Earthquake Geology: A Tool for Seismic Hazard Assessment
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Lecture - 24
Fundamentals Related to Active Faults (Part III)

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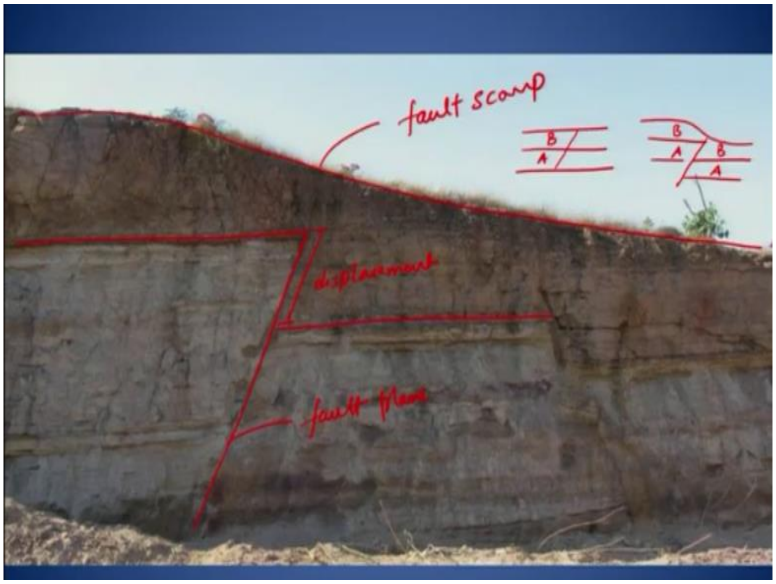

Welcome back. So in previous lecture, we discussed briefly about the importance of active fault mapping and we also discussed that in the areas where we do not have the historical information about the earthquakes or the active fault, then in those areas it is extremely important that we use high-resolution satellite data and carry out the act of fault mapping and related associated landforms.

Now this was the last slide, which we stopped and I was explaining that they have the net displacement along the faults, so this line in section will be termed that as an fault plane and the manifestation on the surface, what we see the topography developed because of this displacement has been termed as fault scarp. So similar deformation will be expressed on the surface, when there is displacement along any particular fault.

So this is the case, a clear case of the reverse fault, because if you have the horizontal layers, so this I will keep on repeating, so that you keep on having the understanding of that and if you deform or displace this deposits along a fault plane here, then you will be able to see a topography, which has been coming upon the surface and you have the displacement of the layers. So for example, you have A and B here, but this will be your B and this will be your A.

So further, if we see what is the basic idea for this lecture, is that we will give you a glimpse of different faulting environment. However, we are going to discuss in detail of different tectonic environment as we move further in this course.

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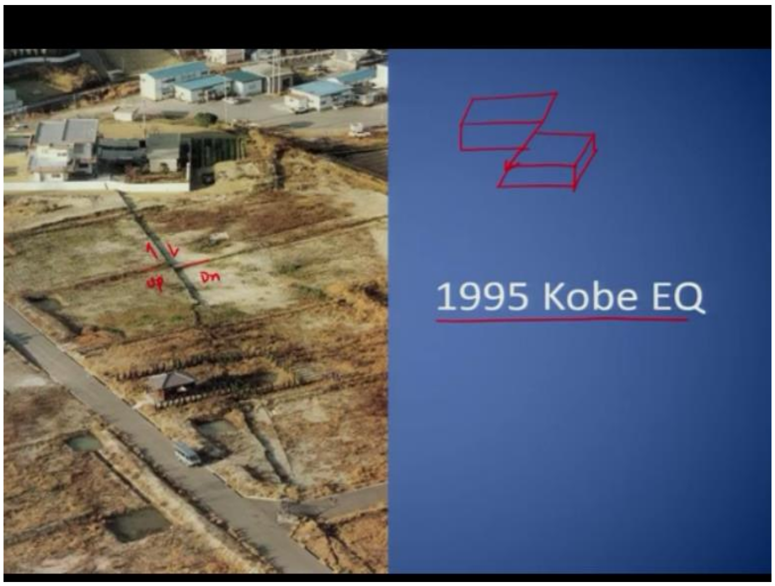

Now the surface expression the recent one is the 1995 Kobe earthquake and the rupture you can see over here, which was oblique slip. Yeah, so it has a component, where if we draw this, then we can make out that this was having a sort of a reverse component. So if I am able to draw the sketch here and what you see is that there is a block here, which has moved up along an inclined plane here. So this side, so we have basically another block has moved over here.

