Natural Hazards
Prof. Javed N Malik
Department of Earth Sciences
Indian Institute of Technology, Kanpur

Lecture – 18
Earthquake and realted hazards Part III (Kachchh)

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Welcome back. Now, this is a case study from a Great Rann of Kutch in Gujarat, Western India. And the this part is important, because this area or the region which falls away from the one of the most seismically active region that is Himalayan belt, sitting almost like a 1000 kilometer away. But nevertheless it is close to one of the active fault system in the west that is a Chaman fault system.

So, we will we will discuss more when we get into the more details of this. The photograph which has been shown here is from Dholavira, which is one of the very famous ancient Harappan site and people have linked this also to the Indus valley civilization.

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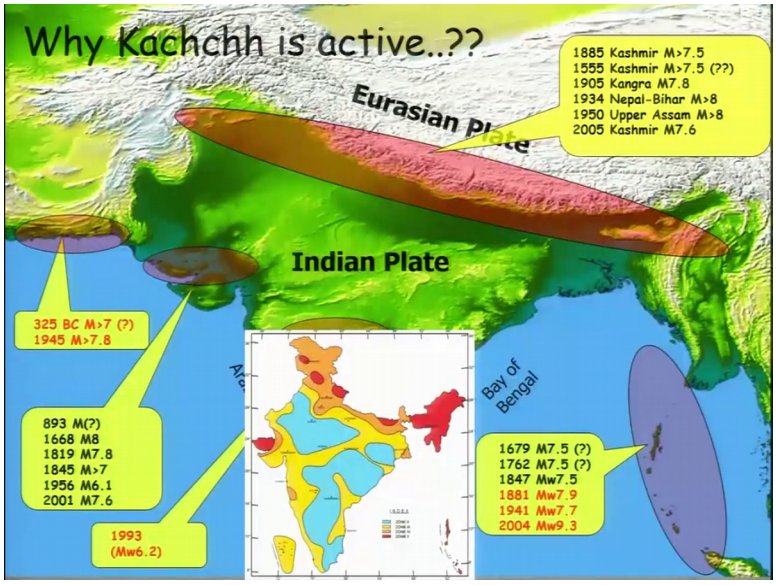

So, why Kachchh is so active, and why Kachchh need to be understood in terms of the deformation patterns, and the earthquakes which are occurring there. So, as I told that this area is falling almost away from the Himalayan belt over here, but close to one of the fault system which is the again part of the Himalayan orogeny that is Chaman fault system.

And this part is your Makran subduction zone, which is also triggered tsunamis in the past in the 325 BC, another one was in 1945. Now, Kachchh region here which is a very small one; but, has triggered a couple of earthquakes. So, if you go back into the history, so far what we have based on the records historical records. And the geological or poly seismic studies, we know that there were earthquakes in eighteen 893, and 1668, 1819, 1845, 1956, and then 2001.

The 1956 was 6.1, whereas the other earthquakes if you see, they are all greater than 7 or it is they are greater than 7.5. And then as I told that there were two major subduction zone earthquake along Makran subduction zone sitting in west of this region, where we had an tsunami event in 325 BC, another 1945. This part I will not discuss, but yes it is important to be taken up here that there was an earthquake in Lathur in 1993, the magnitude was 6.2.

Now, based on this earthquakes, what we have discussed in Himalaya, the Himalayan zone is sitting in 5, and also the Kachchh which is quite unusual to see that the small patch of the land here or the region in this whole Indian subcontinent is sitting in zone 5.

And this is because of the area has experienced large magnitude damaging earthquakes in the past. This event of 1819 which was been named as Allah Bund fault or Allah Bund earthquake, which occurred on the Allah Bund fault was quite unusual in terms of the damage as well as the landscape which got changed after the event.

