Earth Sciences for Civil Engineering Part-2
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Active faults and its related hazard in India (Part-4)
Module 2
Lecture No 7

Welcome back.

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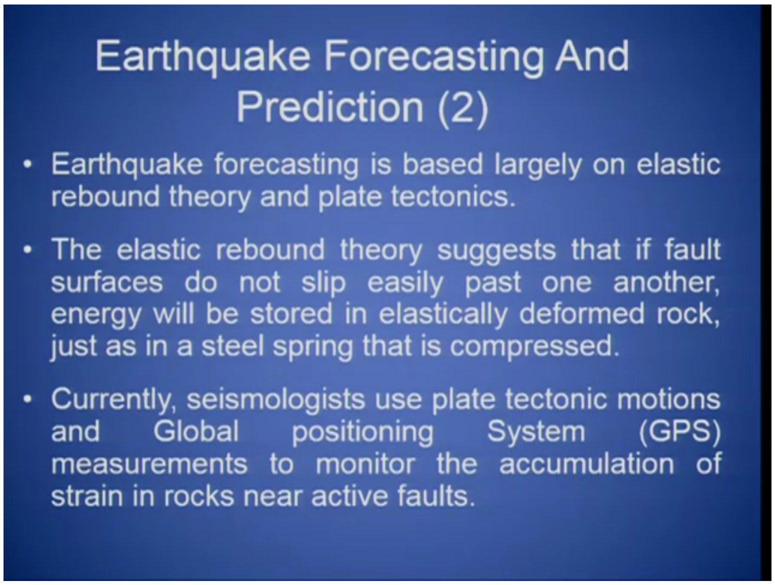

So in the in last lecture we were talking about how Global Positioning system, GPS can help is in monitoring the ongoing deformation.

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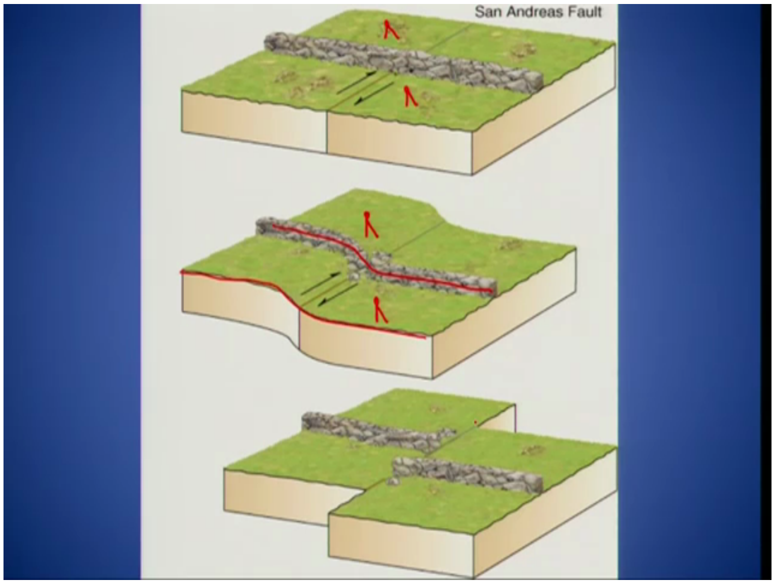

This is what I was talking about the elastic rebond theory, so for example if you are having an act of fault which is passing through any region ok and the deformation is on on that particular fault, what will happen that over the time before it triggers an earthquake ok, before it slip, it will accumulate some deformation that is elastic deformation and you may notice that there is some deformation on the land ok, so you, if you look at this boundary it get, it got deformed and finally when it rupture or what we could sat fracture, it will displace it.

So this deformation can be monitored using either satellite images if you are talking continuously ok and monitoring that area very closely or by putting the GPS stations across this ok. So that will help, so for example you are having the GPS station over here than that will move, so this helps in identifying this accumulation of strain along the fault line and finally we will have the rupture that is what we call it will accompany an earthquake.

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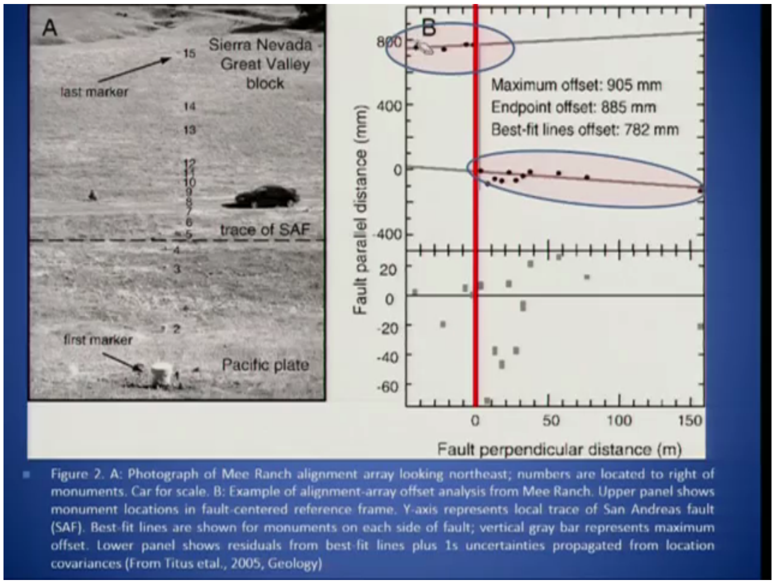

There is one of the example from San Andreas fault again, where they put a number of GPS stations which are numbered in one, two, three and then it goes up to fifteen ok, so what they have found was that over the time they got displaced ok. So for example there is a fault line here this is the measurements which they have put on the graph, so you are having maximum offset which they were able to pick up was 905 millimetre and end point was showing the displacement of that is the end points here ok, the end points were showing the displacement of around 885 millimetre, this straight shows the displacement, so overall average displacement which they found was around 780 meters or so.