So the block has moved in this direction along this one and also along the depth. So more clear pictures, you will be able to see in the next one. So this earthquake, 1995 Kobe earthquake was one of the largest recorded earthquake in Japan and result into massive damage. Now the best way what they did to make aware the people, I will show a couple of slide in this, what they have done. So this was the rupture of 1995 Kobe earthquake, where you had this side was, this moved up.

This was down and then you had a lateral displacement. So if you can mark this one here as two lines, then you can see the displacement has occurred here and similarly which was also been observed along the compound wall of this house.

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Now what they did was, they preserved this whole rupture and came up with a museum. So this whole area, this house has been taken up by the government and this whole area was preserved. Now what you see is the next slide is the photograph from here and this whole portion is under the museum. So this is the wall and this was the house, which I was showing and which also they have preserved the deformation as well as the destruction, which was experienced by the compound wall in this house.

This house was just sitting close by the default line. So that did not get damaged or destroyed, but of course the internal damage was huge in this house also because of the ground acceleration.

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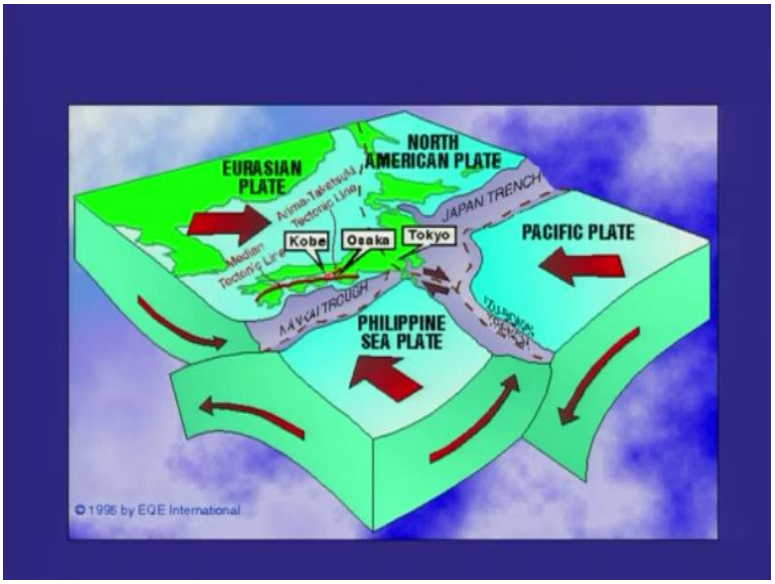

Now, if we quickly look at the configuration of the Japan and I just want to give an idea, overall idea that why this part is important to understand because after this earthquake, that is 1995 Kobe earthquake, the act of fault mapping in Japan was intensified and they have come up with a digital active fault map of the entire Japan. So on the global scale if you look at, then you have the Philippine plates abducting below the Eurasian plate.

And you are having the Pacific plate, which is abducting below the Philippine plate and as well as it also having a trench that is abduction, which is going on between Pacific plate and North American plate. So Japan lies on two plates, that is one is Eurasian Plate and in the northeastern side it goes into the American plate. So it has a very complex tectonic framework on the global scale and in regional scale lot many faults, active faults have been identified, which has been taken up after the Kobe earthquake.

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So details of this, if we go further, then this is what they have the whole shoe mainland, one of the main island and the Kobe is located here, which is very typical of the Bay area region and in Japan if you take the land, which is available to this country is very less, whereas and most of the regions what they have done is they have reclaimed close to the coastal region, because there is an island, complete island chain and very less amount of land for urban development and all that is available.

So most of the regions, where they have the major cities are either reclaimed or they have modified the landscape and they have constructed those cities. So Kobe is again in the Bay area where you have the part of that has been reclaimed. So in such regions the secondary effect because of ground shaking will be extremely high and that what was being experienced during 1995 Kobe earthquake.

