Earthquake Geology: A Tool for Seismic Hazard Assessment
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Lecture – 07
Fundamentals Related to Paleoseismology (Part III)

So, welcome back, in previous lecture, we discussed mostly about the primary structures and to some extent I covered the portion of the secondary structures also.

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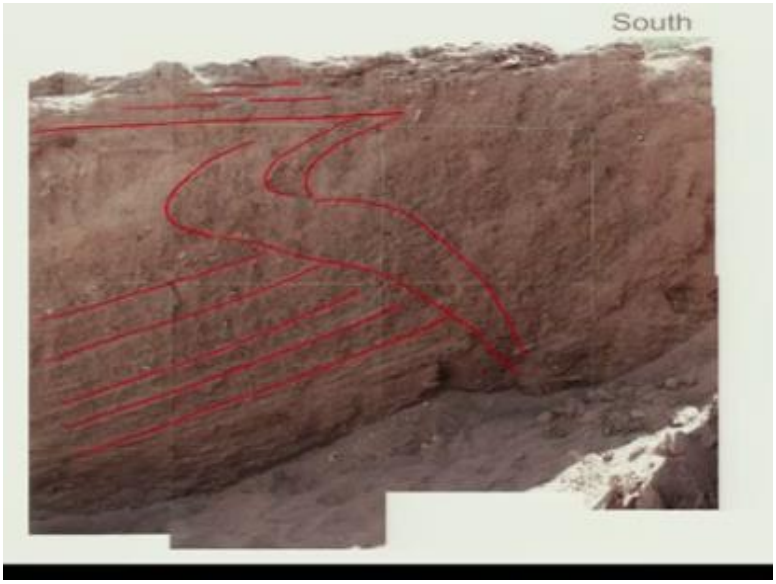

Now, either you call structures or features, which are preserved in the sediments; they are extremely important for us to differentiate between the non-tectonic and the tectonic, that was the main focus of this topic and we will see few more examples of secondary features which are formed of during the deformation. So, this slide which has been shown here, this was the last slide which we discussed.

And you can clearly make out that how the primary features are been deformed and giving rise to in secondary feature so for example, what you are having here the inclined stratification in this sediment succession is basically, the primary feature but now, they are inclined hence they becomes the secondary one and they are also faulted along the fault plane here.

So, you can see if you branching out faults here and the deformation within the sediments that is what we call folding. So, if I just quickly draw it, then what you see here is that you

have this one here which goes somewhere like this and then you have another one now just coming and probably going like this one here, okay so, you have the deformation clearly. Now in other and on the other side of the, what you see this is the material cut inclined stratification.

Now, what another important part which will definitely we are going to talk in the coming slides is that there is a contact here which goes something like this here, okay and again you are having the horizontal certified sediments. So, what this contact is indicating is you have an unconformity basically, an unconformity usually, the terminology we use for which the process which marks the period of a non-deposition.

And change over from the one environment to another one but here the contact; with this contact basically, is the marketing between the tectonic and non-tectonic, so usually that sediments will get deposited in a horizontal fashion, so whenever then there is when next event will be there the earthquake, then this sediments will get deformed. So, for us basically, the contacts; such contacts are important to identify the events.

And basically, what we talk about is the cross-cutting relationship between the sediment layers.

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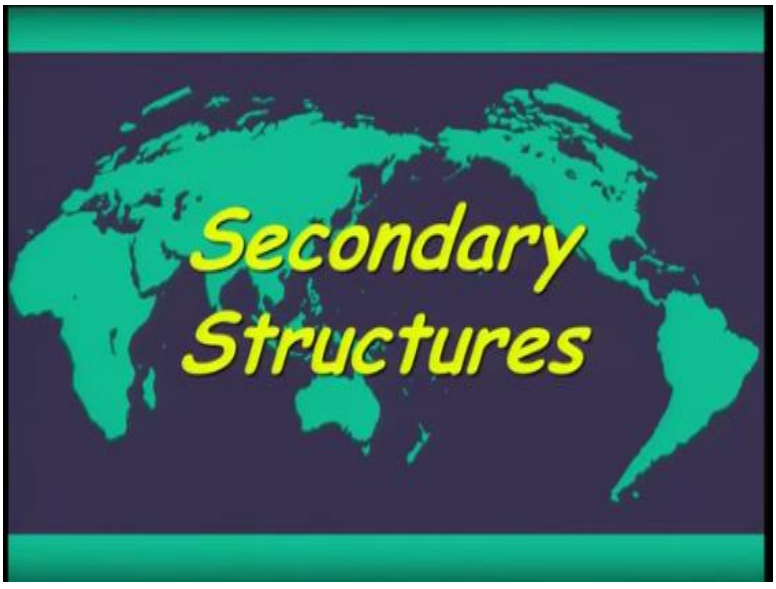

So, coming to the secondary structures; couple of slides we have already covered in the previous lecture also and the last one also was talked where we are talking about the secondary structures.

