Earthquake Geology: A Tool for Seismic Hazard Assessment
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Lecture - 25
Fundamental Related to Active Faults (Part IV)

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Welcome back. So in previous lecture we discussed mostly about the fault topography and at the end I was emphasizing about that use the old satellite data to avoid the erosion and modification of the fault scarp while interpreting the particular regions towards the identification of active faults.

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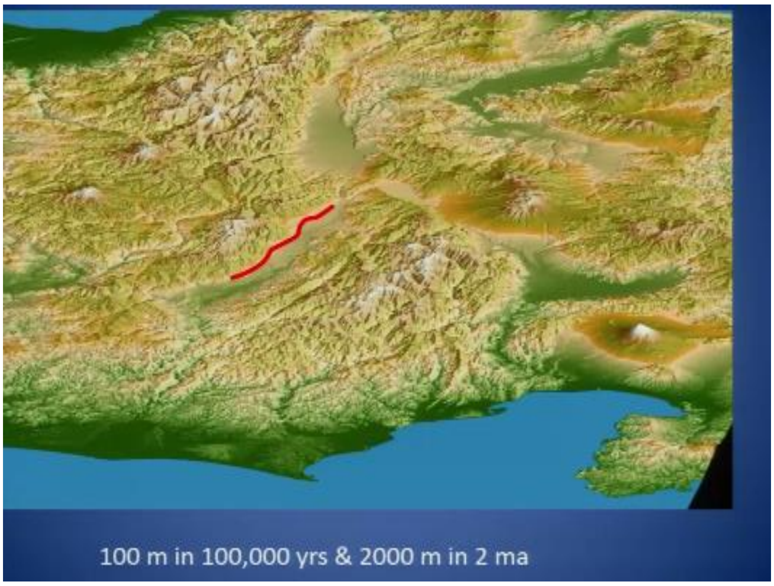

So this is again you can use different methods using the again this is your Satellite Radar Topographic Mission data and so what we will do is we will try to come up with a lecture where you can use different techniques either you are using the ASTER data or you are using SRTM data or you are using the high resolution satellite data with stereo pair capabilities. So with that you can generate the topography of the area and that will help you in indentifying the landforms.

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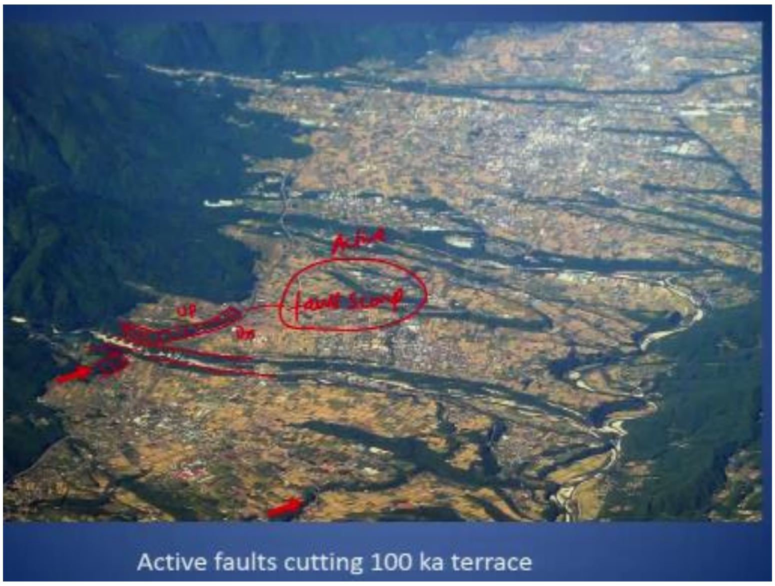

This is another photograph close up of that same. You are having the terraces which have been displaced along the fault lands. You can see this these are the scarp here. So this surface and this surface is the same and got displaced along this fault line. So there are 2 fault traces which have been seen because usually what we take is that at this could be an erosional feature, but if you look at the rivers which are flowing from uplands (()) (02:06) in the plain areas.

Then what we see is that they are almost transfers to the realignment or the orientation of this feature. So you have a scarp so if I just put a section here then what you have is that you have a topography like this and the rivers are flowing transverse to this. So the river was flowing like this then you may say that this is because of the erosion, but this is not the case here the river is flowing like this here okay.

So I will exactly put this sketch on the topography here and you will be able to understand much better. So you have the boundary here of the terrace, you have a terrace here and then you have the same here the terrace and this is your trace of the river channel. The river is flowing exactly perpendicular to the fault scarp. So this is your displaced surface this is up this is down and this is termed as your fault scarp.

So most of the in most of the cases we will be able to pick up such features if the areas is active and it is a different elevation in the landforms where we will not be able to find that the reason that this is because of the erosion then those features are probably related to the active fault along the because of the deformation ongoing deformation and along the active faults traces.