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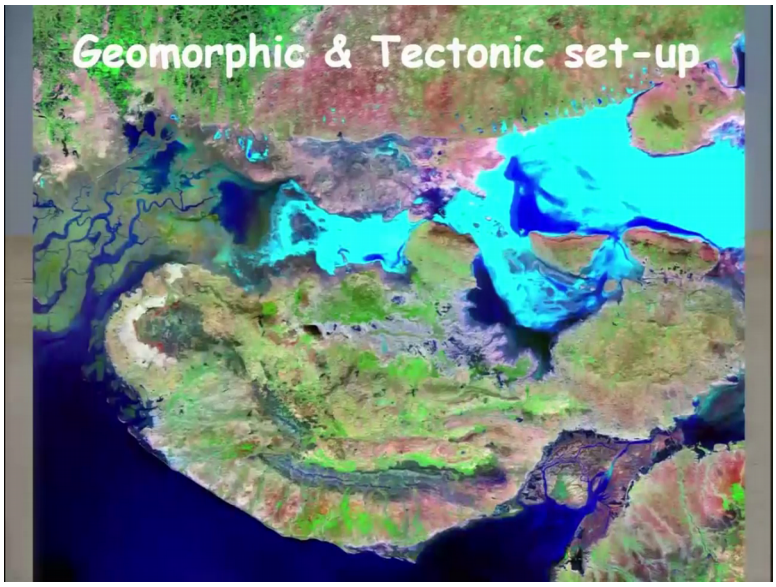

If we look at the overall geomorphic and tectonic framework of Kachchh region, and what we see is that very beautiful, boundary here this a geomorphic boundary between the Lithar. And you are this side we are having the marshy land ok. So, I will quickly go into the details with what we have done in this area.

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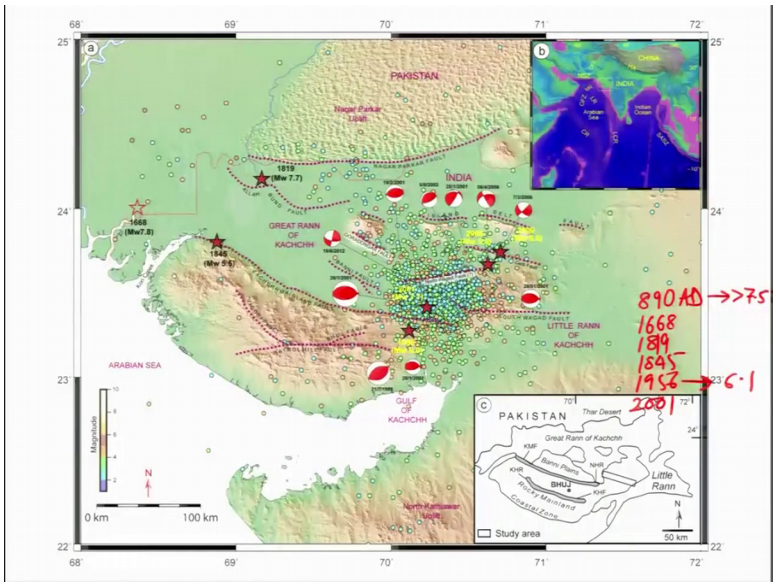

And now this is an area which is sitting quite away from the main seismic belt that is Himalayan arc, and Kachchh is sitting somewhere over here, it is quite far off. Nevertheless it is close to the Chaman fault system which is been shown here, and then another subduction zone in Makran subduction zone.

Now, if you take this on Asian map of India, then you will find that the Himalayan belt is in zone 5 pockets of Himalayan belt. And then we are having northeast sitting in zone 5, there Andaman Nicobar. We can understand that this part is sitting in zone 5 is because they are either close to the subduction zone, and this is your collisions zone.

Now, why this Kachchh which is sitting so far, and very small piece of land as compared to which we take in proportionate to the Indian subcontinent is having in zone 5, and why we are having so many earthquakes. So, when we started working here, we asked several questions to ourselves to but to some extent, we were not able to get the complete, how all answers to our questions.

Now, if you look at the historical earthquake in this region, it goes back into like there were there were earthquake in nineteen eighteen 890 AD somewhere. And then there was again this was greater than 7.5, then we have following earthquake 1668, then you have another earthquake in 1819, then 1895, 19 fifty 56, then we have 2001. This was 6.1, whereas rest are all greater than 7.5, but less than 8.

Now, if we consider this earthquakes or the data, which we have based on the historical chronicles or the geological signatures, it definitely there is a reason why we have put this in zone 5. So, here they are listed a few Indus, this is an Indus earthquake 19, 18, 1668, 7.8, 18.90 Allah Bund earthquake, which took place along the Allah Bund fault here. And then we are having another 1845, which was along this one.

But, this is again as I told that this is probably this one, but it is earthquake which has been recorded here. And this was 1956 of the magnitude was not com as high as 1819 and 2001. 2001 was again 7.7, 7.6 magnitude earthquake. So, this was less actually, it was not 8 or 7.5 magnitude earthquake and 1845, but this was bigger one this was quite.