The rupture, we will definitely learn about the topography of the active fault, but if you see the sharp topographic boundary between the rugged terrain and the flat flood terrain, it lies somewhere here and that what marks the default. So this is Awaji island where the rupture was evident and we have, this is what we have the Osaka Bay and the Kobe is located along the bay area.

So you have this is the major fault line, which is again strike-slip deformation or transform fault system, you have median tectonic line and the earthquake which was triggered in 1995 was at this point. This was the epicenter and the rupture propagated on either side. So they had ruptured towards Kobe and they had ruptured crossing the Awaji Island. So this was the reason why Kobe faced extensive damage.

And this fault which is crossing the Awaji Island was named as Nojima fault. So as if you see here, this is the connecting bridge, which was been constructed, which lies between these two islands Honshu Island and Awaji Island, which also was affected during 1995 Kobe earthquake.

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And other than that, the damage which was experienced in Kobe was massive. So you can see the flyovers where it toppled down and later they came up with the (()) (10:27)) and all that.

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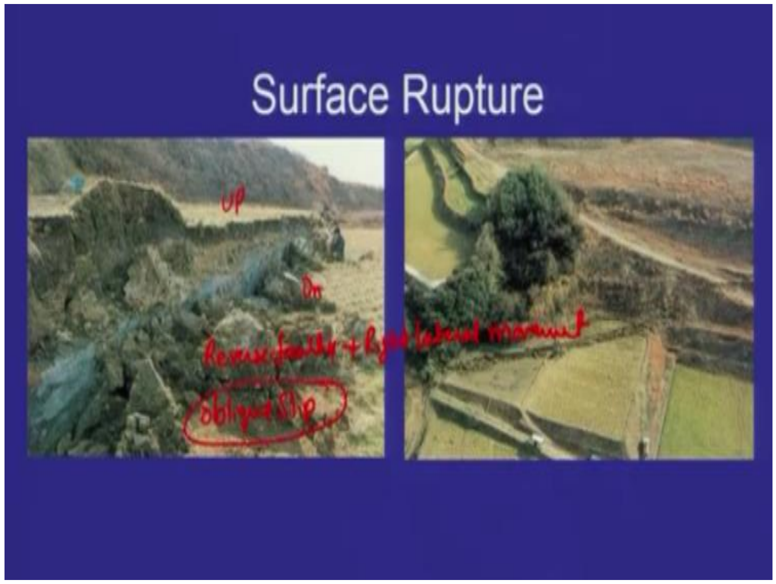

So this was the damage pattern, but and more you can search and Google out and you will be able to see the damage pattern, but most important for us is the surface rupture. So immediate after the 1995 Kobe earthquake, the rupture has been identified and the major displacement was observed in Awaji Island and these are the signatures. This is a aerial photograph of the rupture, which you can see here displacing the agricultural fields, close-up of that.

So I will come to this photograph in coming slide. So you have the movement along the along the fault. So whatever, we were talking or we have seen in the sketches, which I was drawing and we what we have learn in the and the some cartoon clippings of that, how the faulting will take place and which block will move up and which block work will go down. So in this case, looking to this photograph immediately we can make out that this block is has moved up and this is down.

And since we know that the mechanism of the faulting in this region was oblique slip, so this was very evident. So there was oblique slip and the movement was along the fault plane, which moved resulted into the reverse faulting plus you had an right lateral movement. So this was the combination which resulted into the oblique slip movement. So reverse flow plus right lateral you had movement here.

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So this you can easily make out. So you are having the surface ruptures coming right up to the ground and formation of the shear fractures along the fault line and you can easily make out the displacement over here. This is the boundary here and this boundary has been moved like this along this fault. So this portion exposed the fault plane and this was the fault line. So you have the vertical section, you will be able to see the fault plane and on the surface, this oblong view is your fault line.

So this was the fault trace, which has been picked up after 1995 Kobe earthquake. So this is in close up of that. You can see the displacement here.

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And further close up if you see the contact here, that is this portion the next photograph is of this one here you can easily make out, what we call the slickensides. So this we discussed in one of the lecture. So this block has moved this side and all these striations are basically in this originity. So the movement was along the strike itself.

