**Earthquake Geology: A Tool for Seismic Hazard Assessment**
**Prof. Javed N Malik**
**Department of Earth Sciences**
**Indian Institute of Technology – Kanpur**

**Lecture – 28**
**Lab & Field Techniques in Active Mapping and Paleo Seismic Studies (Part -III)**

Welcome back so in previous lecture we stopped at few photographs which were being taken on by the aircraft mainly the aerial photograph oblique aerial photographs. So as I emphasized that we can go for mostly like studio vision photographs but if you are having the aerial survey if you can do which is an expensive affair you can also have that but of course you need money and time for that okay.

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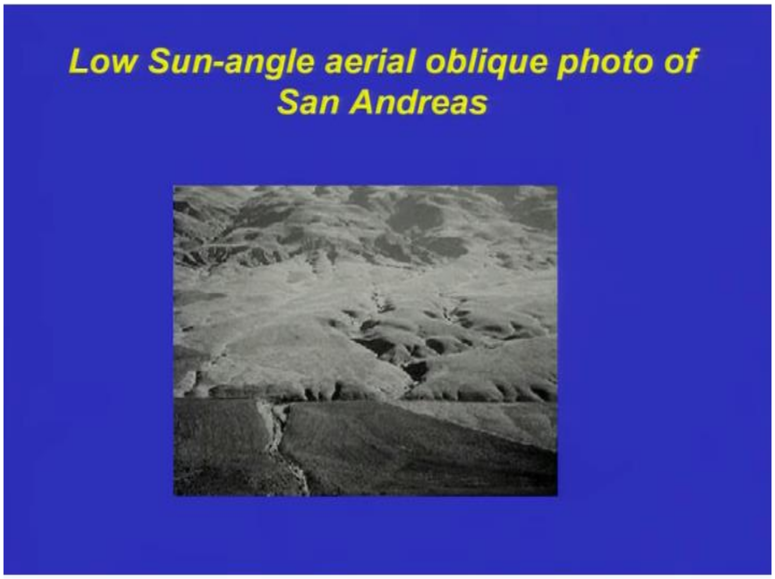


Now there is another example of low Sun angle aerial oblique photo of San Andreas Fault system which shows the clear-cut geomorphic expression of the fault trace and associate geomorphic features as offset of stream and all that.

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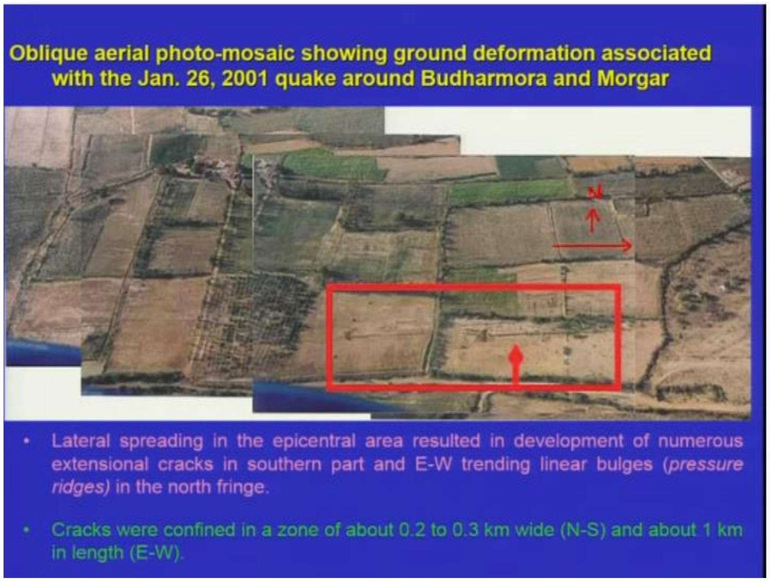


So further if we look at this is the exercise which we did after the 2001 Bhuj earthquake and the aim was to look for the or identify the ground deformation associated with 2001 Bhuj earthquake. So what we did was again we clicked flying at very low height again this was an aerial oblique aerial photograph and we did mosaicing so we clicked for graph in such a way that it has almost like 30 to 40% of overlap and if you use again this photographs like photograph fun for graph 2 you can view in 3 dimension.