So, what we did was that I am not going to talk about this event, but we have like very good signatures of this event resulting into the change in the landscape, and river which used to flow through this not river got disrupted. So, this river used to come here. And then we used to flow through quarry creek, but now we do not see that river. So, probably this was the event 1819, which disrupted the channel of Nara, so that Nara channel which is tributary of Indus used to flow through quarry creek a long back.

So, whether that that we can correlate that disruption purely to 1819 earthquake or they were earthquake in the past, which also in a sense affected the change in the landscape over here. Now, Allah Bund I will just tell a small story here that the Allah Bund event was been named after the earthquake, because it resulted into the we are not very sure that the 1819 earthquake was alone responsible for the disruption of the channel, which flowed through this area and through quarry creek hitting into the Arabian sea.

But now at present we do not see this channel anymore now the story behind this is that the Allah Bund how the Allah Bund name came up. So, this says a Bund of Allah. So, here there is a beautiful pond which god created after the displacement which was experienced on Allah Bund fault. So, the line if you take the cross section over here then what you see is that the area has been uplifted and back tilted. So, the river was flowing through this got dammed up. So, this is what they call as an Allah’s bund.

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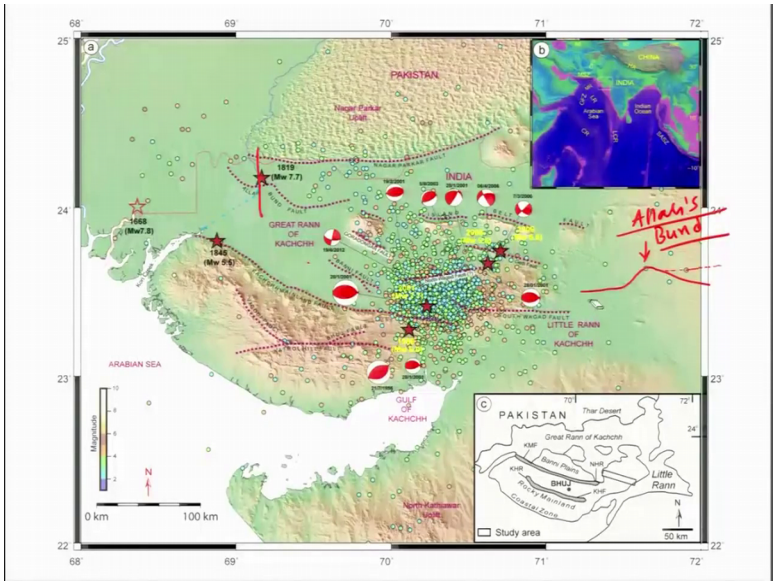

So, this is known as a Allah Bund. So, naturally crone bund of Allah which resulted into the disruption of the channel, so no water is flowing across this uplifted area. Now, our aim was to understand that what exactly has happened in the past whether this are the are the only faults which are available or there are mu new more faults active faults in this region.

So, after 2001, Bhuj earthquake what we noticed was that there was there were a lot of swarm of earthquakes which have been triggered in this area. Of course, this was the rupture area, hence we one can expect the aftershocks in this region. But at the same time what we saw is that there were fewer earthquakes with magnitude 5.6 which took place in 2006, along the gay default and then so in particularly this region. Now, this rupture is in the area where another fault flow fault which lies is known as South Wagad Fault.

So, we were interested in knowing that whether there is an seismic loading which probably has taken place similar to what we see in Himalayas in Kachchh region also. So, because of this event which occurred on in between the Kachchh mainland fault and the South Wagad Fault whether this will trigger another event on South Wagad Fault or not. And whether the South Wagad Fault is an active fault or not. So, this was also one aim of our study that.