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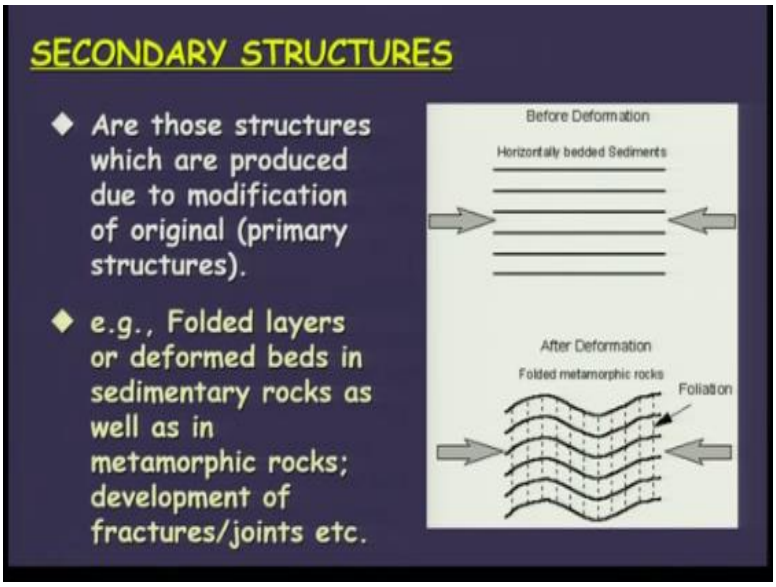

So, secondary structure has the before deformation and after deformation, the sedimentary usually we see that the sediment layers or that what will usually result in to the formation of horizontally stratified sediments and when they are subjected to deformation, here it has been shown in case of the metamorphic rocks, so the metamorphic rocks when or the sedimentary or igneous rocks when they are subjected to deformation, then they will develop some typical structures which are formed with respect to this stress pattern and those are termed as foliations.

So, the secondary features as we discussed in the previous one that the primary features are the features which are formed at the time of deposition but the secondary features are after the deposition which those are subjected to tectonic forces. So, if you take the definition in a broader sense, then we have that the sedimentary structures are those structures which are produced due to modification of original primary features or structures.

So, example we will see on surface as well as within this sediment succession or Rock succession or the folded layers or deformed beds in sedimentary rocks as well as in metamorphic rocks, development of fractures and joints. So, along with that we will also come across the development of fractures and joints and if we see the fractures with the displacement, then we termed those features or the structures as faults.

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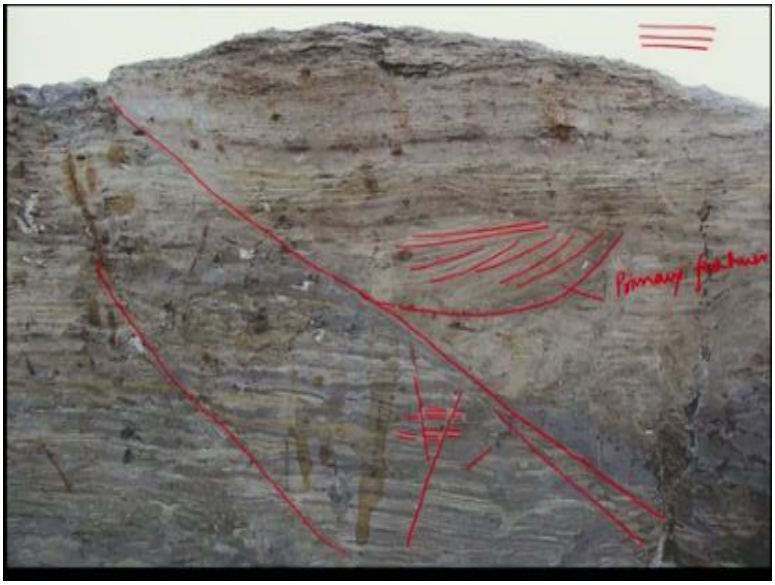

Now, when we study the sediments successions to identify the events and to differentiate between the primary and secondary features, then as I told in the previous slide that we take into consideration, the contacts, okay and here so, we have to be extremely careful while tracing the primary features and then where they are exactly getting abetted or disrupted and those contacts should be marked and try to understand whether those are primary features or secondary one.