So you can have 3d view of this and that is one of the important parameters to have the stereographic vision and you need to have the overlap of the area at least by 40 to 50 or more than 50 percentage of overlap should be there. Anyway but the whole idea was to identify the rupture or more we can say the deformation there was no rupture on the surface but there was at least an hunch that probably this earthquake resulting into the surface rupture but there was just in ground deformation which was observed in the epicentral area.

So close up of that if you see in the next photograph so this feature which was been interpreted as if you can see clearly, I am pointing out the line here. So this was the deformation which was prominent in the epicentral area few groups who did survey after the 2001 Bhuj earth quake suggested that this is probably the primary ruptured but later on what we did and based on our survey we did not agree to this and this was related to secondary deformation and that is what we call lateral spreading in the epicentral area and resulted in development of numerous extensional cracks in the south southern part and east west trending linear bulge.

So this was the east west and in linear bulge which I will show in the next photographs but there was some extension extensional cracks which were developed in this region. So the cracks were confined in a zone of about like point 2 to point 3 kilometers wide and north-south direction. So this what we looked in the photographs which were taken from south and this side is here North okay.

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So we were flying along east west line and in the photographs, which were taken we are looking north. So close-up of this one if you see the extensional cracks not what we were able to identify so we flew at and lower height and then took this photographs which helped us in pinpointing the area and then to finalize our survey points and transits and this was the bulge which we were able to identify very much similar to what one can see during in primary rupture.

Another one is here so this portion so likewise as in one of the photograph I was showing that we also identified the active faults scarps which were been traced and identified using CORONA satellite photos and further with the help of aerial survey we were able to confirm the trace what we identified on the aerial photographs. So the point here is not usually what we do is that with the help of satellite photo interpretation we prepare a map which we call a preliminary active fault map or preliminary geomorphic map.

This is extremely important and first most important step before we get into the field and start mapping the landforms. So whatever we have identified we consider those features or the active fault traces as a preliminary map or preliminary information and we confirm and make certain that the features or the landforms which we have identified are really related to the tectonic deformation.

So this remains an important aspect before you get into the field of course with an experience we are very confident that this is an active fault scrap. But then further finally what we did for us we open up a trench here and look this the deformation in section that is preserved in the sediments.

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So this is the ground photograph so these are the steps which we I am showing that you are you are using first the satellite data then you may go for the aerial survey and finally you are doing the ground truthing. So before getting into this whatever the interpretations we did we say that they are preliminary maps and then you start mapping further down. So you have this was this was the trace which we identified here at this location the photograph was taken the ground photograph from this place looking to the side and this is your scarp and then and further and the back side what you see are the hills which are mentioned seen here.

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Now as I mentioned in one of the lecture and I will try to show you the comparison between the old photographs and the new photographs this is from the northwestern Himalayan foothills zone where do we have the one of the major river which is debauching into the Indo-Gangetic plain is the Bias River. So along with the Indus and other rivers like Yamuna, Ganga and all that in in the northwestern side we have a major river a Beas which flows in typical u-shaped pattern here.

So the advantage of using old photograph was that if we do not see the construction of the Beas dam here and the new photographs if you see the recent one or the dead satellite data you will find that this whole area is under the reservoir. So sometime in the old photographs helps you in identifying the features sharp features on the surface which are not modified by natural processes or they are even not been modified by the human activity.

So we put the interpretations on the maps or on the photographs and then try to locate those features on the surface in ground okay. So this is the field evidence of the same feature which we see here so this side is up this is down and that what we have done and then finally decide that which are the locations for trenching which are been shown here. So we did trenching at 2 locations here so I will discuss in detail when I am talking about this particular area as in part of the case study.