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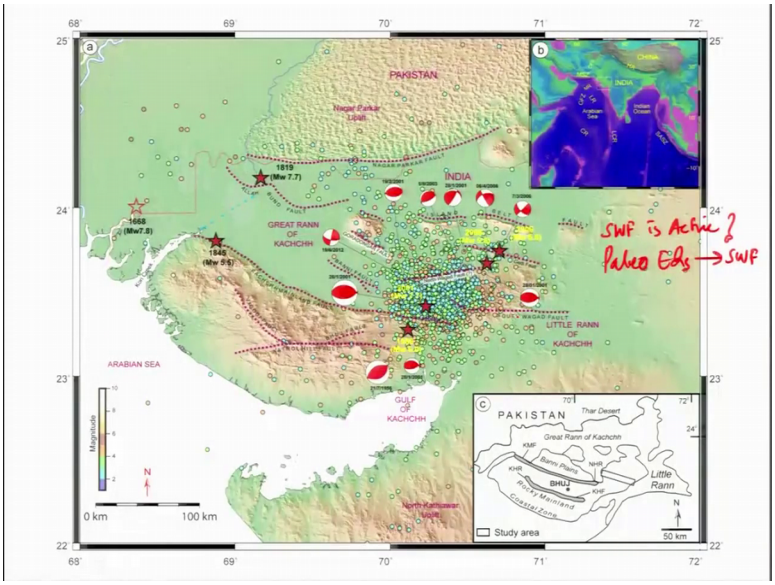

Whether the South Wagad Fault is active that was an question and how many Paleo earthquakes have been triggered along South Wagad Fault if at all there were events in this region. So, we started doing some detailed studies on these two faults that is the (Refer Time: 12:55) and the South Wagad.

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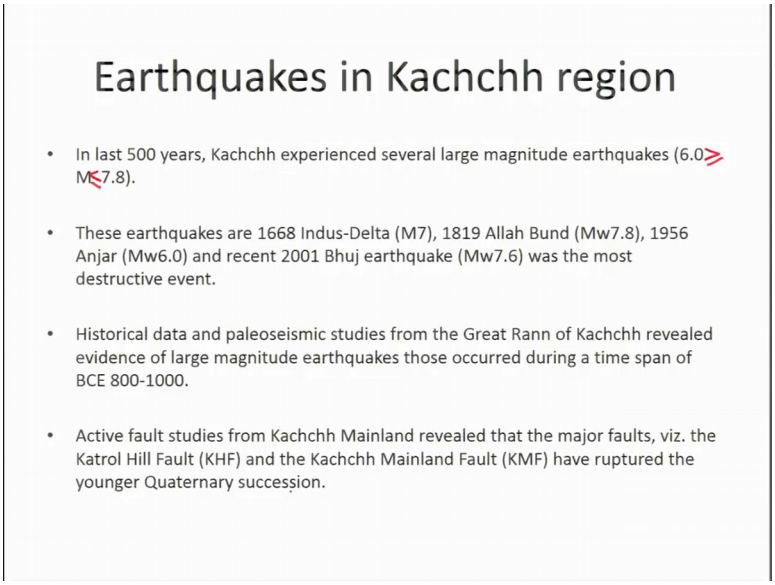

So, in total if you look at what we see is that in last a 500 years Kachchh experienced several earthquakes with magnitude 6 greater than equal to 6, and less than equal to 7.8.

And these earthquakes are as i was talking about mob some of them are listed here at in 1668t Indus-Delta earthquake, 1819 Allah Bund, 1956 and then 2001.

And then historical data also suggests that there were there were large magnitude on earthquake in 800 to 1000 BC. And our study what suggest that the active fault study is from Kachchh mainland revealed that major faults mainly Katrol Hill Fault in the Kachchh mainland faults have ruptured in the caught during the quaternary period or maybe you can see in the recent time displacing the quaternary succession.

Now, these faults are sitting somewhere here. This is Katrol Hill Fault and this is Kachchh mainland fault. So, these are the two faults which are also active and which have triggered the earthquakes in the past. We have practically done the active fault topographic studies along the Katrol Hill Fault, Kachchh mainland fault, South Wagad Fault, Gedi Fault and Allah Bund fault..

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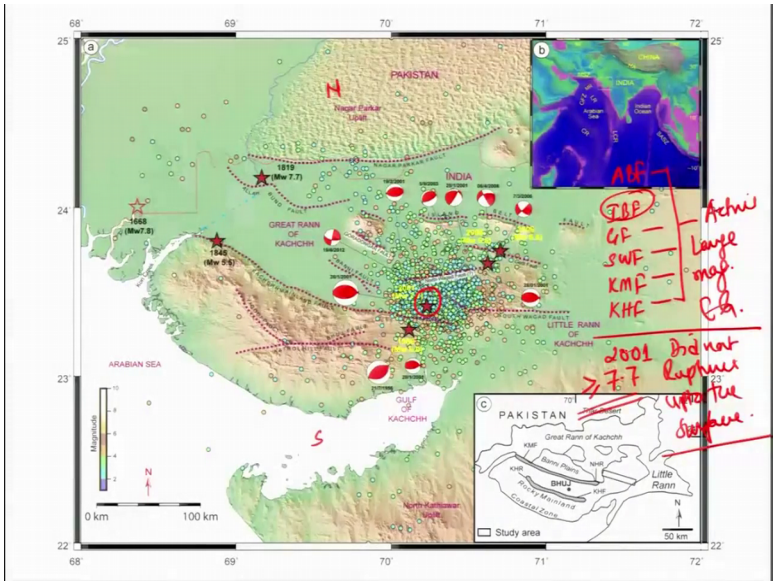