Now, this slide, this succession which has been exposed is from great Rann of Kutch mostly, the tidal deposits, so that is one of the reason why you see the fine laminations here but they are not; they have not remained a with their previous like original primary state but they have been deformed, so I will slowly explain this that how and within this exposure, what we see is mainly primary as well as secondary features.

So, one has to be extremely careful now, suppose we start looking at the whole section here, then the prominent one, the contact; the sharp contact which comes to the eye is this one here, okay. So, this is a very sharp contact which goes here and initially, we can negate or we can say that could be; this could be in primary feature but later on or you can try to justify whether it is non-tectonic or a tectonic feature.

So, let us say that this contact could be a primary feature and then look at the other features which are present within this section. So, if we just put a line here or may be later on I will remove the line here and what we see is this goes somewhere here and then there is a line

here where there is an; this part and this part does not match because what we have understood until now that the sediments will be horizontally stratified.

But there is some break here which indicates that there is a displacement and if you carefully see this here also, along this line, then we having what we call the micro faulting, so this layer is sitting here, so there is an wave fine line which goes here like this, okay and then there is another one which goes here, so there is a displacement. So, if you compare this one here this lines, these are slightly down here but this is sitting here and then even this one.

So, there is a clear-cut faulting which has been seen here as well as in this portion also and there are many such features or the line of what we can say the secondary faulting which has occurred here. There is another one which sets here somewhere, so the other part which we will try to look at this feature and this goes somewhere would here and there but somewhere here okay, so this is a very typical of cross stratification we are able to see on this wall.

So, this part is your primary feature but what you see here at this part here, you have all crumpled material okay, so you can see the material has been folded here and rotated and not in the preferred orientation, they have been rotated here, so this portion we can say that this is in part of the secondary feature and could be related to the plastic deformation, okay.

So, this is one indication of those okay, so within this we are having some sedimentary feature even this you have primary feature here, which is an again a part of this 2, what I have drawn here the primary one are your channel; small tidal channels okay but if you carefully look at along this line, this is an clear cut indication of deformation okay, so you are having a displacement where this block has moved up and there is slight deformation in this one.

So, one can easily make out, if you carefully study the features which are expose of the sedimentary structures which are exposed on any exposed section and try to make out and differentiate between the primary and the secondary one.

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Now, coming to further, so a few of the slides we have already discussed in the previous lecture about the primary and the secondary features and more we will keep talking when we are getting into the details of the paleosiesmic studies but basic idea before heading into this topic is extremely important because we have to be extremely careful in differentiating between the primary and secondary.

Coming to the contact structures in most of the hard rock trains we will come across an intrusive rocks also will result into a very sharp contact, so this is basically the intrusion that is your igneous rocks.

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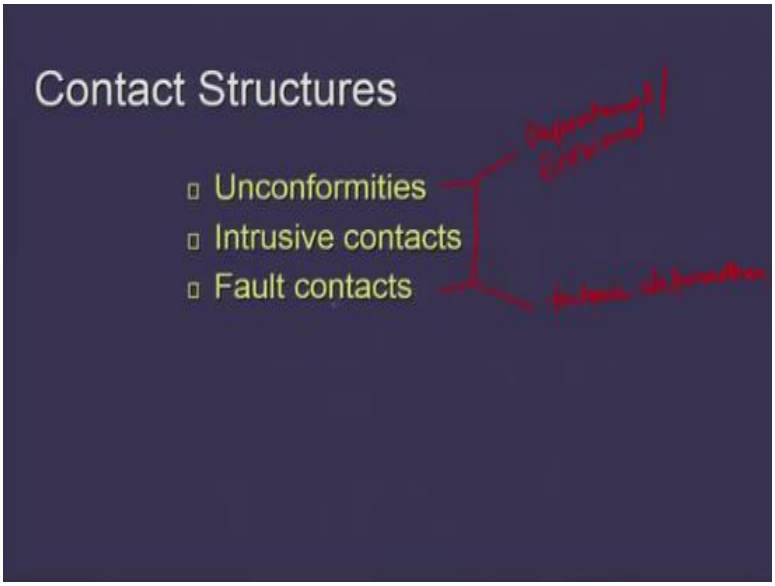