So these are the GPS points which shows the displacement and then end point is here ok, so you are having the maximum displacement in this two points here, so if you, if you close the monitor in fault you will be able to pick up the the displacement or the deformation which is going on on that fault.

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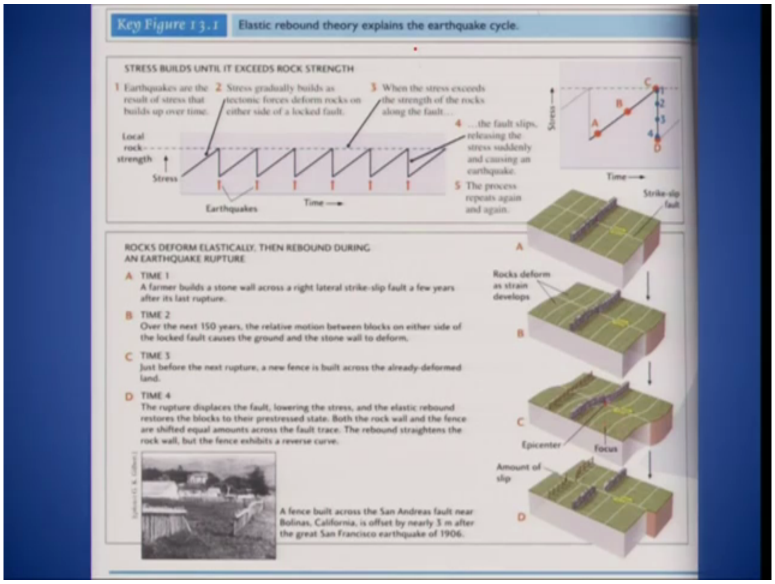

This partly we have discussed about the recurrence interval and all that and then another part which has been shown here is the portion which we were talking about the elastical bond theory.

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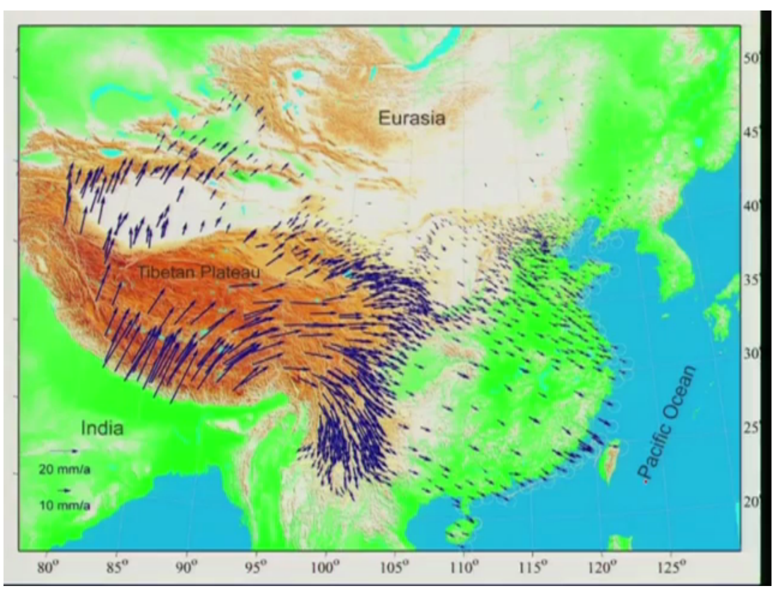

Now there are couple of GPS stations in Nepal and in China but in India also now we have initiated with the help of ministry of science, we have put in many GPS stations and we have, now recently we have a new centre, National Seismological centre under the MOES which is going to monitor this GPS movements ok. So GPS measurements have been also not many stations have been put in the Indian side over here and now recently we are going to put more 15 to 20 stations in this region ok which will help us in understanding that how the faults are moving, so the blue arrows which you see here are the indicators of that how the plate is moving with respect to one another ok.

So here if you see this all vectors are going towards North East ok North East, whereas a few vectors which are showing that they are moving in this direction that is South, South East, so this suggest that this region of Tibet is been pinching out from this area ok because of the ongoing collision. So we have if you look at here this this size of the arrow is 20 millimetres per years, we are having the conversions which is more than 20 millimetre in this particular region in Himalaya across the Himalayas.

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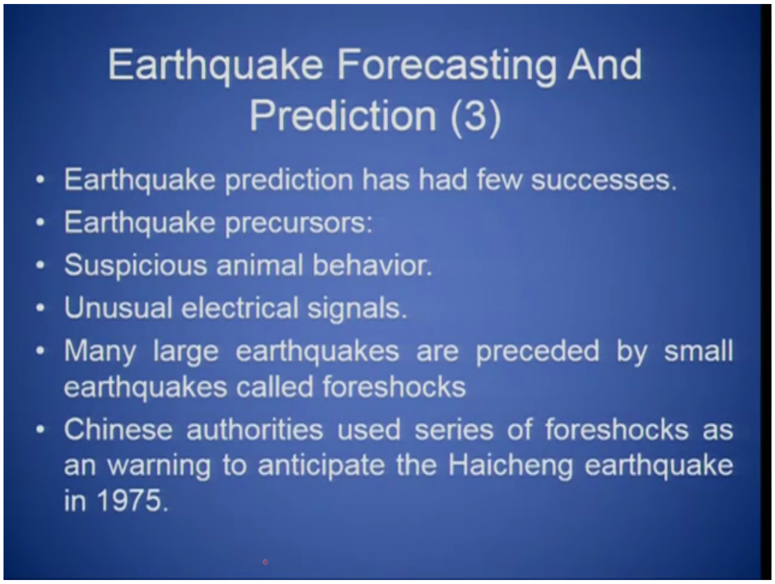

Further in the part of the earthquake prediction and forecasting and prediction, earthquake prediction has had few successes ok, earthquake precursors one can monitor, people have been working on this part also that is the suspicious behaviour of animals and this is very time bond baby, you can, you can pick up this behaviour, unusual behaviour of the animals just before the the earthquake ok and then people have been talking about the unusual signals of electrical signals because off course we are engraved with the electromagnetic energy and there will be change in that ok.