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So surface manifestation of 1999 Chi-chi earthquake the fault scarp can be seen here and the fault trace run somewhere over here. So this is your fault scarp and this was along the reverse fault or thrust fault the low angle which was experienced at the time of 1999 Chi-chi earthquake.

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So this is from another angle the photograph has been taken so fault runs somewhere over here and this block is up and this is down and this is what you see is the fault scarp. Another example of that so you can see the displaced (()) (04:54) running track here and you have the surface which is deformed so fault run somewhere like this here.

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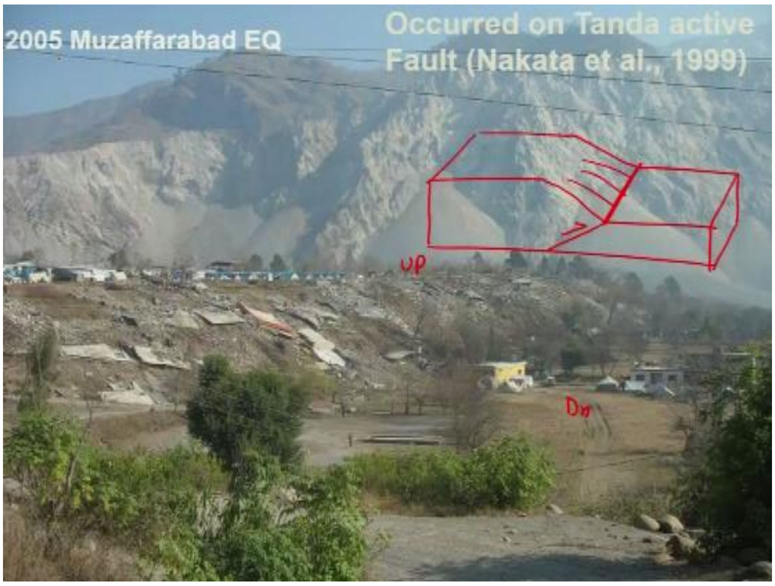

This is the fault scarp of the definitely the old fault scarp but this got reactivated in 2005 Muzaffarabad earthquake. So you can see this portion is up and this is down here. Fault runs over here and this is your fault scarp. So if you put the section then you will be able to look at topography something like this. If I draw the blog diagram then it will appear something like this.

So what you see is this fault scarp and fault traces somewhere over here. This will be your fault trace this will be your fault scarp. So whenever there is an earthquake next earthquake this will move if this is we classify this is an active fault and since what we see here is your very young surface has been displaced. Hence this such features it should be classified as active fault scarp.

And this was identified long back in 1999 by Nakata from Hiroshima University and this was named as Tanda fault in that region and this was the because of the fault for triggering 2005 Muzaffarabad earthquake.

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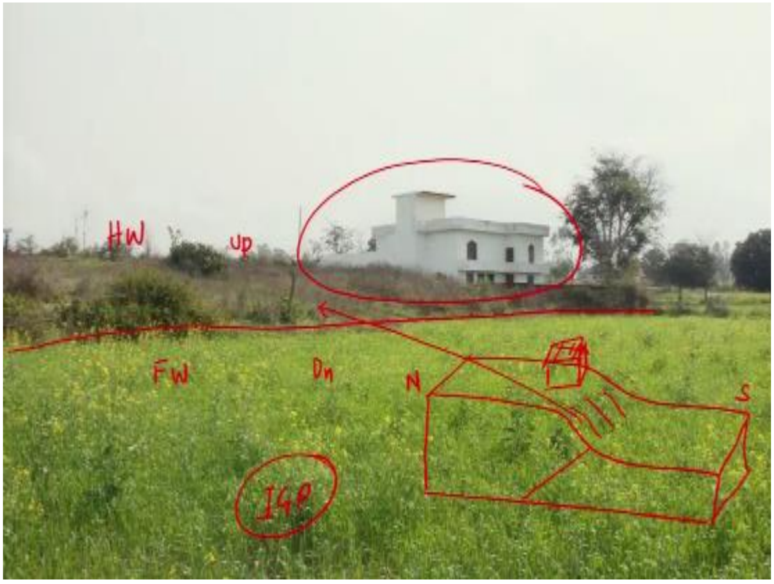

Further, coming to the (()) (06:56) side we will have detail discussion on this particular side, but the fault scarp if you see here is this one. So field photograph based on that you will be able to pick up easily the displaced landforms we have the fault line runs here and this is your fault scarp. So this is not a very good idea to construct the house on the fault scarp which has been done without having proper understanding.

So next event this house will definitely be affected because of strong ground shaking. So this block is the hanging wall and this is your footwall. So again if you take the section here we will be able to see something like this topography. So the house is sitting somewhere over here and this is the topography which you see here and the fault which we identified and did the wrenching is dipping towards North and this is your South this is your Indo-Gangetic Plain.