So, contact structures are also being termed as we can see unconformities, intrusive contacts and fault contacts, so this 2 that is unconformities and the fault contacts, we also say either

the unconformities are the depositional or erosional unconformity and then fault contact as we were talking about we are looking at the tectonic deformation and intrusive contacts may be seen or observed along the fault contacts also.

But mostly, we see that they are just intruded into the country rock and the intrusive, intrusions are to some extent are very widely, show wide extent so, we may confuse between the intrusive contact and the fault contact also so, let us see one by one and some part we have already covered and as I was talking in the previous one that we also look at the unconformities.

And that is within the sediment succession, if we have the primary one then we may classify that as depositional or the erosional unconformities but in case of the tectonic default context, we also say tectonic unconformity. So, this we will be able to see even in the, in forms of the landforms as well as in terms of the sediment succession and then we have shear contacts. So, these are the 4 major one again, this will form a part of the tectonic deformation.

So, we have one conformities, intrusive contact, fault contacts and shear contacts, so what we have started right from the beginning we are looking at the primary, secondary and the contact structures.

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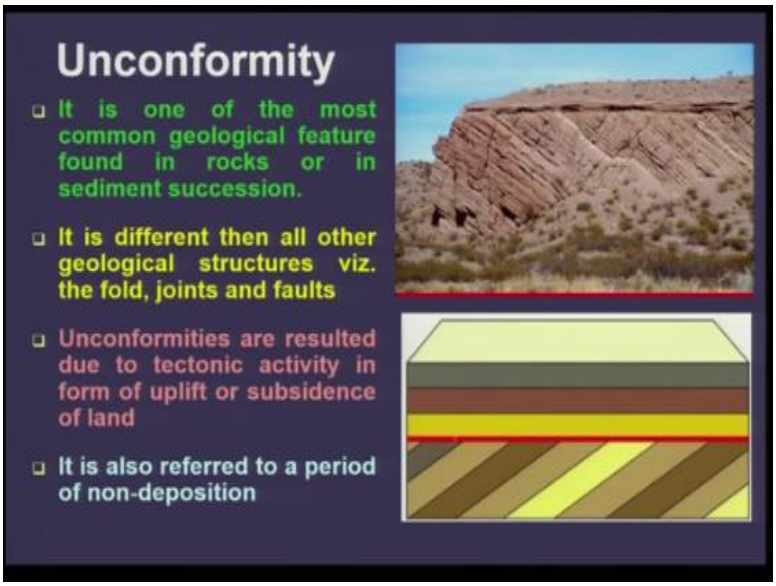

So, looking to the unconformity as I told that we can have depositional, erosional, unconformities and we have even tectonic unconformity. So, if you carefully see this exposure which has been shown in the right hand side of the screen and you see some very

beautiful inclined stratification and then on the top, you are having the horizontal stratification.

So, this also marks the change in the depositional environment and this are termed as an unconformity. So, unconformity if you define, it is one of the most common geological feature, so you will see primary, secondary and or maybe you can say primary or tectonic unconformities also, they are found in rocks or in sediment succession. It is different from all other geological structures namely, fold, joints and faults.

Unconformities are resulted due to tectonic activity in form of uplift or subsidence, so if there is an uplift or subsidence in any area, then this will result into the change in the environment and this part of what we are talking about the unconformities, we will be able to see more or we will try to show you when we are talking about the tsunamis now that and during the examples which we are trying to put forward for the mega thrust abduction zone earthquakes.

And the large earthquakes from the Andaman; Sumatra Andaman trench area, it also referred to be a period of non-deposition, so if you have like there is a deposition of this unit, this is not related to the tectonic activity but in inclined stratifications, if you see or cross stratification, then there is and it marks the end of this depositional cycle and then you start having the horizontal stratification.