And from our interpretations what we suggest is that all these faults starting from the this is south to the north all this faults you are having Katrol Hill Fault, Kachchh mainland fault, then you are having South Wagad Fault, Gedi Fault, Island Belt Fault we have not studied in detail, then we are having Allah Bund fault. All these faults are active and can produced large magnitude earthquake in near future.

Now, the question comes is that what happened in 2001, 2001 = did not rupture up to the surface. So, this suggests that probably the earthquakes which have ruptured the surface might be larger than 7.7 earthquakes; I am taking the magnitude of 2001. So, we can infer that this next events which are going to occur along this active faults must be larger than this one. So, this poses a lot of questions in our mind that what will happen in the in next 100 years or in recent coming years on I mean along this faults actually.

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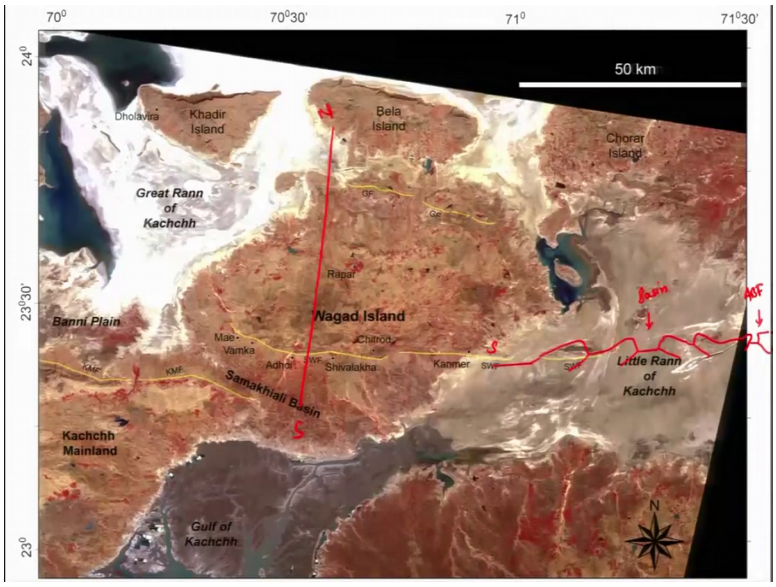

So, this is a topography what we have in the South Wagad, but one thing which I would like to just make it a little bit clear quickly.

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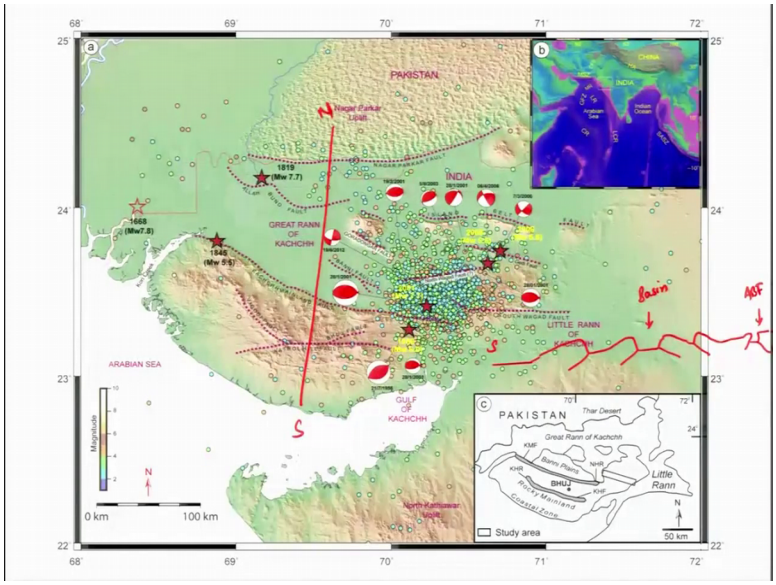

That if you take the cross section like this ok, and say this is north and this is south, then what we see in terms of the fault faulting pattern is we have like if you start from south, and of course, we have the coastal region here then we have a landmass over here the hills ok. And then we have, so this is your south. So, we have like this ok, and then it goes like this, another one then we have in between.

