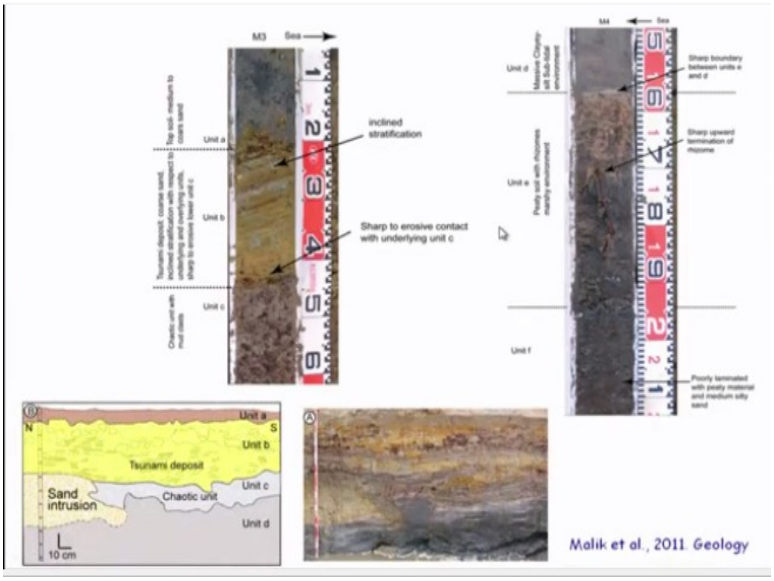

So, similar signatures were we will found from here and these are the ages which together and such signatures in the sediments we try to study which will which tells us the previous conditions or the environment in the region, so this is an the Tsunami deposits which we saw and this is an example of the marshy area and there was an sudden change of the landscape because of the earthquake and then the final deposits which we see here is indicative of the deeper environment.

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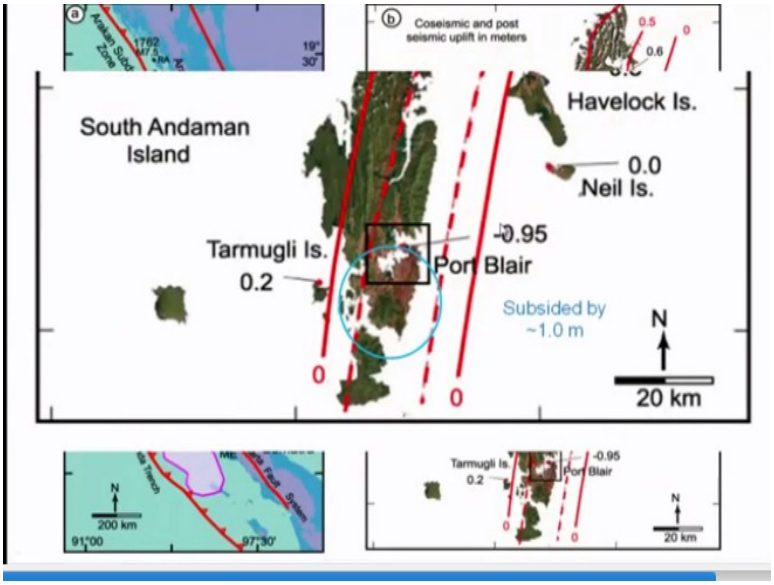

Now, coming to this part here that what we study the subsidence was almost like 1 metre.

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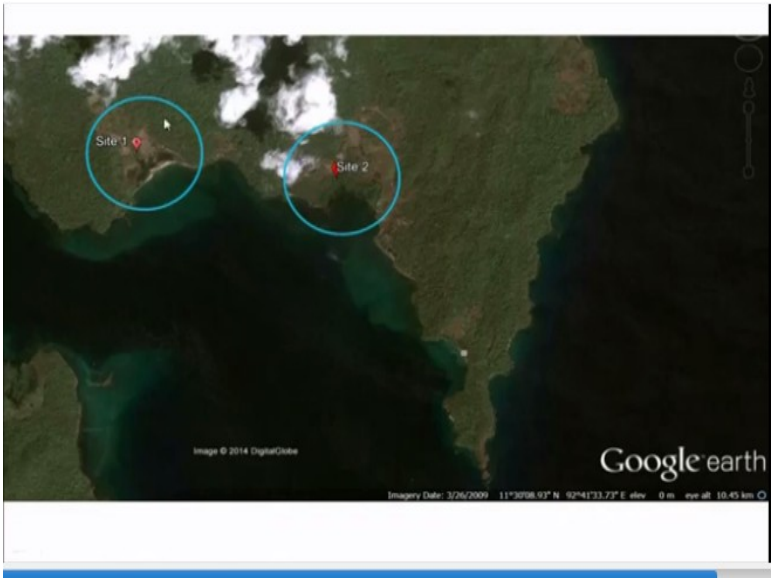