So, changing the depositional environment also marks the unconformity or a period of non-deposition, so there is no similar deposition has been taking place, when these sediments were deposited. So, in a sketch if you see this is what we have, this we are also we termed as an angular unconformity, we are having an inclined stratified sediment succession and then we are having the horizontally stratified.

So, for both the energy conditions are different, so the environment; overall environment of the depositional environment changed over the time and that marks the period of non-deposition or change in the environment and indicated by very prominent contact and that what we term as an unconformity. So, even this cross-cutting relationship we take into consideration, when we are talking about whether it is depositional or non-depositional period or it is a tectonic one.

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Now, if you see the section which we; this we have be open in Kutch region, so this again marks a very prominent features where of course, this are inclines stratified but we did not consider this as an primary feature as I was showing in the previous slide this part okay, so you have inclined stratification and then you are having horizontal stratified material and here also, you can say that we see the inclined one and then we are having contact here prominent.

And then we have the horizontal stratification but we on the largest scale, when we looked at the section what we found was this units were deformed very prominently, among this one, so if I will just put the boundary here and they are coming somewhere like this over here and this goes somewhere like this. So, you have a very prominent deformation which has occurred along this line.

And this goes further if I put this one here clearly, then you see this one here, this goes like this and then here so, if you mark this one, it goes further so, this inclination is not related to the deposition, it definitely got deposited in an horizontal fashion and then there was an phase of or the deformation phase, so first the deposition in the horizontal fashion, then got inclined and folded because of the tectonic event.

And then finally, eroded along this line that is here, this is the erosional contact and you are having all horizontally stratified material, so this is the phase of so, this is a deposition hence this will become depositional contact whereas, this will become your tectonic contact. So, this tectonic contact is your fault of course, this we will consider as a primary features but since they are deformed, we consider that as an secondary one.

So, this unconformity again, you can also classify this as an angular unconformity, so one has to take care about all this features when they are looking at the trench sections or the exposed sections and try to understand whether they are tectonic or non-tectonic.

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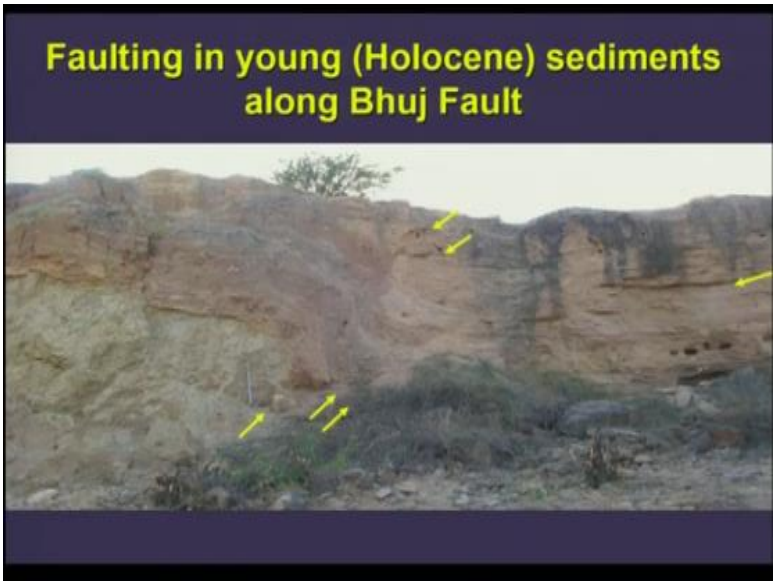

Again, another exposure here where you can try yourself also but I will just put and slowly we can trace out the contacts okay. So, if we start from here, then these units are getting like this, bending here and then abruptly turning down at this point and then on this side, the other sediments are becoming horizontal. So, you can see the horizontally stratified sequence that some point, you will be able to see a sharp contact, which are indicative of folding.

So, this is a bedrock here, then you have a sediment succession here so, if you put the arrows here, then these are the fault planes along which the deformation has occurred so, this again becomes tectonic contact and along with that, we also have the primary structures here.

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Intrusive contact are the contact formed by intrusion of igneous bodies into the country rock, so huge intrusions which may go for 100's of meters or kilometres, this is a view of Indus valley, the intrusion of granite sheet-like features into the basic Gabbroic rocks, okay city and the contact you can see over here. So, you may mark this contact as in fault contact but this is not in fault contact, this is in intrusive contact.