Many large earthquakes are presided by small earthquakes what we call foreshocks, so if we monitor the foreshocks, you may have a chance to identify the, the big event which is following the the main foreshocks ok. Now in 1975 Haicheng earthquake was predicted ok, Chinese authorities used series of foreshocks as an warning to anticipate the Haicheng earthquake in 1975, this was been predicted and they saved many people ok.

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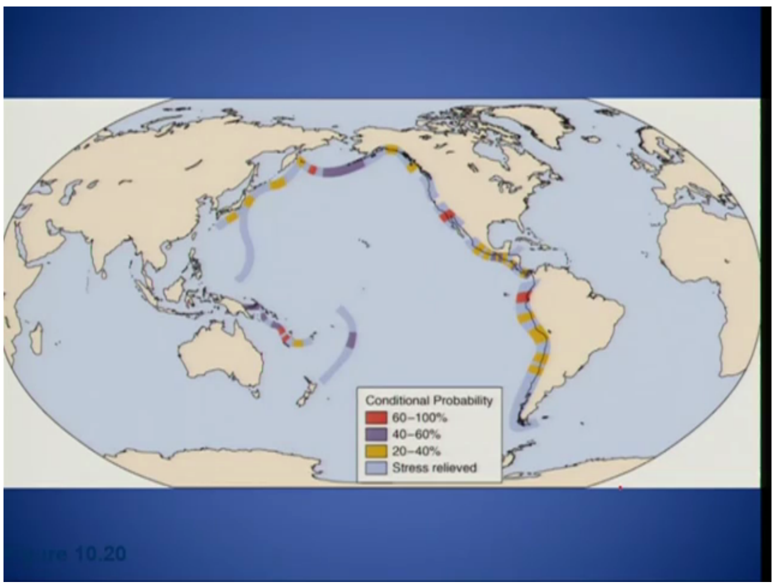

So finally what we are interested in having understanding the of the faults having understanding of the earthquake behaviour and all that, we want to know that what is the probability of the earthquake in around the plate boundaries or away from the plate boundaries, so there is one of the example which has been given here that the, the red areas are having the probability of, high probability of earthquakes which is 60 to 100% ok. So likewise we can have for India also that which portion of the, the Indian plate along the Himalaya is having the higher probability of earthquake in near future that can improve the hazardous assessment part, hazardous assessment part.

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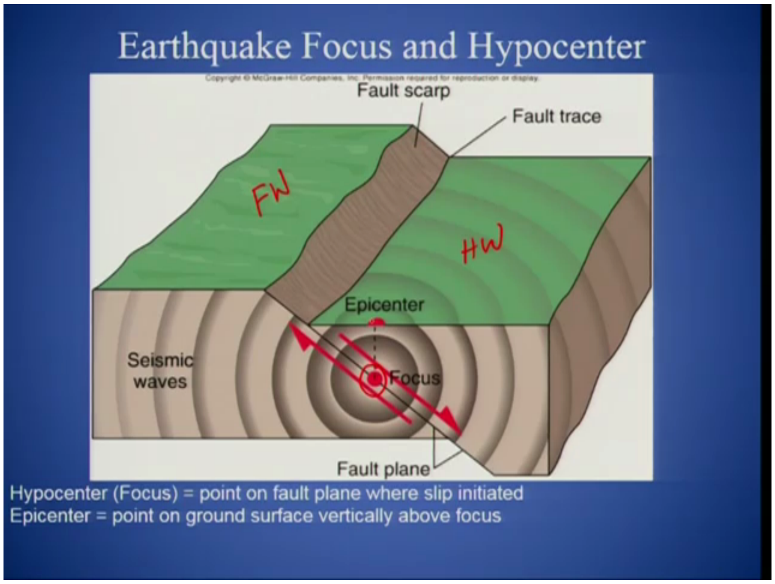

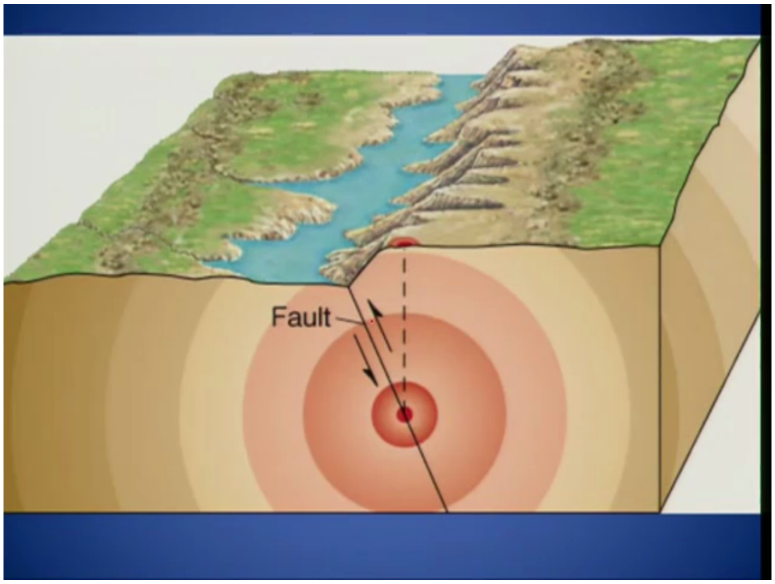

This we have already talked, I will just move ahead that what are the fault scarps and all that, so if you are having a displacement along your fault, this is a normal fault where this block has, this is the hanging wall and this one is here footwall ok, so this wall has moved down, hanging wall moved down with compared to that ok will result into this, this surface manifestation is your fault scarp and then what the base of it we call the fault trace and this is a fault in here and then we have the epicentre and the focus, this is the place where the earthquake will be, earthquake energy will be released and exactly on the top of the surface, this is what we call the epicentre ok.