The Gedi the South Wagad Fault and the Gedi fault and between we have basin here. And then we have the Island Belt Fault is something like that and then we have the Allah Bund fault. So, Allah Bund fault is like that like this is here. But still people are having different postulations for this or it means. So, this we are having this is your Allah Bund fault which is. So, otherwise what I can do is I can put another slide and try to explain you this one.

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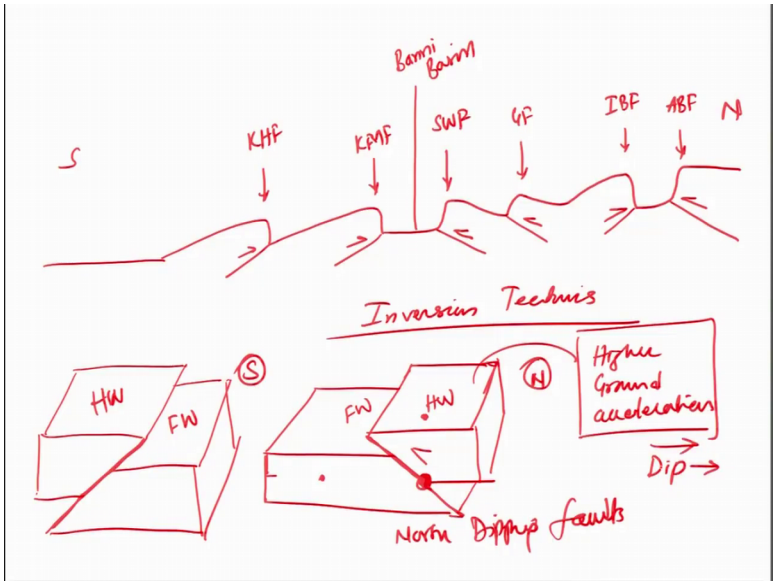

I start from south, then we have this and we go like that. Then we have an Gedi, South Wagad and Gedi fault, then we have an Island Belt Fault, and then we have this one is Allah Bund fault. So, this is your south; this is your north. So, you are having this faults are going like that movement along the fault this is coming up here like this is coming up like that. Then Island Belt Fault and this is Allah Bund fault. This is your Allah Bund fault this one is your Island Belt Fault. Now this is your Gedi fault this one is South Wagad fault. And this one here you are having the Banni basin. And this one is your Kachchh mainland fault. This is your katrol belt fault.

So, we have a configuration of the oppositely dipping faults. Now, this has happened basically because of the inversion tectonics. Now, you might be thinking that why I am I am putting so much of geological and tectonic a portion talking here because for hazard analysis we also need to understand that what is the depth of the fault and which side the fault is dipping. Because as we discussed in the previous lecture about the hanging wall and footwall so if you are having this as an reverse fault maybe I can draw very much similar. For example, if you are drawing Allah Bund fault then we have this block is moving up with respect to this one

So, this will be your hanging wall; this will be your foot wall. And in a simpler way the hanging wall which will move during an earthquake will have higher ground acceleration. And if the earthquake is triggered here, this will be your focus, this will be

your epicenter here, earthquake will not take place here because there is no fault. So, this is for example, if we take this is your north, this is your south, then this is with the scenario with the north dipping faults, but the scenario will be different for the south dipping faults.

So, if you are having the thrust fault which is moved like that ok, then this is your hanging wall and this is your footwall. So, the things will differ from if you if you have the different. So, when we talk about the hazard scenario and Kachchh, we need to be extremely careful that which fault we are talking about, and what is the configuration of the faulting in that sense. So, this was in short what and then this is applicable everywhere or wherever you are studying the fault.

So, so what is that the depth a in which direction it is dipping, so that is important for us. So, if you look at this part here like the South Wagad, then what we see is not, so we have South Wagad which is showing this scarp facing towards south, and the Kachchh mainland fault is showing this scarp which is facing toward north.