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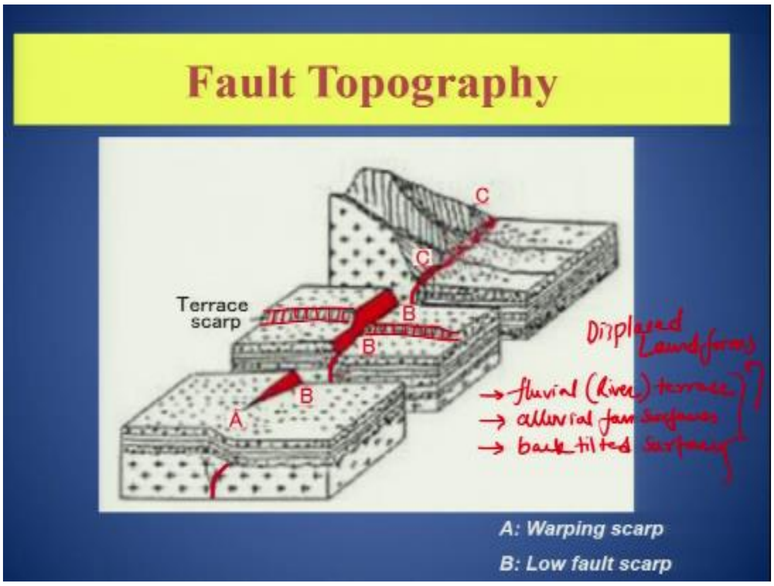

So a fault topography basically is like what we see mostly we will keep on recurring okay and suppose here what we see that there is scarp because the terraces are been displaced and similarly we will come when we will talk about the detail geomorphic markers and then we will talk about the terraces and the scarp here. So I will give one lecture on the fluvial landscape which will help you in understanding that what are the terraces.

And what are alluvial fan surface and all that, but basically we will be looking the displaced landforms which are comprised of the fluvial terraces, fluvial we are talking about the river deposits mainly and the landforms which are sculptured or eroded or deposited formed by fluvial activities or the river activities and then we will have the alluvial fan surfaces then we have like what in one slide where I was talking about the back tilted surfaces.

So basically what we will be looking at is the displaced landforms. So in this what has been shown that you have over the time you will have different displacement here you are having the terraces which are being formed by the river erosion and targeting this place. So we term this as an these are the terrace scarps, but this is the fault scarp here. So you will have to differentiate between the primary and the secondary features.

So this is because of the erosion by the river. So this you have the terrace scarp and this marked in red is your fault scarp.

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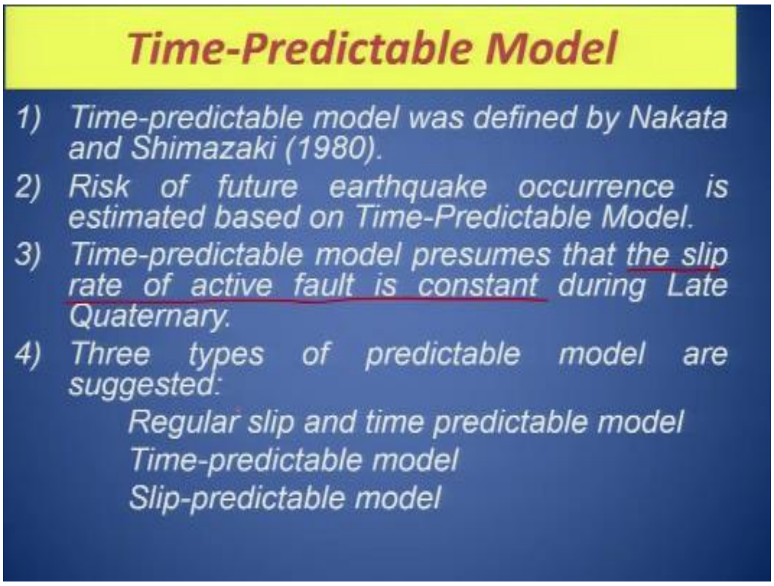

Now time prediction model in was given long back in 1980 by Nakata and Shimazaki. So this is required because when we are talking about the hazard assessment so risk of future earthquake occurrence is estimated based on time prediction model. So when will be the next earthquake on a particular fault and what will be the magnitude that is extremely important. So time prediction model presumes that this slip rate of the active fault is constant during Late Quaternary.

But this remains a question the slip rate on the active fault. So what we have learn from our investigations that this slip never remains the same and the magnitude never remains the same, but the prediction model assume that this slip on a particular fault remains the same and similar magnitude will be triggered every time whenever there is next earthquake the similar magnitude earthquake will be triggered.

But it is better to take into consideration the maximum amount of slip recorded or registered on that particular fault. So 3 types of predicable models I have suggested. A regular slip and time predictable model, time predictable model, slip predictable model. So these are the 3 different type of predictable models have been suggested by Nakata and Shimazaki in 1980.