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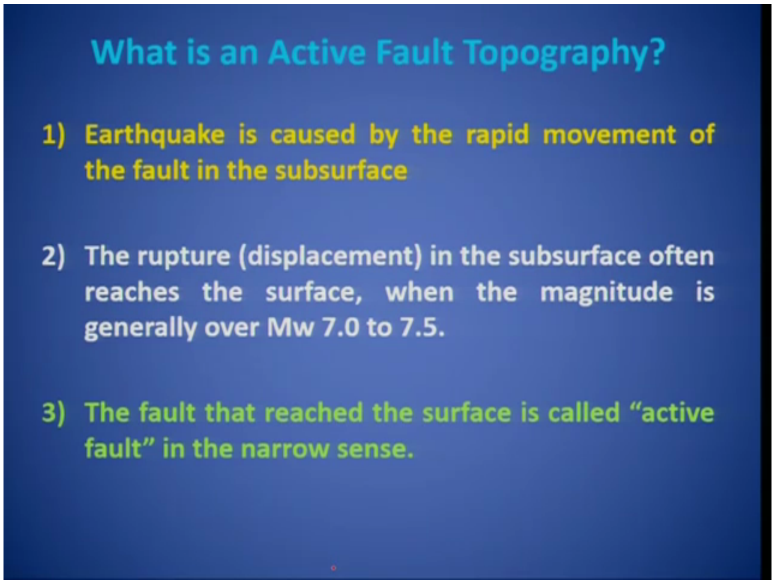

Now this part we have talked about why it is important the active faults, now what is an Active Fault Topography ok and how we identify, I will show couple of pictures of the fault topography and then we will move ahead in this course. Earthquakes is caused by rapid movement of of the fault in sub surface ok, so there is an sub surface displacement which is coming right up to the surface or the ground and that what we call the fault topography or the fault scarp is again what we call the Active Fault Topography.

So the rupture of the displacement in the sub surface often reach is the surface ok, when the magnitude is generally over, movement magnitude is about 7 to 7.5, if you are having less magnitude 5.5 or so, no rupture will be there and then those earthquakes are not going to harm much ok because it will not result into the, the large amount of shaking of the area, hence we are not very much worried of the 5 magnitude earthquake and all that.

But even 6.5 magnitude earthquake in India is, will be hazardous because our buildings are not capable to withstand that much of shaking which will be produced by 6.5 or 6.9 magnitude earthquake. So mostly the the surface ruptures which we see or the displacements along the faults which are coming right to the surface, those surface ruptures are produced by earthquakes magnitude greater than 7 or 7.5. So the fault that reaches the surface is called the active fault in the narrow science ok.

However, if you remember one cartoon which we were talking about that there are times where we will not have the rupture coming right up to this surface that what we call the earthquake has triggered, has been triggered on a blind fault ok and this happens in most of the time ok, the earthquake cannot, the earthquake cannot produce the surface rupture but it took place and it result into the damage, it result into the ground shaking and all that ok.

So no signatures on the surface ok, so sometime we try to correlate or find out such signatures or the, the evidence ok from the literature try to understand. For example in recent past, say 2001 Bhuj earthquake was on blind fault, no surface rupture came right to the surface. 2015 Gorkha earthquake was on a, did not rupture the surface, so historical documentation is also the is important to be noted and reporting of such earthquake is also extremely important.

So what we did was that immediately after 2001 Bhuj earthquake we went into the field, we got some deformation features which were secondary but we noted down the report at that ok and even in 2015 Gorkha earthquake and followed by the Kodari earthquake we, we mapped the the surface expressions where we can again say that it was not secondary but we were able to pick up some signatures of the, related to that deformation.

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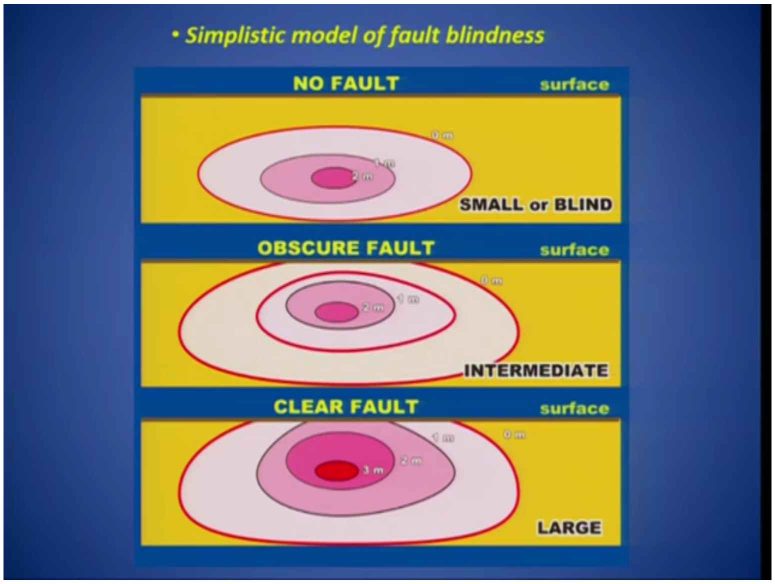

So this is what it explain the simplistic model of the fault lines ok, so if you are having a small earthquake or if you are having a smaller area getting ruptured, it will not see the surface ok, it remains blind. Some intermediate magnitude earthquakes will come right up to the surface or the rupture comes up right into the ground but very small area will get rupture and very often this signatures will be optional or may be deleted or eroded you can say from the surface but if you are having a large magnitude earthquake then we will have a prominent surface manifestation.