And this area if you see, we finally what we concluded as the subsidence in this part was around 45 to 50 centimetres, now the landscape changed here, I will cover this side.

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And if you see the subsidence during 2004, so this is an example of that so, the wall along the coastal road before 2004, the area subsided and then they construct the new walls, so this is the present day wall which has been constructed to protect the erosion of coarse, the height of the Tsunami was almost like 3 metres here.

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Now, this is a good example, this is an old house which is sitting here, this is before or the tea stall before 2004 and this was constructed in higher area; slightly higher portion to avoid the inundation and that was in 2000; after 2004.

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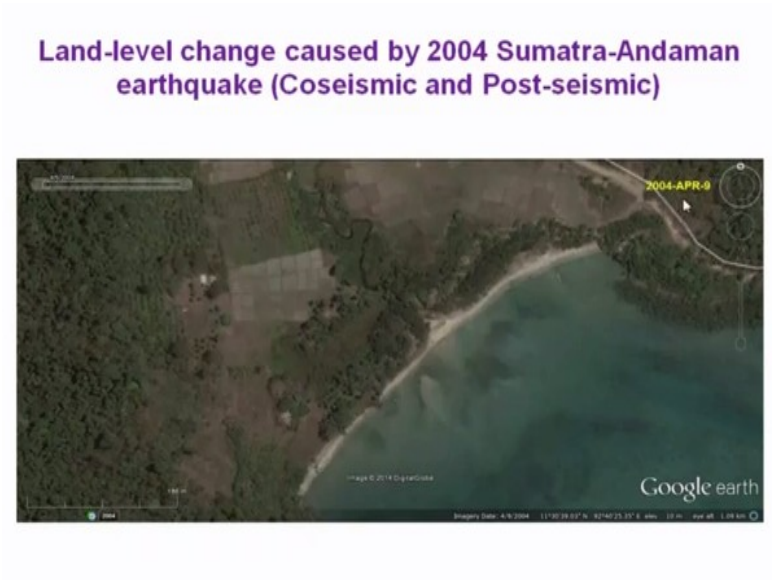

So, if you see this, this is the photograph, Google image which was been taken in 2004 April, before the earthquake; earthquake was in December.

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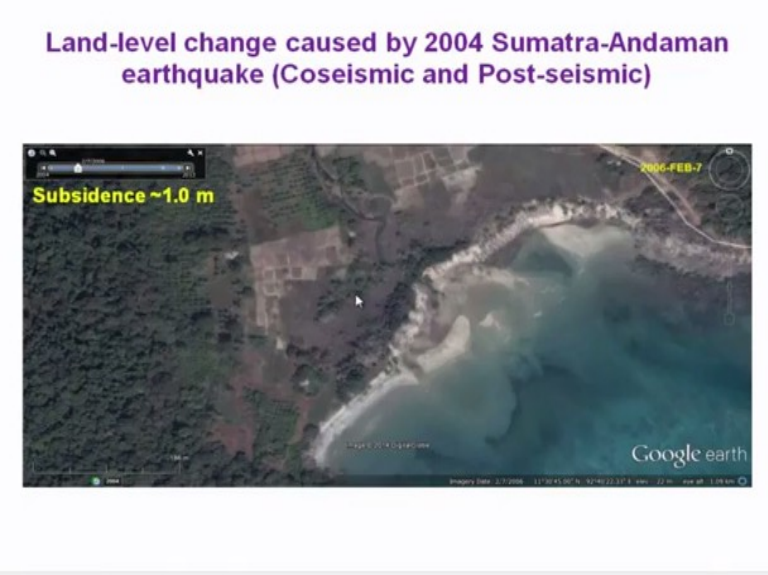

And this is 2006 post earthquake, so the landscape which completely changed because of the subsidence, you will have the; you can see this here the channel coming here and flowing and taking here and flowing in to the ocean and having the bay mouth bar here and this beautiful beach and this area is the back marshy area, this portion which you see here is the beach ridge. Now, what has happened that the beach is completely broken; it has moved inland, the meander pattern has changed here.