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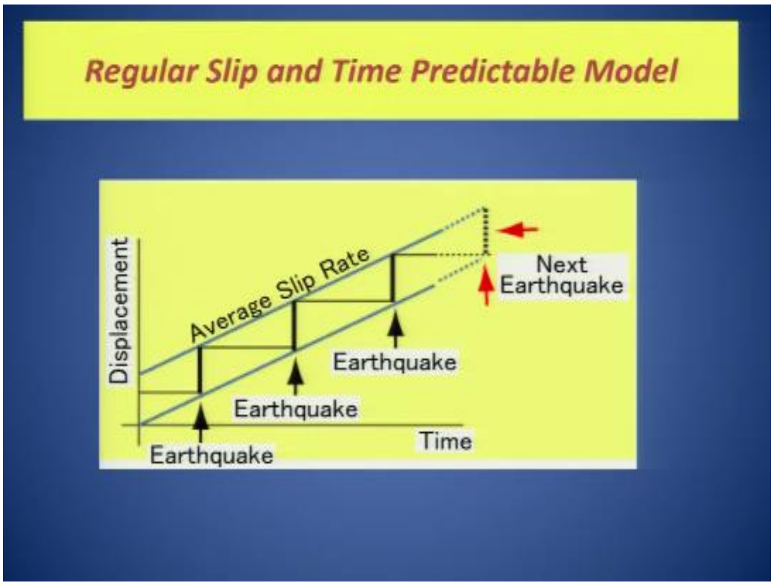

So if you take the regular slip and time predictable model then in one of the lecture in the beginning we talk about that if you have similar amount of strain which is getting accumulated along a fault then at a particular time which is more or less similar between the two events at that time it will slip okay. So this what it shows is again you have the time here and you have the displacement.

So over the time these strain will develop and then you have an earthquake over the time the slip will develop and then you have an earthquake. So if you have the regular slip and then and with the help of the averaging you can even predict that when will be the next earthquake okay. So this shows the last earthquake event and these are all 1, 2 and 3 and 4th one you can predict that when the next earthquake will occur considering the average slip on the fault plain.

So you with this at least you can consider the varied slip observed between during different events and taken average and you can predict. So this is the model which shows the regular slip and time predictable model.

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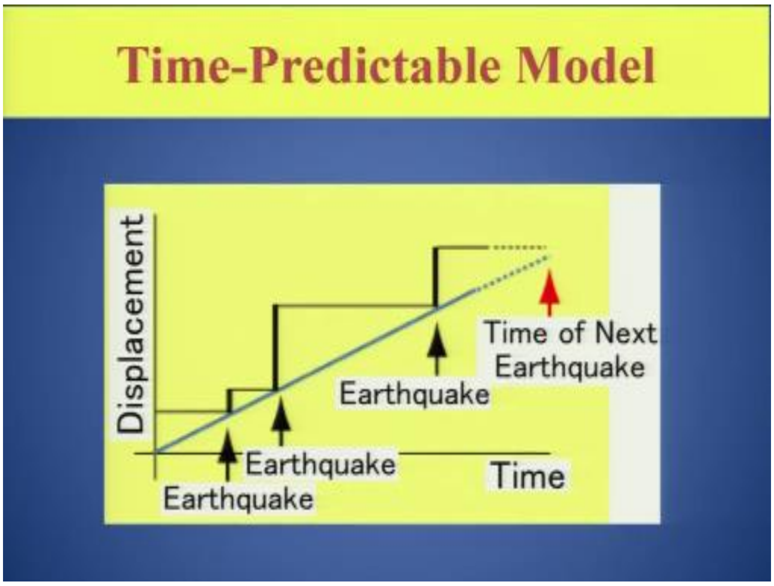

Whereas the time predictable model mainly does not take into consideration much of the amount of slip. So here what has been shown and that you have the earthquake with the less slip here that is displacement, but the another one was with the larger slip as compared to this one in a very short period. So this also helps us in understanding that if the entire accumulated strain or the energy has not been released during or it has been released by small earthquake or moderate earthquake or large magnitude earthquake.

Then the actual slip is available or you can say that the slip (()) (15:21) will trigger another earthquake in very short period. So you have so between because it has smaller earthquake here then immediately in a very short period you had an another one, but when after having the large displacement or the large magnitude earthquake because the displacement will also tell us about the deformation or the amount of energy release and that is directly related to your magnitude.

So large amount of displacement hence the time which was been taken between the next earthquake was comparatively larger, but then also with this (()) (16:07) you can predict the time of the next earthquake. So this is based on the time we can do and first one was the regular slip and time prediction.