And another one; so, the dikes basically, the contact form due to intrusion of basaltic dikes in pre Cambrian sediments; sediment succession, so such contacts could be on a very small scale but dikes can be of a very large dimension also, so you may not be able to see in one go the whole section so, if you were just looking at this part on a larger scale and then you may mistake this as an fault contact.

So, one has to be careful about the different contacts which are available in nature and need to be carefully; careful while identifying those contacts in differentiating.

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And coming to the fault contacts we have seen couple of slides in the previous slides we have, we tried to show you some fault contacts from the young deposits; so basically, the fault contact is a contact which develops due to slippage okay, slippage of rock blocks or the sediments succession with respect to one another. So, on surface you will be able to see a very prominent displays landforms.

And in section what I have shown you in the previous slides okay, so this is in this section here you can see the fault contact, where the 2 different rocks are been displaced here or the rocks succession has been displaced here.

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Another one you can see the depositional feature over here or the sediments and then you have the displaced layers along this one, so these are the difference between the fault contact and the depositional contact.

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And the hard rock; if you see them again, the basic idea or the technique which one should apply here or to any expose succession is not we try to like fix our eye on one particular very prominent layer and try to see the let us extend and how it goes whether it is moving like it is extended horizontally or it is getting bended or getting abrupt terminated at along a particular plane or a contact, okay.

So, if you see this black one and the white one here, the rock layers and you see that they are coming here and then getting into this one, so this is an clear indication of a fold okay and this are getting (()) (25:48) along here and then you have the horizontal one and more prominently, you can see the white and grey layers over here, they are all faulted. This mark is in water mark because this is an pond where this mark has come.

Because of the water which was stagnated here but this goes further down here in this direction, so this is an clear-cut deformation of like what we see the folding.

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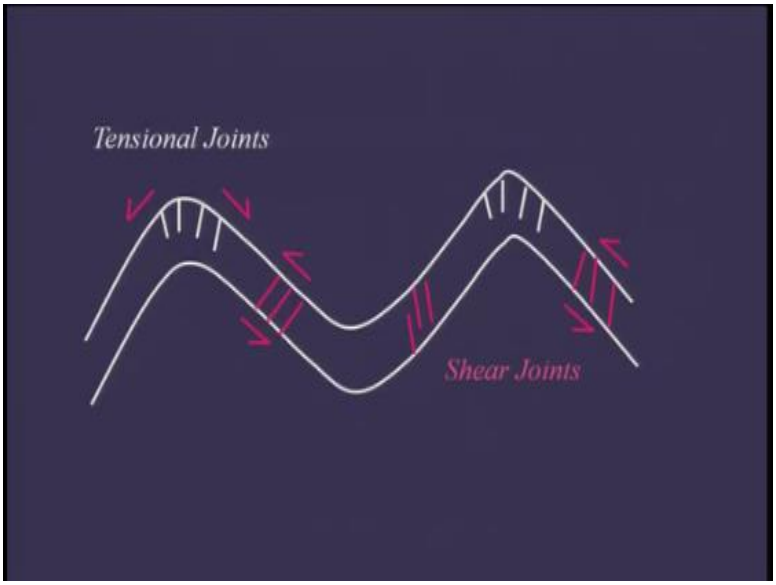

Then, the fractures which we can say that they are secondary features mostly, seen developed on the crust part or the crust okay and then the trough we have, so we will have; we will see mostly the joints okay and those joints are shear joints and the tensional joints, okay. So, we have shear joints along the limb and on the crust of the folds, we will see the tensional joints and if you see some displacement of course, you can classify there is a (()) (27:01) faults.

But those this faults basically or the displacement if you see along the shear joints then such features you can classify as an faults but they will be the secondary fault and they may not be this is (()) (27:19) okay because we are interested in looking at the faults or the features I manifested on the surface which will be responsible for triggering large magnitude earth quakes.