So this what we are now, not all earthquakes are of are blind or are will occur on blind fault but there are few, so we have to take into consideration those signature also. So what we do is that we try to concentrate if you are having, we know that most of the some areas if you are having most of the earthquakes are occurring on a blind fault then we try to take into consideration the secondary features.

Now this secondary features are for example liquefaction, so if you are having a liquefaction preserved because liquefaction will occur at any place ok, doesn’t have any boundary maybe because of the earthquake which has been triggered 200 kilometres away but if it is powerful, if it is, it is not problems if they are blind but then also it will reserve into a liquefaction, so those things we can and even the land slip ok, so land slide, land slip liquefaction such features can be taken into consideration to identify the the earthquakes which occurred on a blind fault ok. And if they are large enough to rupture the surface then we have the active fault topography to be identified.

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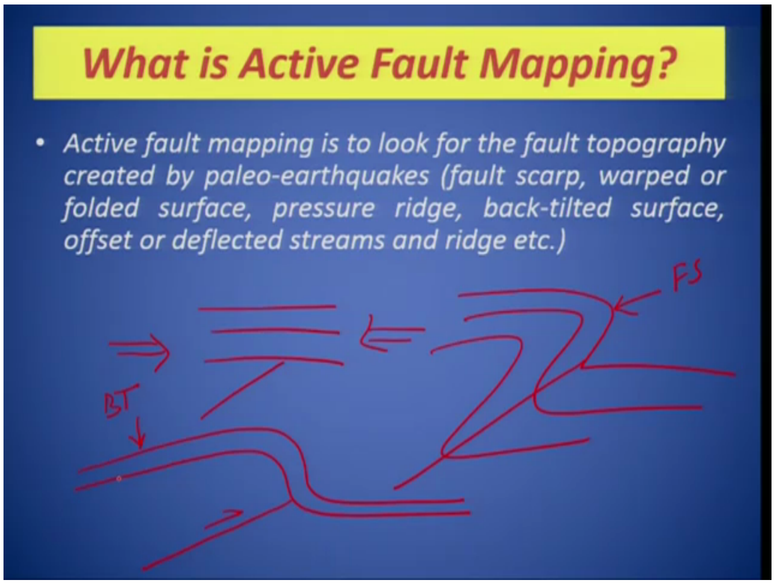

So what is an active fault mapping, what we do in the active fault mapping part and this is like I told that we are in process of building up digital active fault map of Himalaya and Kachchh ok, so active fault mapping is to look for the fault topography, created by Paleo earthquakes, ancient earthquakes ok for example fault scarps, warp or folded surfaces, pressure edges, bad treated surfaces, offset or deflected streams ok.

I was showing one example of the deflected streams ok along the San Andreas, so this is what is the fault topography part of the fault topography and the fault scarp, maybe in the next slide I will show that what are the fault scarps and the warp surfaces ok because when there is an deformation. For example if you are having different layers here and if you are folding it ok and there is a fault here, so you are folding it, so what will happen, so this will be displaced along the fault and they will get folded, so this manifestation on the surface is termed as fault scrap and some cases what we have seen mostly is that the surfaces, this surface will be like this ok, there is a fault here, fault plain which has moved like this, this is what we call back tilting.

So the surface is tilted towards back and this is very common in most of the the fold and thrust belt ok and what we have is of the, the mightiest one is the Himalaya, so we will come across such manifestations ok, that is what is the fault topography and we, we are going to pick up those ok.

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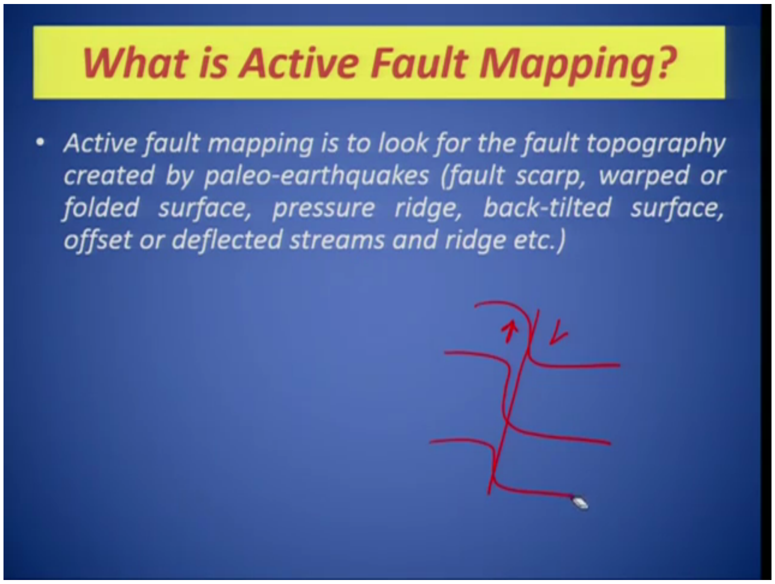

So for example on the surface if you are having strike slip then the streams which are flowing will be deflected ok this way, so this is your sense of movement, the stream flowing are getting offset, so this is another feature which one can pick up as a fault of the active fault mapping.