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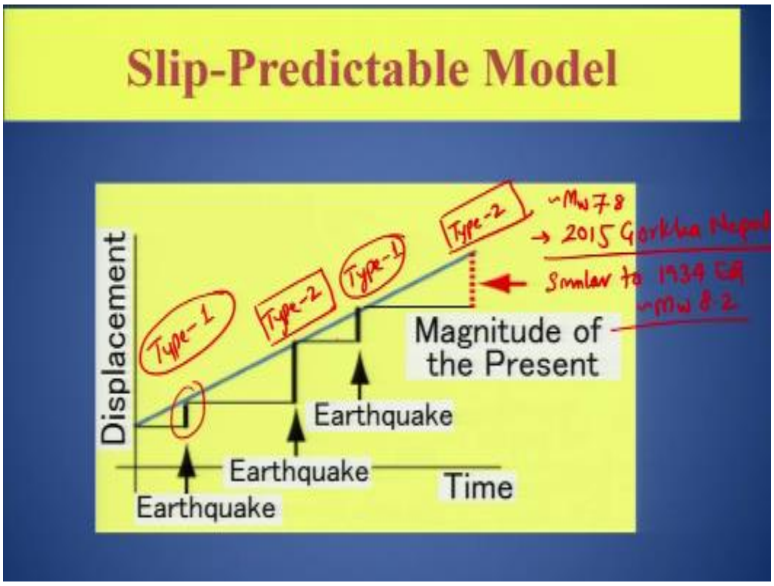

And slip prediction basically if you take then you can have very much similar to that, but here what we are getting is the time is not the same. So what does this indicate that you had between this and this earthquake you will have very much similar time which has been taken, but the slip varies in different earthquake. Slip does not remain the same here the displacement is less here, displacement is less here.

So what one can suggest is that this was for example Type-1 earthquake and this is your Type-2 earthquake and this is very much similar to your Type-1 earthquake. Now this 2 you have based on the slip so what you expect is that the next one will be your Type-2 and this is what exactly has been predicted for the earthquake after 2015 Gorkha event in Nepal. So what the scientific groups believe that this was like 7.8 or so.

So next event will be very much similar to 1934 earthquake and this was magnitude 8.2 or so. So you can predict the next big earthquake based on the slip prediction.

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So what we do is after identification of the surface deformation old surface deformation preserved on the surface or rupturing along the rupturing of fault then we open up the trench to understand the pattern of displacement, the pattern of slip and that what we call trenching. So this is the technique which we will discuss as we move further in this course, but just to have a brief understanding we can quickly look at what we see here.

So if you can see here is that we again use the knowledge of the sedimentology and so we have used this geomorphology part and then what we are looking at in the section is the stratigraphy of the succession and the structural geology we use because we are looking at the faults and all that and the property of the material.

So gray in size, color everything will be able to see. So this we can classify there is a soil here humus rich soil on the top and then this layer goes somewhere over here we have within the contact that is the discontinuity between the two units is very clear here and this portion which has been seen folded comprised of gravel here. This is sitting somewhere over here. So this is the net displacement what you have.

And this portion is your share zone along which the faulting has taken place. Now this example it shows that the displacement this layer was not displaced and the faulting remain blind whereas there is a displacement between this layer. So this is (()) (20:45) event, but the recent one you do not see displacement reaching right up to the surface, but of course the deformation has reach. So this we can say the earthquake was on blind fault and the earthquake remained blind.

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Coming to another one is your strike slip and as we have discussed that it is the lateral movement along the horizontal plain. So geomorphic marker associated with strike slip faulting environment.

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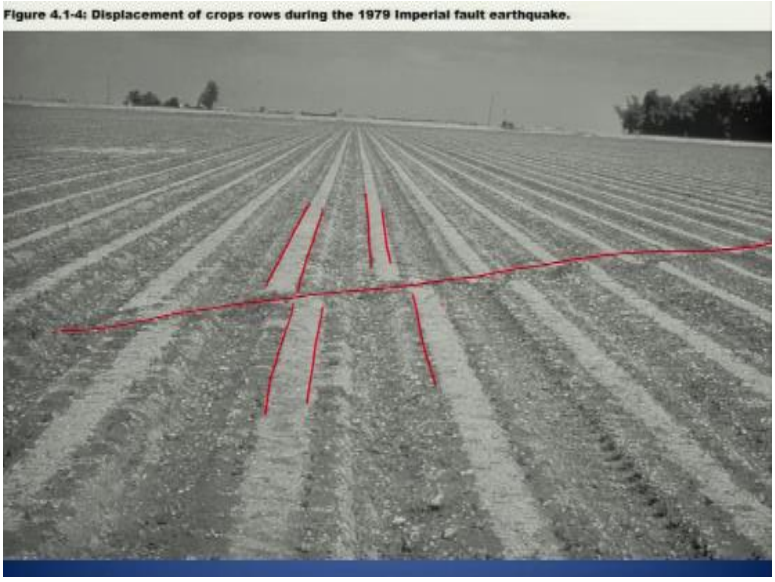

If you look at then what we see is the offset of any surface feature and this is an example from 1979 imperial for earthquake where the trace has been seen here very much similar to what we are talking for the examples or the evidence of 1995 earthquake surface rupture. Here also the agricultural field has been displaced along this line. So this is your fault line and the displacement you can easily make out over here. So you have this one here, this is one is here.