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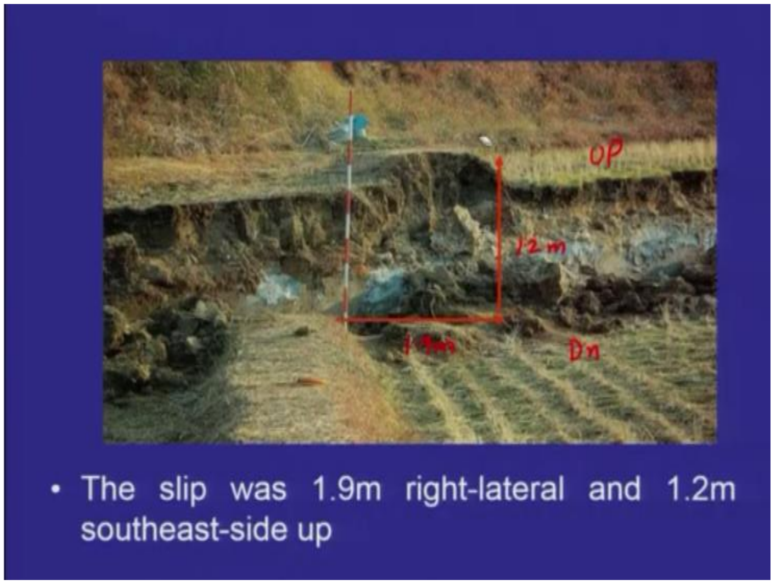

Now coming to this one, this is what I was talking that this block is up, this is down and if you put the demarcation here, then this portion of the boundary of the agricultural field has been displaced again. So you have this one here, which goes right here. So this is you have the lateral displacement of this one. So you have the up thrown, that is the slip was about 1.9 meter right lateral and 1.2 meter southeast side was up. So this was 1.9 meter and then this was 1.2 meter.

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So few more examples, which shows the displacement and the fault trace over here, close-up of that. So you have clear-cut right lateral displacement, which has been picked up.

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Now along with this, you also had some ground fracturing or the cracks which were developed and this was associated with the liquefaction phenomena. So secondary effect will always be seen in the region associated with the strong ground shaking. So this was the case of liquefaction.

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Now as I told that this house has been taken into the custody of the government and it was preserved along with that, this whole area has been preserved and they came up with a museum.

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So idea was to make the people aware that what exactly happened during an earthquake. So this is a very strong outreach program, which Japanese governments usually ask the scientific community to do and this rupture has been one of the preservation of this rupture and construction of museum is one of the example. So you can see the right lateral shift of this. So it has been shifted like this and similarly you can see the outer boundary just coming.

So the fault runs somewhere close to this, that is over here, if I precisely draw it on this curve itself. So you have, it goes like this here and the displacement is, this block has moved in this direction. This has moved in this direction. So what we see here is the lateral movement along the strike of the fault, whereas as the vertical displacement, you can see in the next slide.

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So this is a close up again of that and you can easily make out that along with the lateral, this block has moved down. This is a compound wall, which was straight. Now it is sitting down here. So this is the vertical displacement between the two blocks and this is the side view of that, which clearly remarks the lateral shift and this is, in the vertical section, you see this block is up. This is down here. Similarly photograph from the other side.

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Now what they did was, they preserved this whole area and let us see what they have shown in the museum. So this is the museum right now and this portion, the part of the museum, the house is somewhere located in this side and this portion is from this area. I will just show that. Yeah this is the entrance of that and then you get into the Museum here and then you see the house and the next. So that museum, which you see here the building is from that part. So this road was the old and now they have completely modified this whole region.

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So if you enter into the museum, then this goes as part of the museum. So what they did or they had this rupture, so they dug this portion to put it in such a way that you have the. So this photograph is during the construction which was going on. So they open up the trench, they excavated the section and they put the glass over here, so that the people can see the contact between the two blocks of different rock types and the displacement, which has occurred.

So you have the displacement. This is the fault plane which is high angle. So again we will say that this is the reverse fault and then we have the displacement, which took place here right laterally, which has been shown in other slides. So this portion was completely preserved from the museum.

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So liquefaction and lateral spread were experienced in the reclaimed areas mainly and near the Kobe.

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As I was talking that most of the areas, if you see around the bay regions have been reoccupied or areas by filling the sand and the material there and those areas were extremely got affected because of the strong ground shaking.