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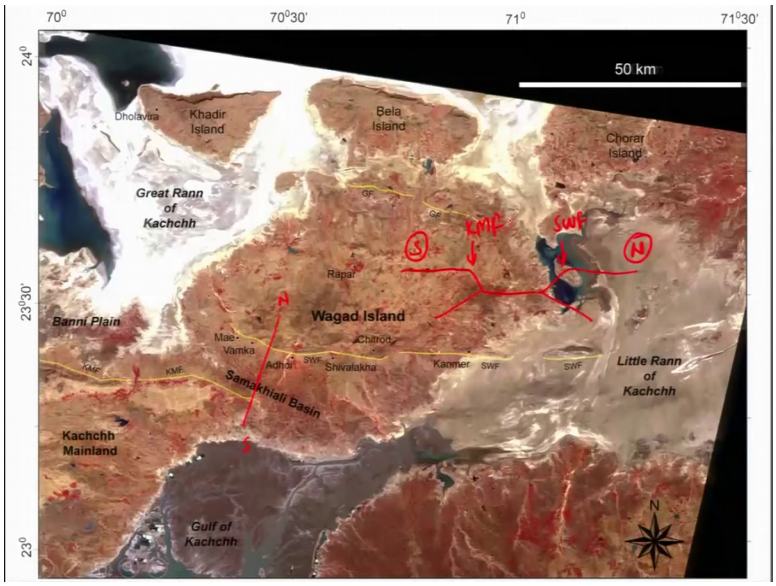

So, if you quickly take the cross section here, what we see is that we have from north to south, then we have north which goes like that and then we are having the basin and then we are having the Kachchh mainland. So, this faults are dipping on either side this is your north this is your south. And this is your South Wagad Fault, and this is your Kachchh mainland fault.

So, the geology or which you see here is not we having the mesozoic and the cottony recovers similarly over here, and here also we are having mesozoic and partly we also see the tertiary rocks. Geomorphologically if you look at then we are having an chain of islands this is in Khadir Island. And on Khadir Island this host the famous Harappan site that is Dholavira and then we have Bela Island Chorar Island and then Wagad Island. And this is connected or with the with the Kachchh mainland as a part of small basin which is known as Banni or some (Refer Time: 24:21) basin.

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So, we did detailed study and mapping of the faults and the geomorphic landforms which are attached or associated with this. And we identified and very like prominent site in terms of the active fault scarp and then dug the trench tried to look at the value earthquake history from this area. So, I will quickly take you like through the field which we did from Mahe area right up to the Shivalakha area.

And very quickly show you the at what is now one thing which you can easily make out is that these are the structures the geological structures which you can see here are all what we call anticlines ok. And then in some locations what we see is the elongated anticlines ok, and the arrows which are been showed here are the arrows of the movement of the anticlines. So, whenever there is there will be in rupture, there will be an addition of the length here as well as it will gain the height.

Similarly, this is the plunging anticline which is moving in both directions. And so if this anticlines keep moving towards one like in either direction, lateral movement what we say during the during different earthquakes the time will come it will link up and these are the linkage segments which have been shown here.

So, in Himalaya also if you look at we having a smaller force like this, and like but the time will come then this fall folds will get linked up giving rise to a larger fold segments. So, these are moving in this direction, this side notch is moving here like this. This is what similar phenomena of deformation we observed in even Kachchh. So, this will be a short of a linkage area which has been shown here this is the linkage point of two segments and slowly this will grow.

This also testifies that yes of course, there is an moment which has been experienced by South Wagad Fault in the past. So, this was another important finding. So, we are just not jumping directly saying that this is an active fault and this is hazardous or not, but we are also taking into consideration that what has happened in the past and similar things can or the process will prevail in future also. And for sure that this region or the South Wagad Fault must have hosted large magnitude earthquake in the past very much similar to or must be probably greater than what we experienced in 2001 Bhuj earthquake.

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These are the examples which we see or the signatures which we see in the deformed areas. And these are the old rocks tertiary rocks which have been folded. And this is the

scarp at Mahe anticline which I was showing in the previous slide over here this is the area at the Mahe anticline.

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And then further we are moving to the next one that is close to Vamka this see an uplifted Terries. So, South Wagad Fault which we have marked is running over here actually. So, if you open up the section across this, you will be able to see the displacement. So, these are the evidence of that. So, this area if we take the profile, then it looks something like that. So, this uplift was not in the single event, but this was resulted into a driven by and multiple events or multiple earthquakes. And the height which we see here from this top up to the base here is your cumulative height. So, multiple earthquakes, so again it proves that this area has experienced earthquake in the past ok. This is another example of fault scraps which were observed further ahead near Halra.