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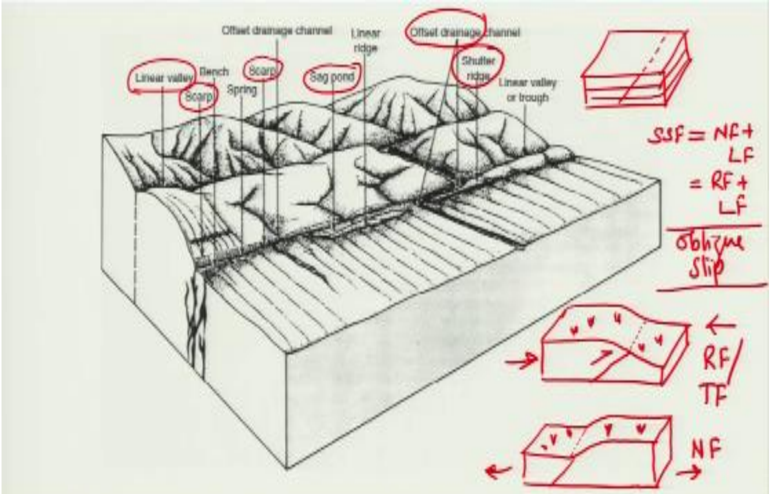

Figure 6.8: Assemblage of landforms associated with strike-slip faulting. From Surficial Geology, Building with the Earth; Costa and Baker (1981). Copyright © 1981 John Wiley and Sons; reprinted by permission of John Wiley and Sons, Inc.

So the landforms basically what we will come across along this strike slip fault that is the geomorphic signatures mostly the thrust fault and the reverse fault you will be able to see the formation of scarps. So if you are having for example the horizontal surface here before the formation and then after the deformation in case of the reverse fault what you will see is you will have the fault scarp which has been formed like this.

We have the fault which is sitting here or slight precise over here. So this block has moved up. Now in case of the normal fault so in this case this portion will go up this is going to be the footfall, but in case of the normal fault this block will move down and this block will remain stationary. So the feature again what you will be able to see it will be something like this in case of the normal faulting.

So you have the fault is here. So the topography which you will see in the normal fault. So this is in the case of normal fault and this is in the case of reverse fault or you say thrust fault. So here we are having compression and here you are having extension. So this prominent topography is very much similar in the case of normal faulting and the reverse faulting, but in case of strike slip faulting which will have the component of so the strike slip faulting will have the combination of normal faulting plus lateral faulting.

And or you will have reverse faulting plus lateral faulting. So you will have combination of this two that is what we call the oblique slip. So this oblique slip will result into the formation of different landforms within combination of this scarp as well as the lateral displacement or the deformation of the features on the surface. So for example what you will see is the formation of the linear valley along the fault trace then you will have scarps.

You will have benches which have been developed like the multiple scarps here then you will sag pond this I will talk in detail later on that how sag ponds have been formed and the shutter ridges and the you will have offset. So this few geomorphic markers are extremely important which I will put as in box here. So that you will be able to so anyway but these are like linear valley scarps, sag ponds and then offset of drainage is important and the shutter ridges okay.

So these are some very important parameters to differentiate between the different type of movement what we see as one is on the either it is reverse fault, normal fault or in strike slip fault.

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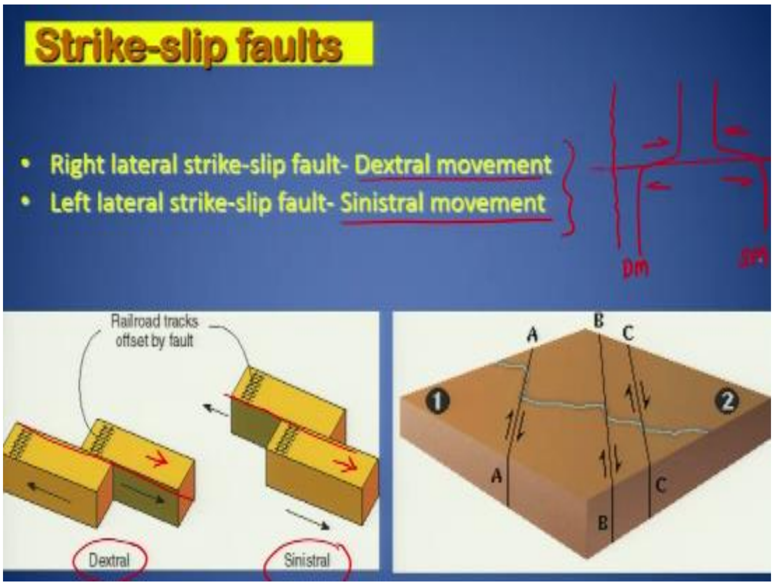

So as we have been discussing about that right lateral and left lateral. So this slide will make things bit clear about the sinistral of movement what we classify as the right lateral and left lateral. So right lateral strike faults are termed as dextral slip fault or it shows the dextral movement and sinistral is for the left lateral strike slip faults. So this figure it shows the offset or the deflection of the channel along the black line that is your fault line.