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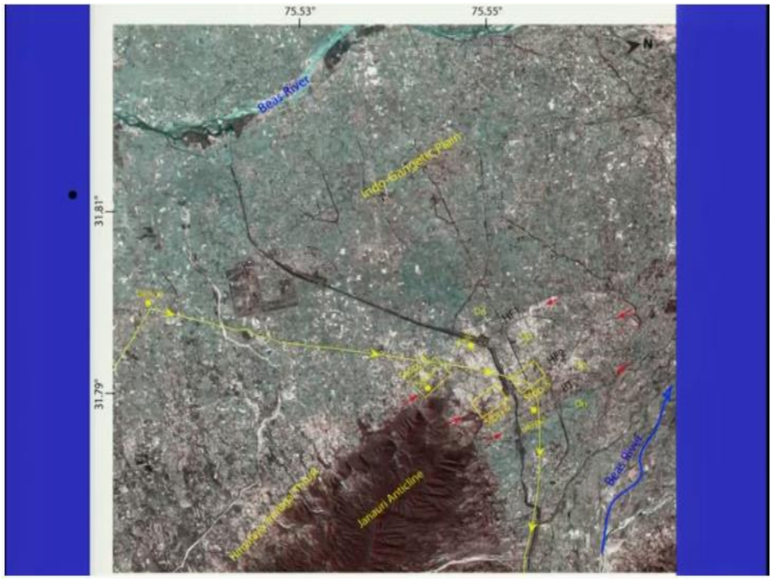


So this part again you can use the so that portion what you see here again you can easily make out that this is the feature which has been shown here. But now what we see is and this line so this before this this photograph this is Carto sat photo satellite photo of not very old maybe a couple of years old, but this is a CORONA satellite photo which was taken way back in the 60s okay. So this photograph is the upside down in the next one of the CORONA photo and what we see is the construction of a canal across this one which is which was not seen in the previous CORONA photograph.

So this is what I was talking about that the new structures may alter to some extent this such features which are sharply preserved and seen in the old photographs okay. So we have the Beas here and you have this tongue shape feature which has been seen or identified. So this image is the anaglyph okay. So we have used two stereo photographs to generate this image. So if you use the glasses of different filters either it is blue or red then that that will give you a 3d view of the strain that helps in identifying the features which portion is up which portion is down and whether we are able to pick up the sharp contact between the landforms which are deformed.

So this exercise as I have been telling you in couple of lectures that this will be and will give a separate lecture on this not how you will prepare the anaglyphs of this particular region.

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Now further what we can do is the classification of the landforms. So we used how we can use the stereo pairs of the given area or the area of our interest and then start preparing the detail geomorphic map. Because classification of landforms will be an important part because that will decide that whether the fault has remain active since last 100 years or 200 years or more and it has whether it has displaced the older landforms as well as the younger one or not.

So with this just simple 2d view you will not be able to pick up the fault traces which I am showing right now here since we know that this based on the satellite data interpretation that is stereo pairs and after looking at the terrain in three dimension we were been able to pick up that these are the areas or the lines which demarcates the fault traces. So we took this portion for the detailed mapping of terraces.

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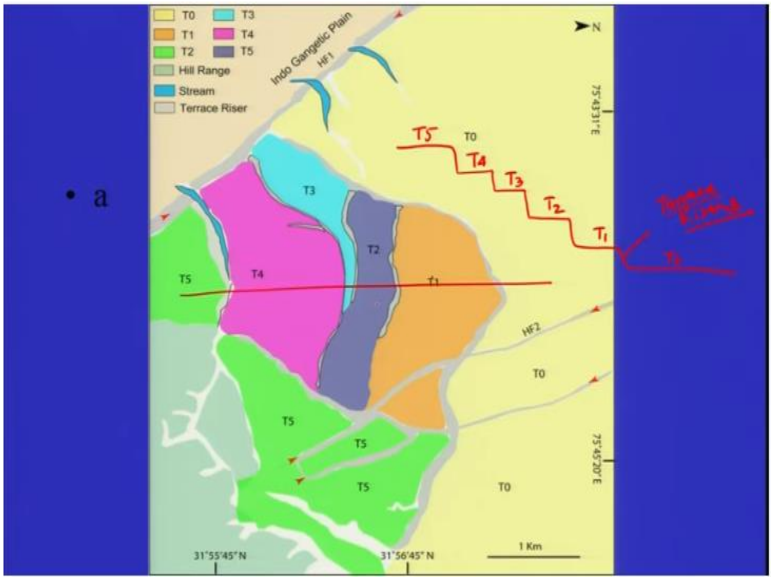