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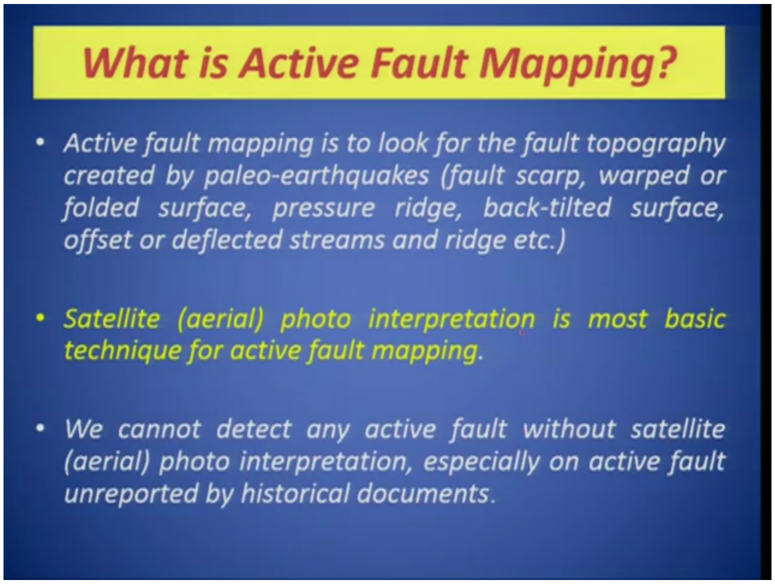

Then satellite photos, so what we do is we use very high resolution satellite photograph because we do not want mess even a topography which is been created by Paleo earthquake, having the surface manifestation of maybe hardly 1 metre or 1.5 meter or less than that also ok, so we are very precise in mapping those, so hence we have to use very high resolution satellite photographs ok, so that is what we call the satellite photo interpretation is the most basic technique for identifying the active fault.

We cannot detect any active fault without satellite data, especially on the active fault unreported by historical accounts. So if there is no historical account how you are going to identify those structures of your surface, manifestations of the Paleo earthquake, we need to use the satellite data, so if you are having expertise to identify such features which we have been talking either the fault scarp, warp surfaces, pressure edges, back tilted surfaces, deflected streams will be able to pick up those on the surface ok and it is difficult to go in field and map those ok. For the first, as a first step ok, so we use high resolution satellite photographs, we prepare the basic maps and go in field and map it ok.

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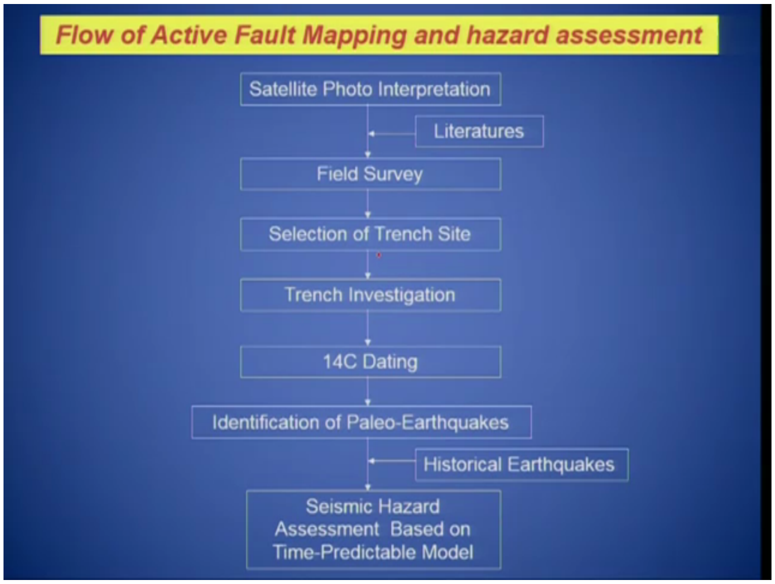

So this is a flow chart how we do the studies ok like Paleo-seismic studies or how we are doing and what is the outcome of that, so first what we do is the photo interpretation, satellite photo interpretation also the literature survey, from the literature survey we try to look at the historical documents ok and in during the historical documents it is quite possible that you may come across a very mythological language ok or maybe in philosophical language talking about the earthquakes ok.

In, in many ancient chronicles we will be able to find this ok and there is a famous professor (()) (20:05) is from ISC Bangalore who documented this and translated it ok from the Babar nama, Akbar nama and Sanskrit literature and also from some Vedic literature he tried to translate and try to understand that what exactly they want to talk about if they have recorded any earthquake ok and there is a very beautiful paper which talks about the ancient earthquakes from India that helps us in knowing that fine this region had an bigger earthquake in past ok.

Probably the way of describing it may be linked with some religion or maybe some myths but ultimately we need to understand what exactly they are talking about ok. Then we do the field survey to identify those features which we have picked up from the satellite data then we try to select the site for trenching ok, so this is what we do, we try to because whenever there is an earthquake or the past earthquakes the deformation is preserved within the sediments and on the surface ok.