So movement is this stream is flowing like this getting offset here and then again flow straight here. So if you are having zone of strike slip fault then you will see multiple fault lines and the displacement very much similar to what has been shown here. So this is in case of the right lateral strike slip that means you are looking at the dextral movement. So in a simplest way if you see this then you are having the dextral. So right block is moving towards you, your side and left block is moving away and this is your fault line.

And in this case the right block is moving away and the left block is moving towards your side in case this one is the right here so in this case we have what we say the dextral movement and in the left lateral we say sinistral movement. So this thing you should keep in mind that you are having left lateral then you say that is in your sinistral movement. So similar to what has been shown here the offset of rail track.

So this is manmade structure which is been shown we discussed and got displaced whenever there is a movement along this fault depending on what type of movement will take place of course the strike slip remains the same, but you will have either it is sinistral movement or dextral movement and the landforms which are with that those exist on the surface will also get deformed and modified depending on the type of movement.

So for example if you have like in if you just put a stream here which is flowing straight and now we are having stream like this getting bend here and then flowing. So this will be your left lateral movement oh sorry right lateral movement and when in case of this one here if you are having like this then you have left lateral movement. So if the fault is passing through this area then so this part you can keep in mind.

So you have this is your dextral and this is your sinistral so dextral movement and snistral movement.

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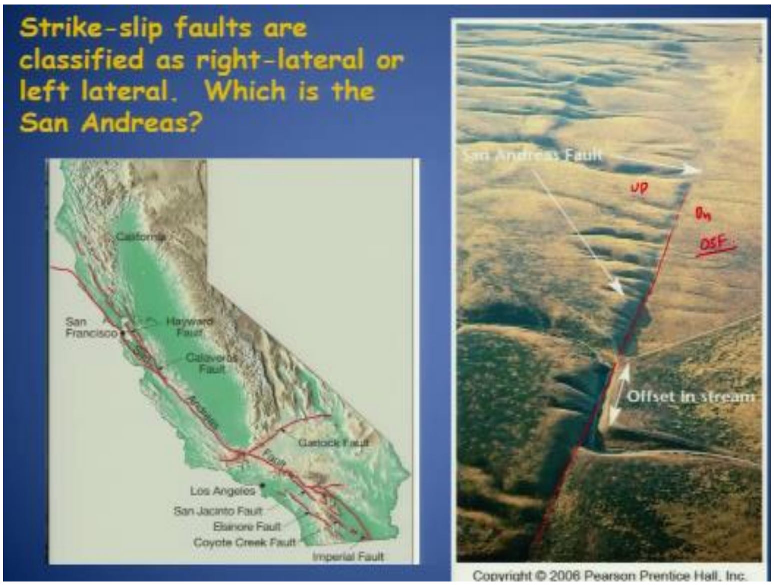

So this also I have shown in one of my lecture the one of the best example on the earth surface is the right lateral strike slip fault that is your San Andreas fault system in US and this is between the North American plate that the deformation is due to the tectonic boundary between the North American plate and the pacific plate. So what you see here this is an aerial oblique photograph then you see the scarp which has been developed here a very linear valley or the trace of the fault here and then you have the streams which are being offsetted here.

So this shows the offset amount of offset of the stream and even smaller stream are getting displaced here. Now this portion if you see carefully has blocked this channel here. So this type of features are termed as shutter ridges. So they are acting as a shutter in front of the channel which are flowing across the scarp here. So this portion of course is up this is down. So this portion is up this is down and also we see the lateral offset along this fault.

So then in this case I hope you will be able to easily recall that what type of fault in total we will talk about. So this is your oblique slip fault.