And this again we did with the help of stereo photographs and this is these are the image which you see is the anaglyph of this region. So with this what we did was we prepared a detailed map which has been shown here. So you have the fault race which is going now in this direction that is your HF1 and then there are another fault which is which is hitting here, and we have different level of terraces which were been marked in total we had like T0, T1, T2, T3 and T4 and T5.

So total 5 terraces were been identified based on the elevation difference with respect to one another. So this gray patch is the terrace escarpment, or we can say terrace scarp these are all terrace scarp, or we also termed this as an terrace risers. So if you if you take a profile along this one like this and then you will be able to see that there are the clear-cut steps here okay. So you have like this is your say T0 and you have T1, T2, T3, T4 and further one more is your T5. So you have then and this portion which has been shown in this curve the cliff okay termed as terrace risers.

So with this we knew that the T0 is the youngest one and then further moving up to T5 is the older one. So the classification has been given here as a very broad classification but at least we have marked the major geomorphic features here. So we have terrace risers which has been shown here then we have streams in blue and then we have hills which have been shown here and then the terraces with T0 to T5 and T0 is the youngest one and the faults which have cut the this terraces.

So if you look at this one here then we have the older terrace as well as younger terrace has been displaced and this trace it has displaced even T5 and T0, T5 even T1 is also displaced here. So if you have the ages of this terraces then you will be able to talk about that when exactly the terrace was abandoned and when this terrace was faulted in true sense and that can be correlated with the events which you can identify by putting trenches across this faults.

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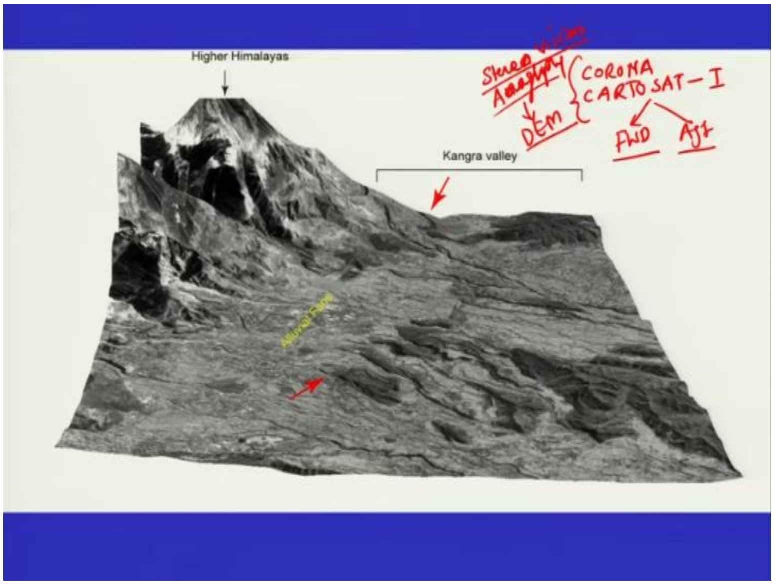


So another view of that we can you can use anaglyph you can use either the CORONA satellite photo and based on the because we are going to have the CORONA satellite photographs CORONA or you can use CARTOSAT 1 you can use both this are having stereo vision capability and with this you can generate anaglyph.

So anaglyph will help you in viewing the terrain now what we have done here with the help of anaglyph we have been able to generate DEM and the image of one of the image which we usually classify as forward or after image has been draped on the DEM and that gives you the 3d prospective view of the terrain and as I was showing in one of the slide in previous lecture that you can rotate this or tilted depending on your requirement and try to look at the features which you which are interest to you and map those  for us it was this was the feature of interest because this line is demarcating the fault line. So even you can create in movie and fly through using different software’s.

