Earth Sciences for Civil Engineering

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Module 3

Lecture No 14

Seislmology and the internal structure of the Earth (Part-2)

Hello everybody. Welcome back. Yesterday we discussed about different type of seismic waves.

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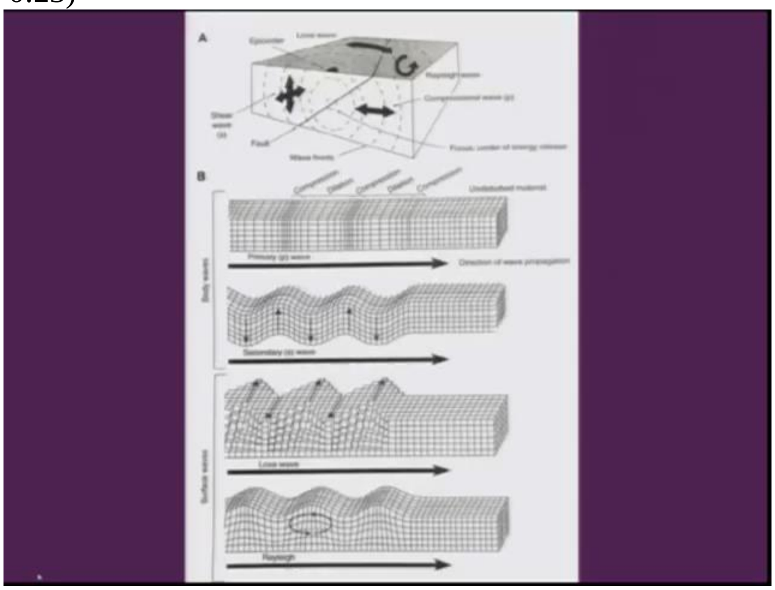

And mainly the body waves and the surface waves. And we also discussed about their motion and they typical characteristics that the P waves can pass through, they are the compression waves, they can pass through all medium . Whereas the S waves, they have the capability of shearing. So they are the transverse waves. They can only passed through solids.

Where is the love waves again, they are the surface waves and rayleigh wave is also surface wave having the motion that is related to love wave. We are having it moves land side-by-side whereas the relay wave as having elliptical. So in short we experience all types of motion at the time of an earthquake okay.

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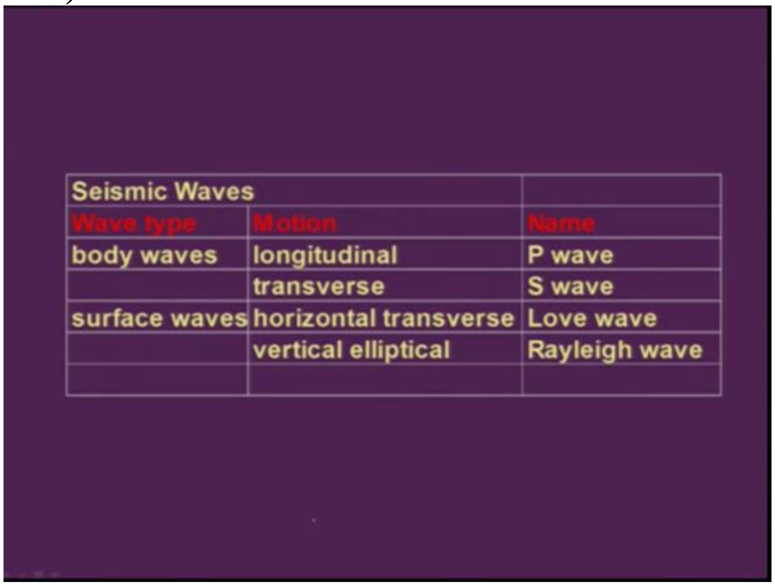

Seismic Waves		
Wave type	Motion	Name
body waves	longitudinal	P wave
	transverse	S wave
surface waves	horizontal transverse	Love wave
	vertical elliptical	Rayleigh wave

So we started talking about the earthquake. We will move faster to that. And the this part we already discussed yesterday.

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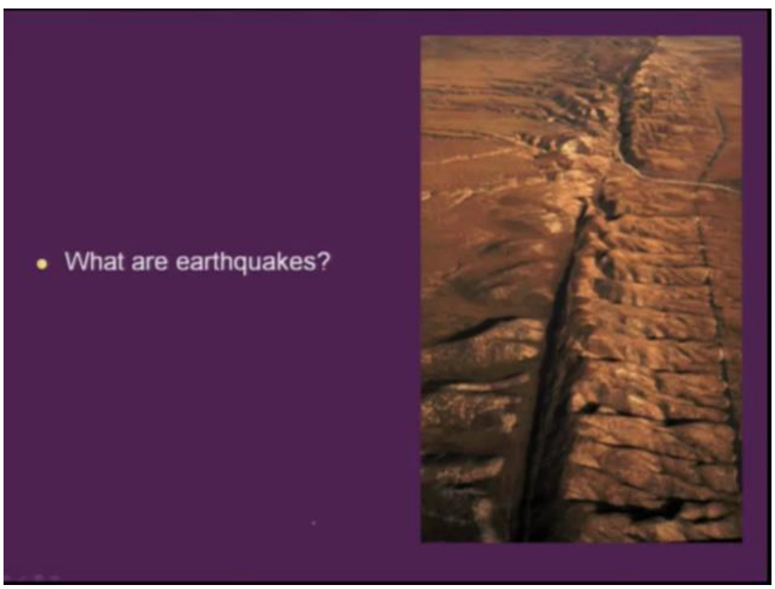