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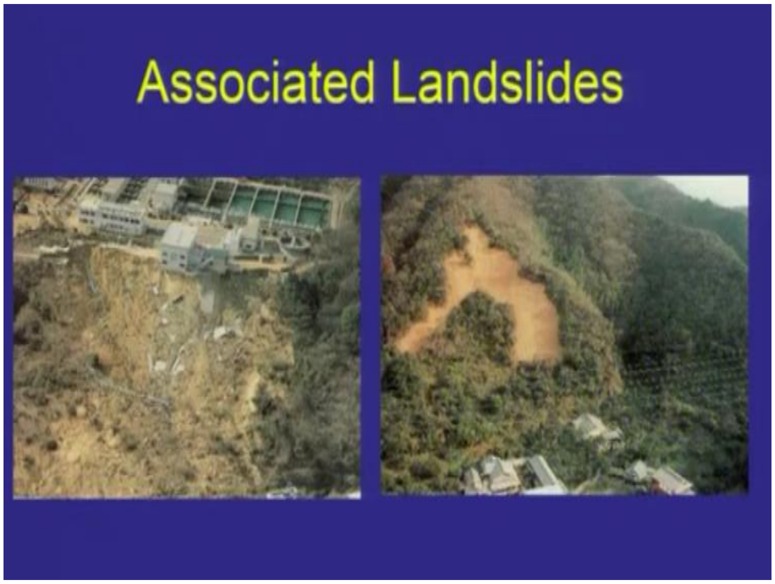

Associated landslide is another phenomena, which one will experience other than the liquefaction.

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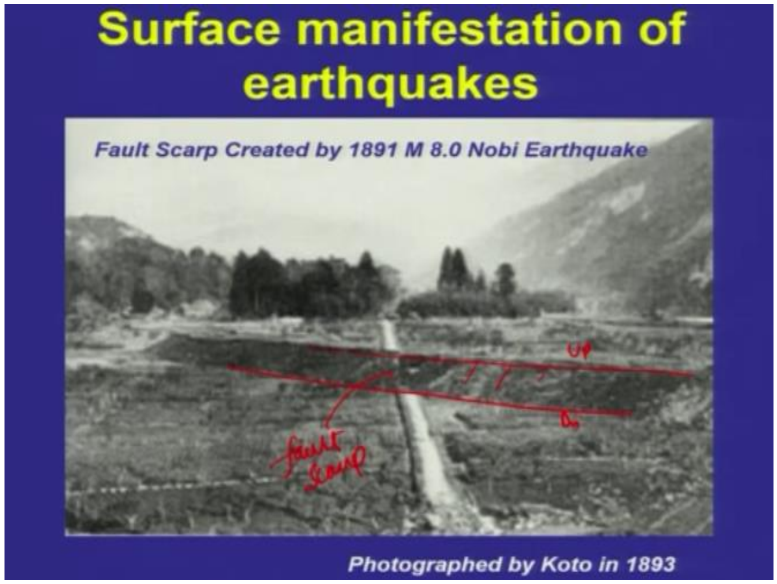

Now coming to the surface manifestation of earthquake, so this was an example of 1891 magnitude 8 Nobi earthquake again coming from Japan. Now as I mentioned in one of the lecture, that the human memories of course very short okay. So we keep forgetting the things which have happened in the past very quickly. So the new generation come up and they will also not be much bothered because the time interval between the major earthquakes will be more than 100 years or 200 years.

Now this is one of such example from Japan where people did not recall or remember because no earthquake has been experienced in last 200 years or so. So this is a fault scarp, which was mapped and photographed in 1893 and this earthquake was 1891 Nobi earthquake. So you can see the fault scarp over here. So this block is up, this is down and this portion which you see here, I will just put the line here, so that it is clear. This is your fault scarp.

Now what happened over the time? Let us see that again. So surface manifestation of 1891 Nobi earthquake.