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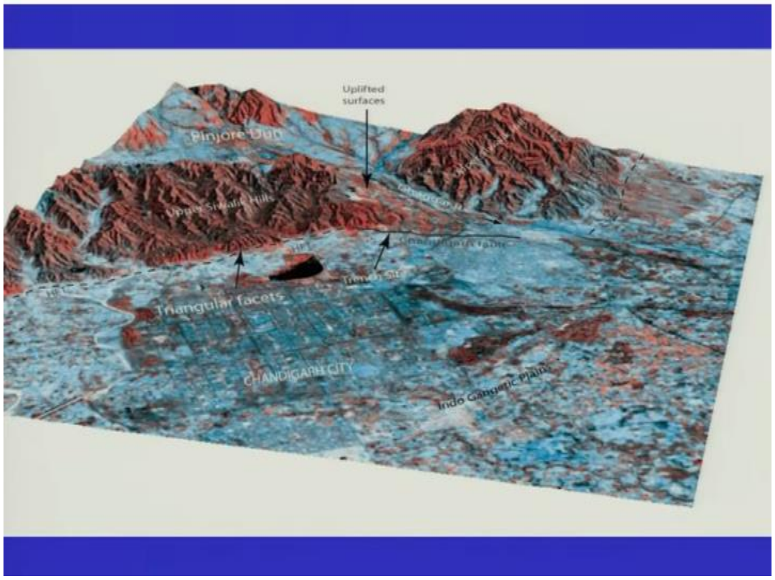


This I have already shown that this is the land set data fault scaler composite which has been taped on SRTM data.

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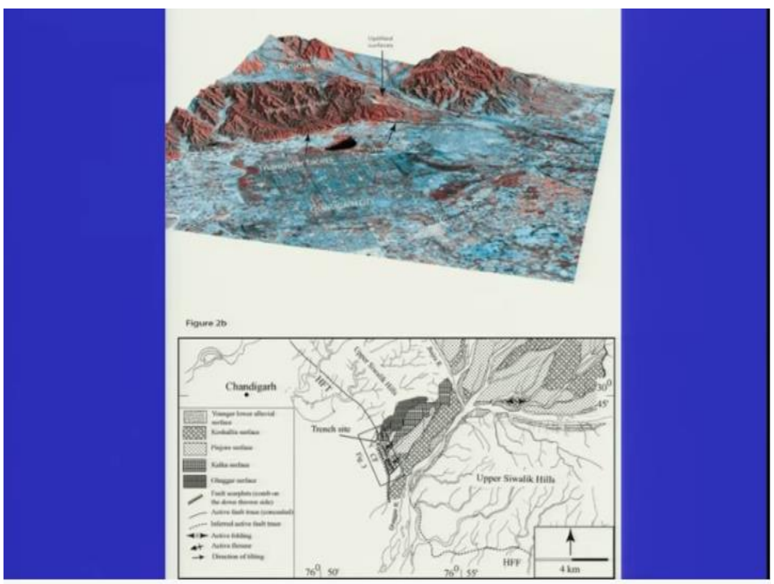


So using this information all the steps or different type of data you can use the basic idea is to generate a detail zoomorphic map along with the fault races which are cutting those landforms.

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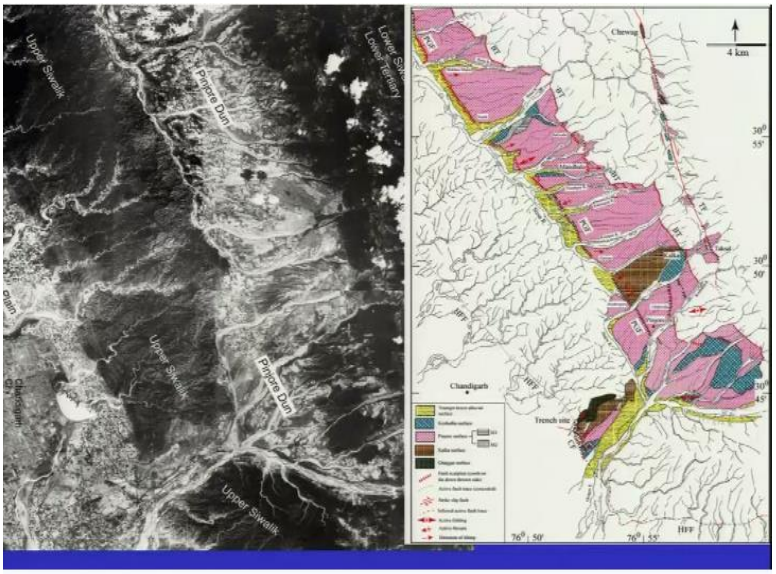