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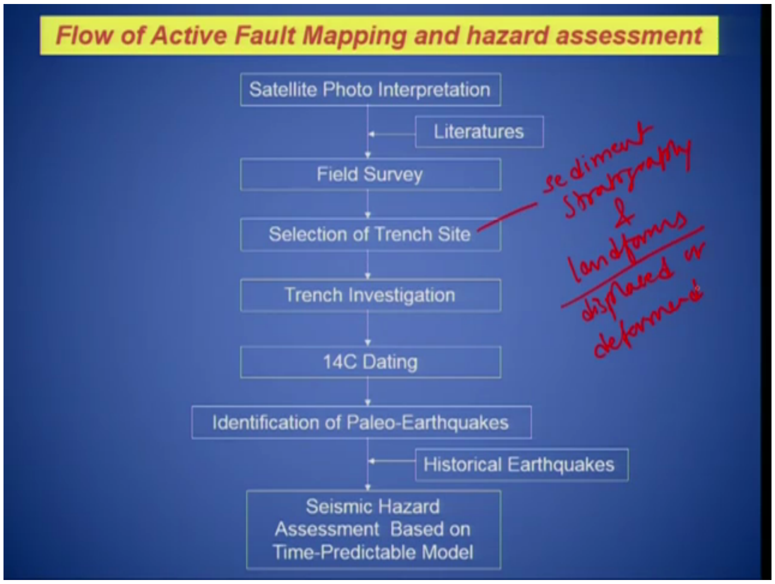

So that what we call the the the earthquake signatures are preserved in sediment stratigraphy and in form of land forms ok, so this is the space land forms ok, displaced or can say deformed,

deformed land forms ok. So we try to do that and then trench investigation we try to look at that how many times this fault was ruptured in the past and we did those sediments or the, the buried coal or maybe we can say charcoal ok with the help of different techniques ok.

And then we try to understand that when exactly that earthquake took place ok in the past, then based on the the chronology of the layers or the sediments, we identify the, the earthquakes ok, so we try to bracket the events when exactly that earthquake took place ok. Then we try to compare with the historical data, if it is been recorded we try to compare it and the likelihood of that we can suggest that this earthquake is, is the earthquake which occurred during this period ok.

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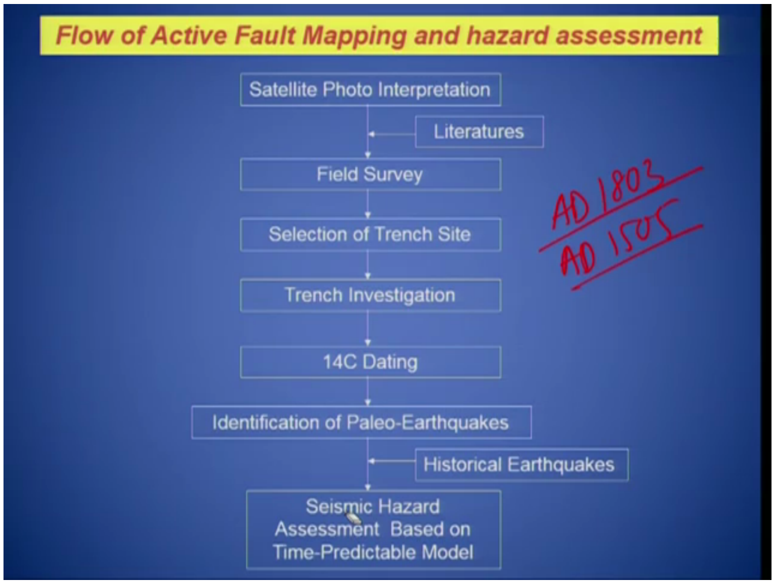

As I told in the my previous slide I was talking about that there is a record of AD 1803 earthquake and AD 1505 earthquake in Babar nama and Akbar nama and Tarique Hasan ok. And one novel is there named as Devnagri which also talks about this earthquake ok and even during this period Britishers were around, they have recorded this earthquake and documented, so those that data particularly we take into consideration and then try to correlate if it is available. And this earthquake was at the time when the Mughals were here, so they have record of 1505 and the the another was in Britishers time ok and then finally this data is important for the seismic hazard assessment based on the time prediction model.

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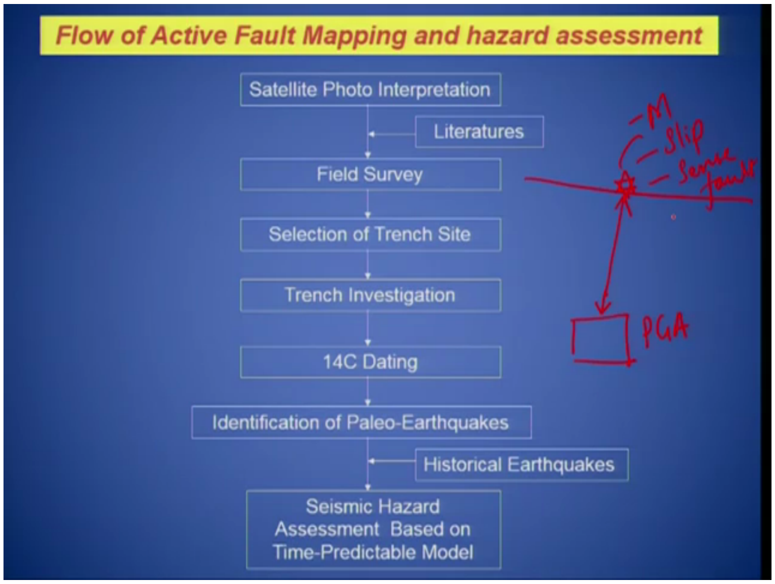

So if I say that ok fine the earthquake if there is an, this is your site here and then fault is somewhere here ok and then earthquake has occurred across or along this fault then you can easily talk about that what is the distance here between the source and your site and what will be expected seismic shaking ok, so you can talk about pique round acceleration and all that. Even with based on the Palue seismic studies you will be able to dig out the magnitude, you will be able to talk about the slip during single event they will be able to talk about the essence of fault whether it is a thrust fault or a reverse fault or strikes fault.