And the back marsh which used to occur here, now it is extended its area further north-west. So, subsidence was total up to 1 metre but here what we measured finally was around 50 centimetre.

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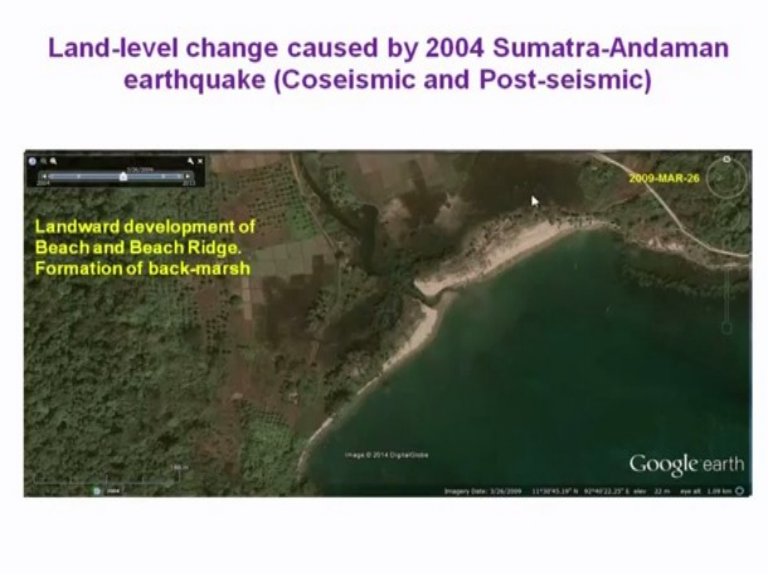

So, this is a situation in 2009, so we have the beach which has moved inland and meander has changed and the back marsh which used to occur somewhere here is moved further inland. So, landward development of beach and beach ridges; beach ridge formation and back marsh, so back marsh has also moved further inland.

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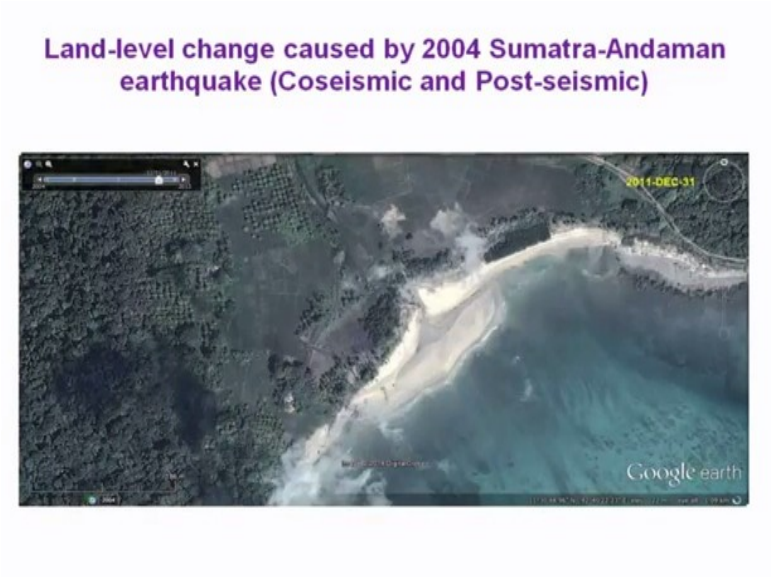

So, this is the situation in 2011.

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And this is in 12, so if you see the 12 image, you can easily mark the change in the channel patterns which has left out this channel here started flowing straight and then you have the back marsh, beach ridge is here and the beach which has moved inland.

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So, this is what local people have done as they have artificially filled the area to protect the paddy fields from inundation.

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Post event changes; beach ridge migration towards inland due to coseismic subsidence and because of the subsidence, more forest area which was along the coast were subjected to the inundation, so they are subjected to the trees were killed and the dead forests now exists which resulted into the formation of dead forest. So, I will stop here and we will continue with the new topic in the next lecture and mainly on talking about the (()) (46:13) landforms, thank you so much.