So this is an example of the area from Northwest Himalaya near Chandigarh so with if you compare this image with this map you can understand that what derails we have put. So even using just the plant view you will be able to demarcate this boundaries but unless and until you will not be able to see the landforms in 3d you will not be able to mark the fault traces which are been shown which are shown here.

So we have one fault trace here of Himalayan frontal thrust then we have been Pinjore garden fault and we have Barsar thrust we have Taksal fault which is traversing in this direction here. So there is just a comparison that what data you can extract using the satellite images or satellite photo interpretation and final you can still say unless and until you have not done the detail fieldwork you can say that this is your primary or preliminary interpretation or preliminary geomorphic map along with the fault traces.

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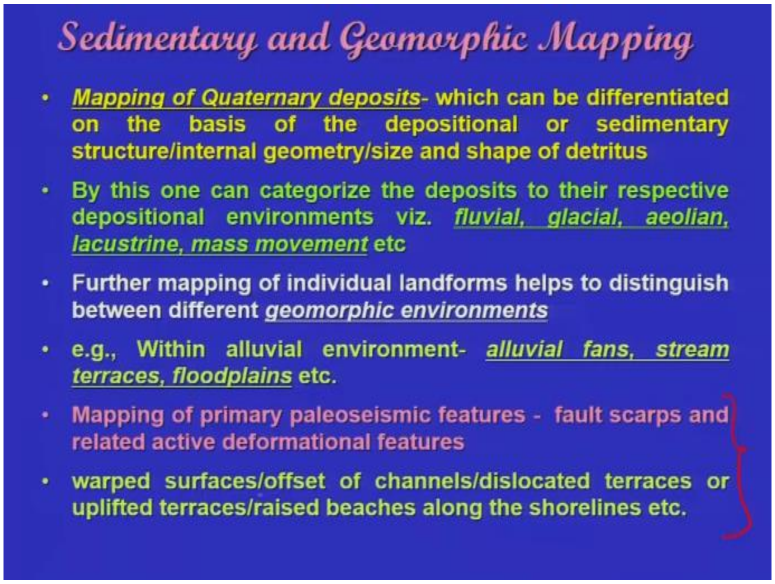


Now another important part is after you have done like your field survey where you have done the mapping of or identification of the fault scraps and the landforms tectonically deformed or tectonic Lee developed landforms another important aspect which comes as the sedimentary and geomorphic mapping okay. So geomorphic mapping you will do the basically using the different instruments.

Because we need to have the precise elevation difference in the off of those list deformed landforms and the signature of the deformation preserved in sedimentary succession. So mapping of quaternary deposits which can be differentiated on the basis of depositional or sedimentary structure internal geometry size and shape of the detritus we usually take into consideration when we are looking at the sections.

So the quaternary deposits we need to have understanding of sedimentology when we are talking about the basic sedimentary or primary sedimentary structures and all that because that will help in identifying whether the deposits which we see in the section that is in the trench or in the exposed section along the river valleys what environment they are indicative of okay whether they are channel fill deposits or they are over bank deposit and so on.

So buy this one can categorize the deposits to their respective depositional environments either they are the fluvial deposits, glacier, aeolian lacustrine, mass wasting because of the landslide.