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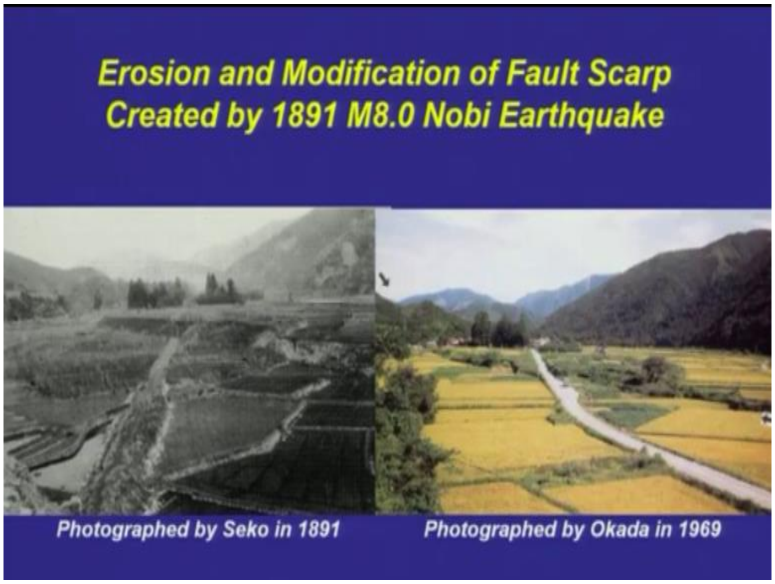

So erosion and modification of the fault scarp created by 1891 Nobi earthquake. You can see that modification has been done and this photograph was again taken at the time, just after the earthquake, but later in 69 okay, in 1969 the same photograph, not the same but same area has been photographed and what you see is the modification because of the erosion.

So this will also be a part of the process, because whatever the surface rupture is, it is seen on the surface at the time of earthquake will not remain forever. It will be modified because of erosion. Also it will get modified because of the land use planning and all that.

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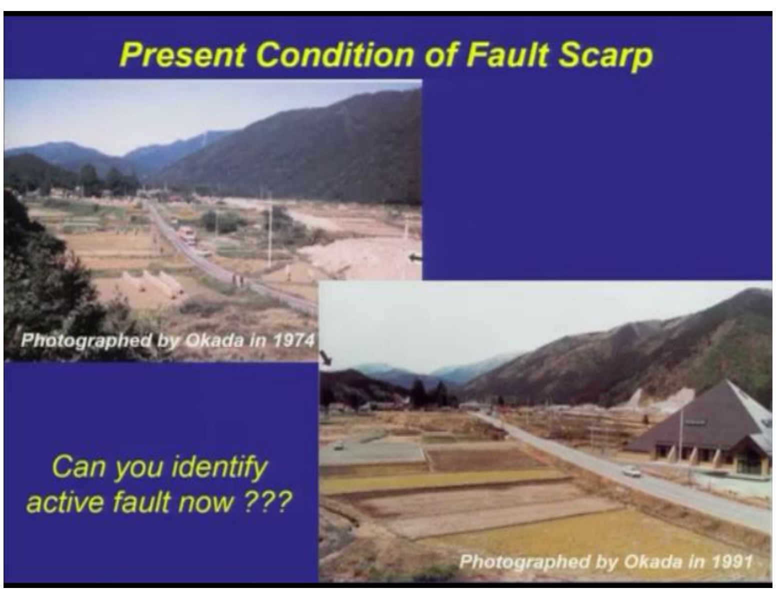

So present condition of the fault scarp, you see, lot of constructions have come up and the fault scarp remains here and the roll crosses this fault scarp that in 1974. Further, if you see, then what you have is that you have the fault scarp, which runs here just almost close to this building here. So this was photographed in 1991 by same geologists in Okada in 1974 and further 1991. Now the question remains that with the modification and erosion.

The modification is by erosion as well as by the local people or the town planners, this will slowly obscure. So it will be difficult sometime to identify the fault trace in unpopulated area. So if suppose, you get an old photographs of this region and in case of the Nobi earthquake, you had in 1891. So if you are getting the photograph of 1891, then you will be able to trace that fault very easily.

But if you are looking at the photographs of say 1991, then it will be difficult for us to some extent, but I do not say that it will be absolutely will not be able to identify. So usually what we do? Why I am pointing out this is that usually what we do is, we try to use old satellite photographs. So for example, in India that what we have experienced that when we use the recent photographs or satellite data, then it was with the total modification and urbanization again.