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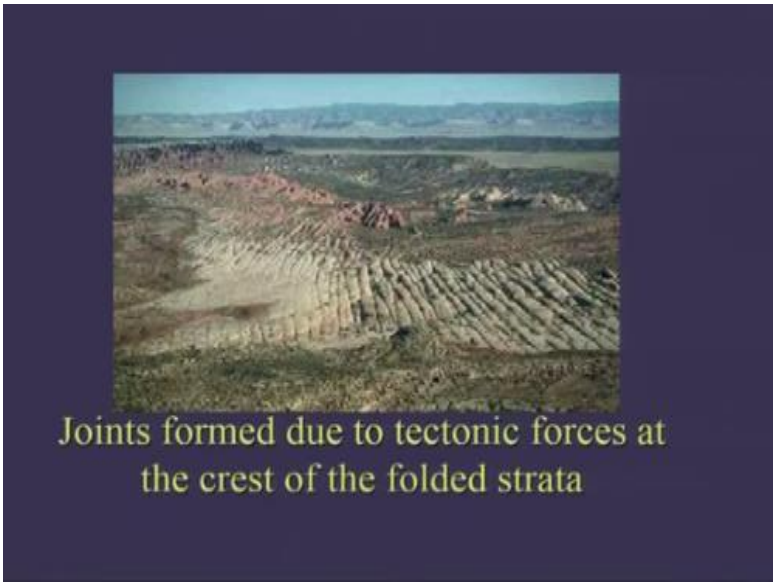

So, further like what we see in terms of the jointing on the surface because of the tectonic forces and this we have already covered, so I will just move ahead, okay.

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Close up of that so, what we see here is but of course this one is in primary faulting, okay so the main fault runs here but along with that the deformation what we see here is shown in the next slide, the close up on is the micro faulting, okay. So, you can see clearly these are also termed as faults but they are micro features, okay and you can see clearly here this deformation, the layers are displaced.

And you go further, there is some folding which has been shown here, so these are all we got what we call as an micro faulting, so they are not deep-seated, they are just there and they will be seen within the succession but major faults will be deep-seated.

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Another example and the hard rock so, as I was talking about the basic criteria to locate the discontinuity of the layers either it is sediment layer or the rock layers or the bits then we try to look at the physical properties basically, the colour and the composition of the material we try to see. So, if, so this is from Kutch region, they exposed succession of the Mesozoic rocks, what we see is these are the inclined towards this side.

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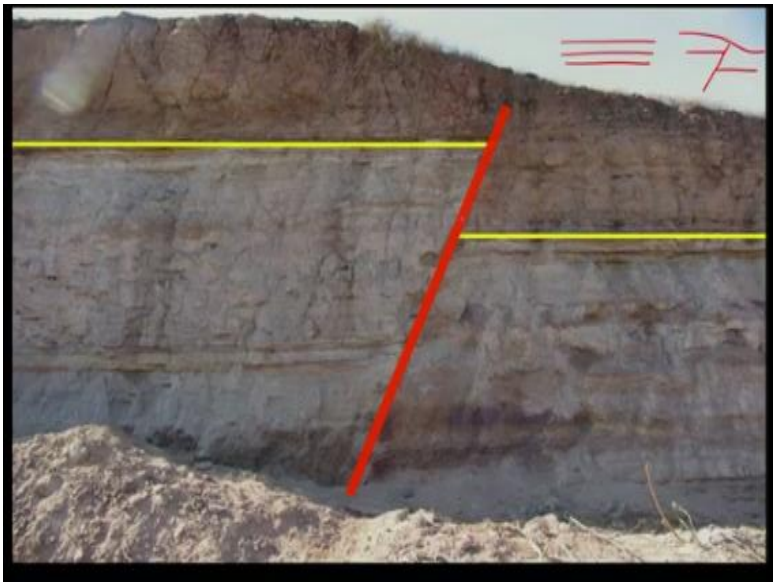

But they are getting abetted at this part over here, so close up of that if you see is the whitish layer rocks you are having which are sitting here on this side on the right hand side, on the left hand side there, they have been pushed up so, whole type of fault is this, we will try to discuss when we are talking about the different type of faults but for your; at present what we see here is I will just explain that.

So, this contact; the depositional contact between this 2 rock layer is sitting somewhere here, so these are been displaced along this one and one more thing which of course, we are going to talk later on but when they were deposited or existed earlier, they were horizontally but when they were deformed they are able; we are able to see the displacement here and at the same time, this was like the flat surface at the time of the pollution.

But when they are deformed what you see is a development of a topography, so this topography has evolved because of the displacement along this fault, okay. So, this has moved in this direction, okay.

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Another contact here; you can see the folded units along this contact, so this is in typical fold contact, so I will stop here and we will continue in the next lecture, thank you so much.