So these are the few examples just been given but within the fluvial also you will be able to categorize if you define the units using the internal structure, internal sedimentary structures that what type of deposition must have prevailed okay.

So for example if you come across a gravel bed and then you have the sandy deposits on the top thick sandy deposit and then you have some soil which has been formed. So then you can easily make out that the energy condition changed and this gravel deposits probably were indicative of channel deposits and this indicates the finer ones probably are the indicative of the over bank deposit and then the channel shifted that allowed the area towards the development of the soil and all that.

So and if any tectonic disturbance probably if has altered the depositional environment that also will be able to pick up if you have detailed understanding of the sedimentary deposits. Further mapping of individual landform helps in distinguishing between different geometric environment so one we are differentiating we use the understanding of the internal structures and we classify the different environments that is depositional environment as well as the geomorphic environments.

For example the area experience deposition or it was because of the erosion or the we can say that whether the landforms which we have marked is related to the fluvial or it is like fluvial terraces or alluvial fan surfaces will be able to make out that is within the alluvium that is we can talk about the alluvial fans okay.

So in the setting for the formation of alluvial fan will be different than just for the terraces and the floodplains so you can also classify along with the including the sediment type and the landforms you can further classify the overall environment. So this will be important and mapping of primary Paleo seismic features like fault scarps and related act of deformation features will be another important one.

Then comes the warped surfaces though so do you have the mapping which you are going to carry out mainly the fault scarps and related active fault deformation features such as warped surfaces, offset channels, dislocated terraces or uplifted terraces, raised beaches along the shoreline. So these are some of the examples which are been listed here which will be targeted to identify the as in preliminary paleo seismic features.

So unless and until you are not going to excavate the trench and you are not going to justify within enough evidence that this such warp or offset channel are related to the paleo seismic event then it will be difficult. So it has to be it is important that in field you have to collect lot of information which justifies that these features which we have identify are related to the tectonic events and not just the erosional one.

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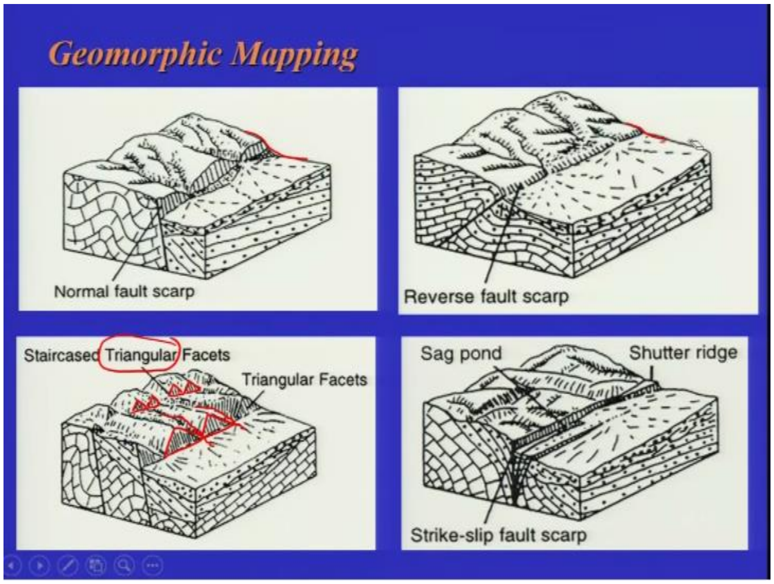


So geomorphic mapping usually we look at the fault scarps and the triangular facets I will come to the detail but the term itself indicates that along the zones you will feel you will find a typical shape or triangular shape feature along the foothills zones and these are real are again an indicator of ongoing tectonic activity. So these are the portions which are which exist between the true adjacent drainages which are flowing on the plain areas.

Then you have the reverse fault scarp so such sharp features will be seen in normal fault scrap in reverse fault scarp you will see the warping because what you see here is the of course that is a deformation here. But the deformed material is been displaced along a very sharp line but as I told that over the time the erosion you will have very similar feature okay. So after the event when this material is exposed, or this surface is exposed it will result into the surface like this okay.