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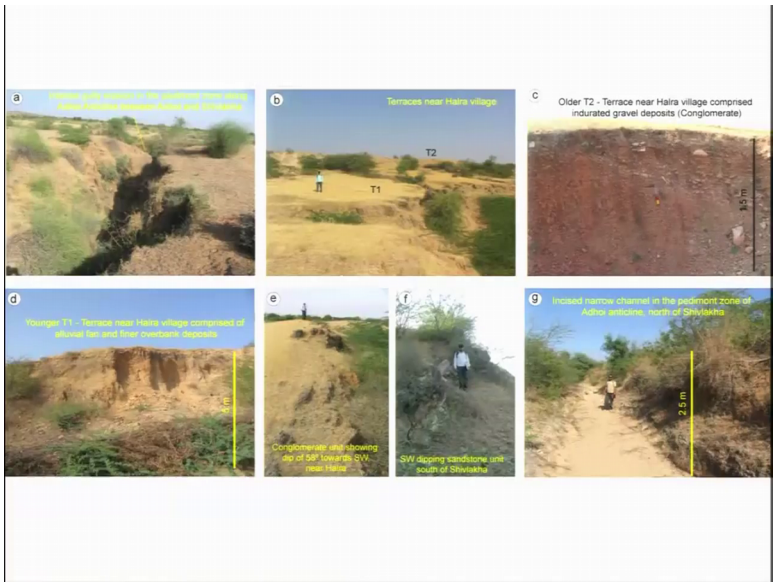

And then we also looked at that small streams which are just having a few kilometer of the basin area or the watershed area have incised the region or the area like it shows deep incision this is a gain and occasion of an sudden land level change because of the base level change because of the uplift. You can see the incision of more than 2.5 meter or so it and another feature free features which we see is the formation of the terraces along the river valley.

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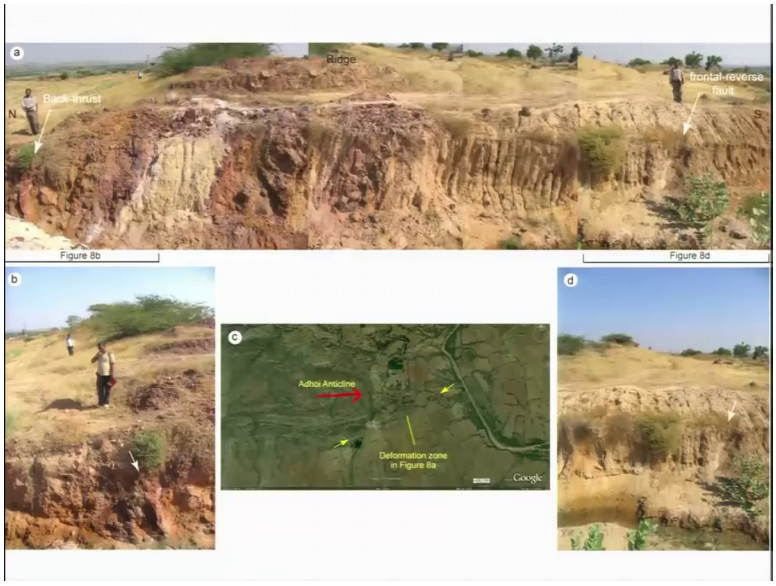

Then in one place where we found that this is the most was the most prominent area to open up the trench. If you see the see the google picture here this is the eastern nose of Adhoi Anticline which I was showing in the previous slide. So, this is the fold which is propagating in this direction. Now, taking and advantage of what we did in Himalaya, we also applied here, because this is again is an example of fold and thrust belt very much similar to Himalaya, but this is one miniature scale this is not at the magnitude what we see in terms of the region ok.

The towering height of Himalaya if you see here in Kachchh is not the same, but yes of course, I say that this is on the miniature scale. So, we applied the similar technique or the methods to identify the best site for trenching. So, this is Adhoh Anticline which you see here where we identified the site and this was the section which we encountered in one of the artificially dug trench by local people for agricultural or irrigation purposes. So, we found that there is an evidence of very young displacement in very young deposits and so we decided that we will open up the trench here to identify the paleo earthquakes which have occurred in during the historic times.

So, what I can do is I will stop here and we will continue in the next lecture and try to discuss more about the interesting things about the South Wagad Fault, and then we will also like to see whether the South Wagad Fault was responsible in shroud often it was whether it was an damaging earthquake or it was just an earthquake we did not affect the region ok.

Thank you so much.