So this data is extremely important for us to have a proper seismic hazardous assessment in any seismically active regions ok and off course the location of fault is more important because we should not put any structure on those faults ok.

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This is what I was talking about that this is from Bhuj area and the section and the topography is both can be seen in this photograph ok. So we have the surface manifestation here, now this is been created because of the displacement around this fault ok and you can mark the displacement very clearly here, you have this contact and you have this contact over here. So this is your net displacement and the surface which is getting wrapped can be seen because of this displacement ok. When we move the lines here, so now if you can see here we have the, this is the contact here and because of the displacement along this fault we have the surface manifestation, so this before the displacement could have been something straight ok.

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Like this because of the displacement now it has gone like this, there is a space down here ok, so this is what we call the fault topography and if you look at in the section then you can measure and take out lot of information out of this that how much was the displacement during the most recent event and what was the angle of the fault and all that ok, now based on this as we have been talking about this is a reverse fault ok because the angle is greater than 45 degrees.

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There is another surface manifestation photograph showing of 1995 Kobe earthquake and if you carefully see here, this is the surface manifestation of the Kobe earthquake, it just passed close to this house ok, so this house was been saved but if you can see here there is a close, there is a compound wall or the boundary which got displaced and the displacement was this wall, the side wall moved up and then there was a lateral movement ok, so it is an what we call the right lateral movement took place ok.

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So the block moved like this, this side went up and laterally moved ok, so it is an oblige slip fault we can say.

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Close up of that house and the the wall which you can see here, so fault just crossed this one here, this side is up, this is down and with some lateral displacement.

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So what they did was after 1995 Kobe earthquake they occupied this area, the geologist and the the city people they occupied this area and they converted this into museum, so the photograph, the next photograph which I am showing is been taken from here viewing this side ok.

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So this part is an is a museum here and this is also now, this house is also a part of the museum they have taken away this house ok.

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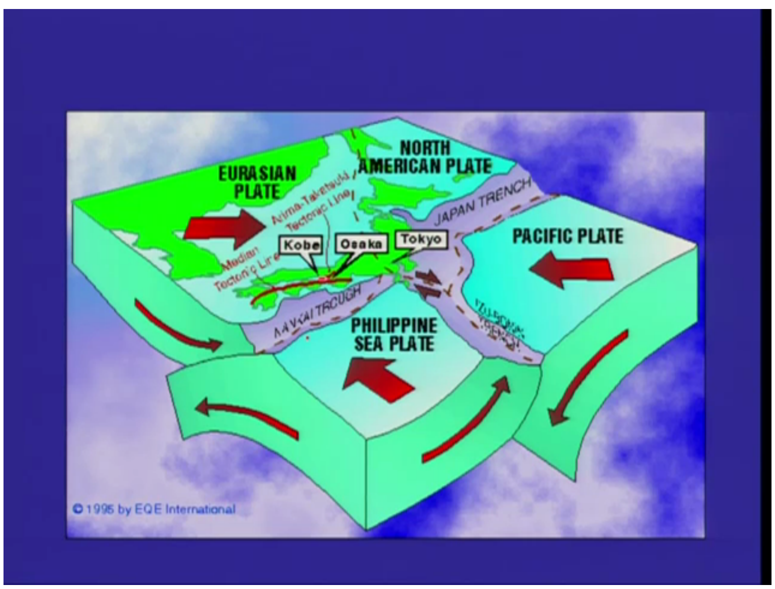

So this was an very deadly event which took place in in Japan in 1995 of Japan has lot many plates which are subdecting below each other ok and the main land of Japan there is a islands of Japan are sitting on the some part in the North American plate and some on the Eurasian plate and when you are having the Philippine plates subdecting below it and here the specific plate subjecting along the Nankai Truf what they call and then Japan trench, so this we are having.

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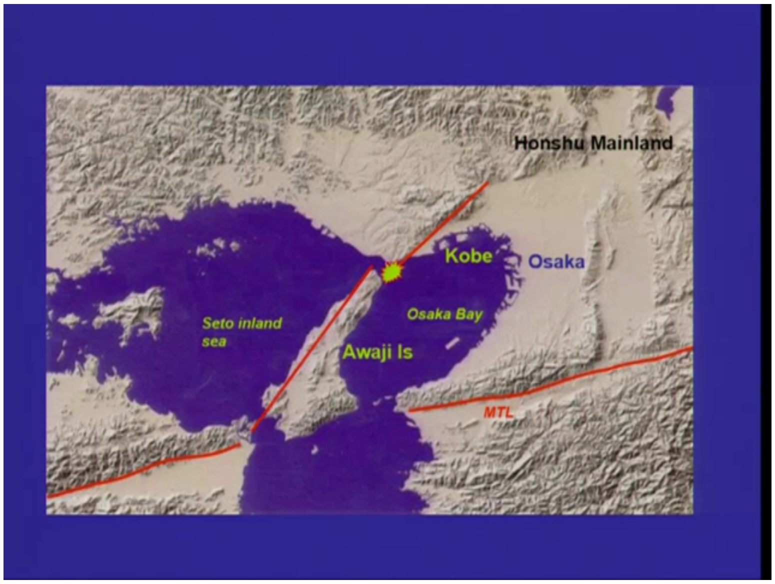

So this was an earthquake which was in which ruptured the area here, so this is an Honshu Mainland Kobe, Kobe was most devastating city and then we are having an Awaji Island ok. So this fault is the part of the MTL mean Median Tectonic Line very much similar to what we, we were talking about the San Andreas fault system, so earthquake occurred here and the rupture moved on, so we will continue in the next lecture, thank you so much.