And similarly if you look at this one you are having slight warp okay just an sloping surface here very much similar to what you see here okay. S there are a few very important geomorphic indicators which we usually take into consideration to classify the fault as an active fault. So this is not the normal faulting environment reverse faulting environment and in strike-slip what we see is most common in certain ranges or we see sag ponds and all that.

And how the sag ponds are formed I will talk in detail when we are talking exclusively on the strikes slip fault and further let me tell you that we will emphasize more of our studies like the lectures on reverse fault as well as only strike slip fault and few lectures on we will talk about the normal faulting also.

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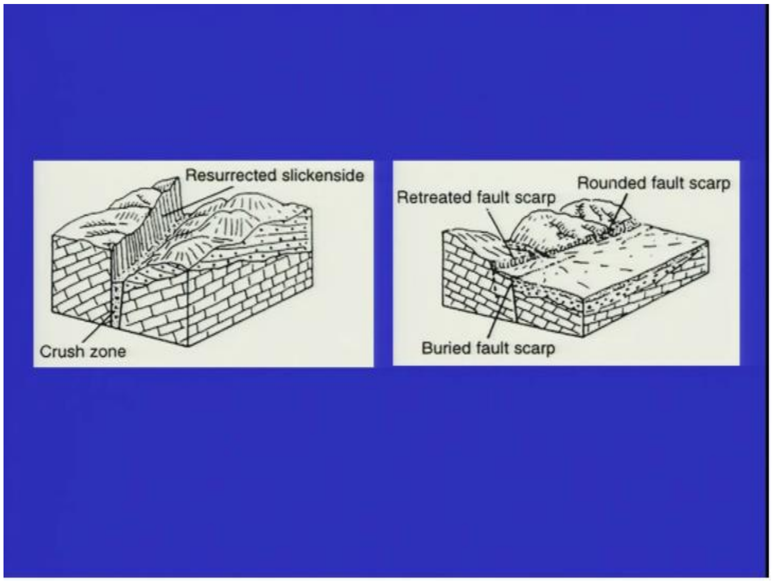


So with this we can also look at the slickenside surfaces and one of the slide I was showing from Japan or you can have the buried fault which are not resulting the displacement on the surface. But you can see some sort of grounded fault curves could be related to the buried faulting.

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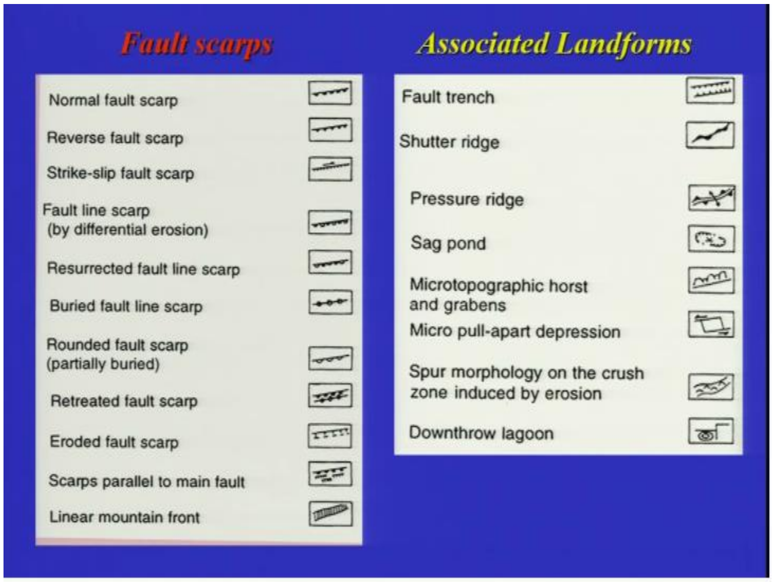


Now the fault curves can be denoted so you will find such symbols on map for normal faults, for reverse fault, for strike slip fault and so on which you can refer and associated landforms what you see is the fault trenches, shutter ridges, pressure ridges, sag pond and so on. So I stop here, and we will continue in the next lecture. Thank you so much.