And a lot of the construction came up, because of the increase in population and people are moving and slowly this city or the town is growing and so lot of modification along with the erosion, but if you use the old data, old satellite data or any such literature, which is available either in the historical chronicles or been reported in a published literature or any written records are there, that will really help in locating the active faults, which are modern the active fault signatures have been modified over the time.

So this is one of the best example, which we can learn from 1891 Nobi earthquake and related fault scarp.

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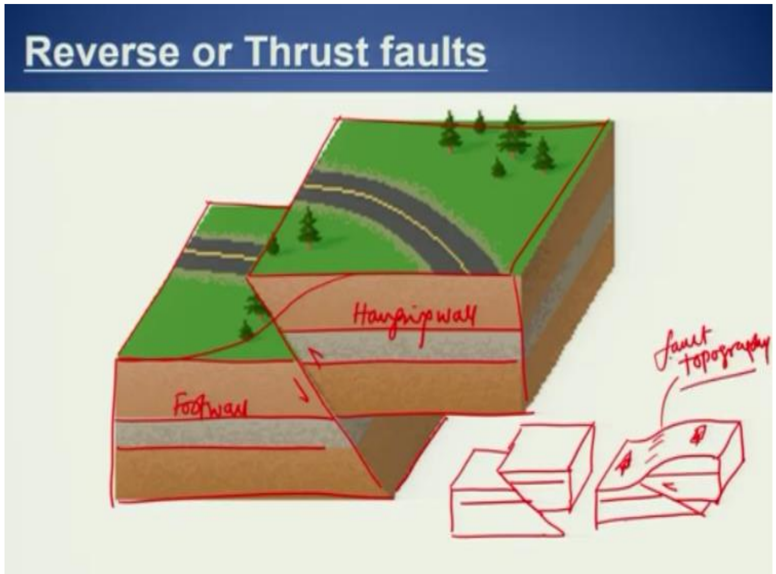

Now, coming to the reverse fault deformation, so please recall the section, which I was showing from the Kobe earthquake that we have the block has moved up and we have the high angle fault and this block has moved up and so this is your, so you can see show the direction something like this okay. This is down and this remains the stationary wall or we can say the foot wall and this is your hanging wall.

So again you have very clear features here, you have fall plane and you have the surface and in section, you can see the disk pate layers. So these are the displays there, the marker horizons, you can take based on the physical appearance as well as the grain size and all that; this part we will learn later. So at least, this you can easily make out. Now over the time, this will get modified okay and you will have and profile something like this.

So for example, you have the displacement, which is taking place at the time of the earthquake and after the erosion what you will be able to see something like the topography like this okay. So you have the modified topography in field. So I am just drawing this, so that you have a better understanding. Anyway, so this block has, so after the erosion, you will be able to see this type of topography.

So at the time of earthquake, you may have the sharp topography, but after the erosion and modification will be left out with a very gently sloping warped surface and that is what we require to pick up and this is termed as the fault topography.

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So this is another example of the thrust fault system aerial photograph from Japan, central Japan. So what we have planned is that we will give you some lectures on and particularly on how to use the high-resolution satellite photograph and how you will be picking up the different landforms. So with the basic understanding of different faults and associated topography like thrust fault, strike-slip fault and normal fault.

Mostly, we will be concentrating, will be emphasizing more on the reverse fault and the strike-slip the fault. So first what we will do in module, we will give you a lecture, how to use the high-resolution satellite photograph and as I have been mentioning that you need to use high resolution photograph, but other point which I will emphasize is that you need to use in stereo pair.

Because even though if you are having very high resolution photographs, the 3D perspective view, until and unless you are not having, then you will not be able to identify the displaced landforms or displaced surface. Because most of the time what we see in using the high resolution satellite data, the photographs either they are panchromatic or that is black and white or gray scale you are having or you are having the colored for photographs okay. So in that, you will be able to differentiate between the displaced landform or demarcate the geomorphic boundary based on the tonal variation.

Now tonal variation you will be able to mark, but the displacement that is the vertical displacement or the lateral displacement you will not be able to pick up, unless and until you are not having the 3D prospective view. So if you are having aerial photographs, then to some extent you will be able to pick up the deformation, but if not because the aerial photography is going to be very expensive process. So it is better to use the high-resolution satellite photograph or satellite data. So I will end up here and will continue with the next lecture. Thank you so much.