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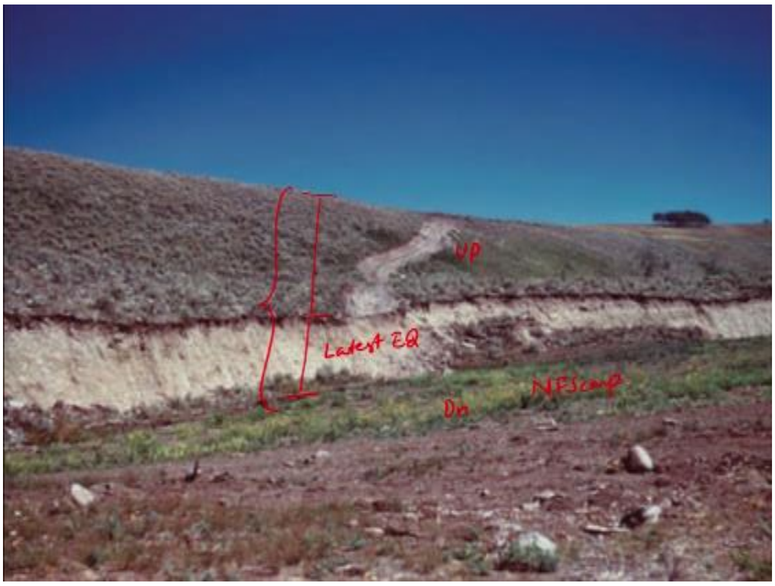

This is another fault scarp which has been seen over here of course you see this exist and then this one is the fresh one. So this is the latest event or latest earthquake this scarp has been formed. So this for total if you see is the cumulative scarp. So this side is up and very fresh straight scarp has been seen this side is down and this indicates your normal fault scarp. So in case of the topographic wave if you look at on again on a very large scale.

This is again an aerial photograph, but the contact which has been shown for any active deformation will be very sharp with respect to the geomorphology like what we are talking about the geomorphic boundaries. So very sharp geomorphic boundary between the upland and the plain areas. So this marks the trace of the fault here and based on such interpretations at the initial stages you can mark that this area which is going to have a potential active fault.

And further detail studies or the close up of that you can take and try to identify the fault scarps and other related features.

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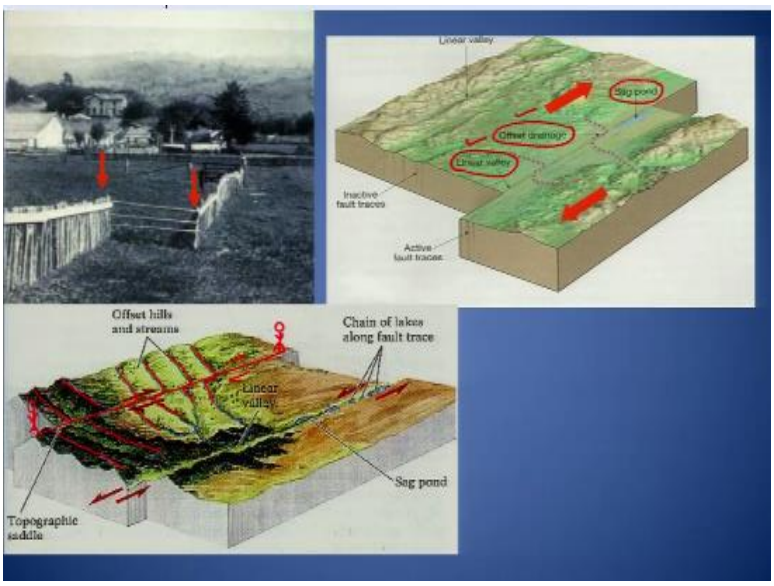

This we have already discussed we will just go ahead, but the important part here is that this is the winds which got displaced in 1906 San Francisco earthquake, but the features which have been shown here along with the linear valley along the fault line is your deformation of the linear valley then offset of streams which have been shown here and the formation of sag ponds.

So the most common and important features which we will pick up to classify at least and this is strike slip active fault or this three features. So if you are able to see the sag ponds you are able to see the offset of stream and formation of linear valley. So these are the two most important one. The movement here is again you are having this offset of streams. So the movement is your right lateral strike slip movement.

Again similar one so whatsoever the landforms you see on the surface are present on the surface during the deformation will be deformed or will get offsetted along the fault plane and that will along the fault line and that will be preserved will remain preserved either they are ridges. So this shows the offset of ridges here. So this is the top of the ridge line here and this goes somewhere over here like this and similarly the ridge line is here.

And then this shows the offset of streams. So all the streams which are present on the surface along this fault line are displaced or offsetted. So again this is this streams have moved like this we have the right lateral strike slip. As I told in one of the lecture that either you stand here or see that what type of movement has taken place whether it is right lateral or left lateral it remains the same from both the sides.

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This also we discussed this is because of the creeping of the right lateral slip here so you see this is an offset along the fault line.

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And similarly this also we discussed I have couple of photographs which I have already shown you in one of the lecture from Hayward fault which shows the creeping.

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The fault runs here and on the surface we see the offset. So that was with the stream offset and this is related to your offset of manmade structures. This also is the close up of that.

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So I have already explained this so I will just go quickly ahead so we have an offset here so we have the offset of pedestrian path.

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And similarly the offset of the rail track. Thank you so much.