So and we in short we talked about little bit about the earthquake also. So earthquake is a process where it is a phenomenon of the sudden energy which has been stored within the crust is been released along weak zones.

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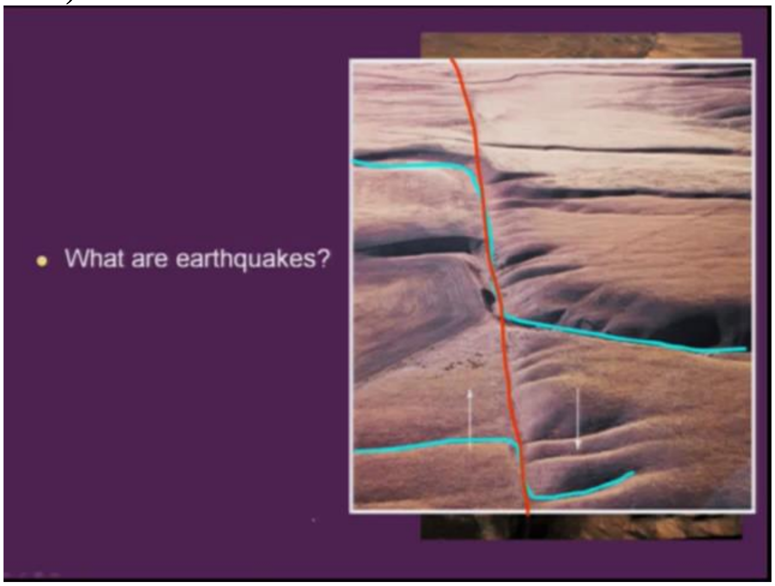

And the surface manifestation of such displacement or dislocation is very well seen in form of the active faults. We will talk later about this, what are the different types of active faults and all that, how we can identify those and why it is so important for the society. Because this helps in reducing the seismic hazard in any seismically active region.

So identification of fault lines and knowing that where earthquake will occur and when it will occur, it is extremely important in developing countries okay. And in particularly in India we have so many seismic sources available. Back in and the month, we have in Himalayas and in Kutch region. So we need to have this detail that with us.

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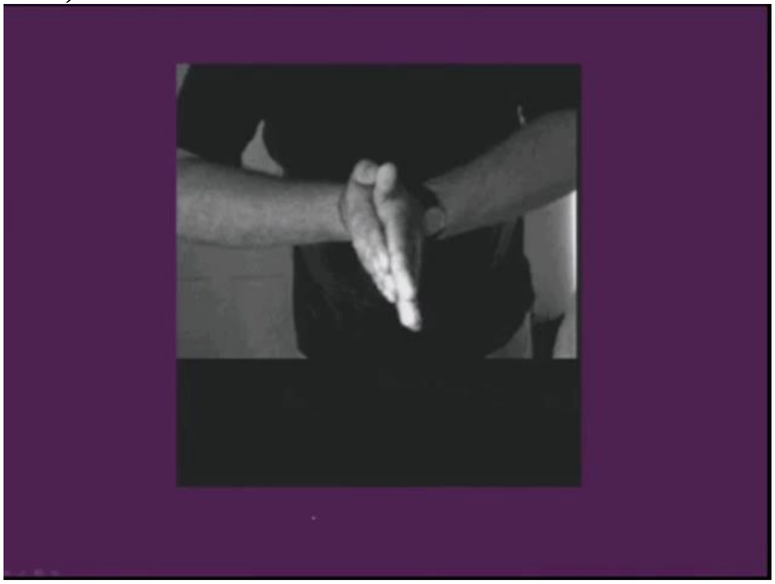

So yesterday we were talking about this that if you push your two palms against each other and try to slip so there will be some sort of a pressure that will be developed on your palms and then when you slip this, you will find some jerks which are coming on your hands. So that jerk is your vibration which is very typical to the when the energy is sudden energy stored is released okay.

So energy is getting stored here and then when there is a slip, you will find that the some vibrations are been passed on your hand side okay. So that is one one way you can understand that earthquake occurs. So for example, 2 plates or the blocks along a weak zone here are colliding with each other or they are there is an energy which is getting stored here because you are applying force from either side and then suddenly is of than due to this slippage along this plane, you will find that there is an vibrations which are been triggered. So that that process is an earthquake.

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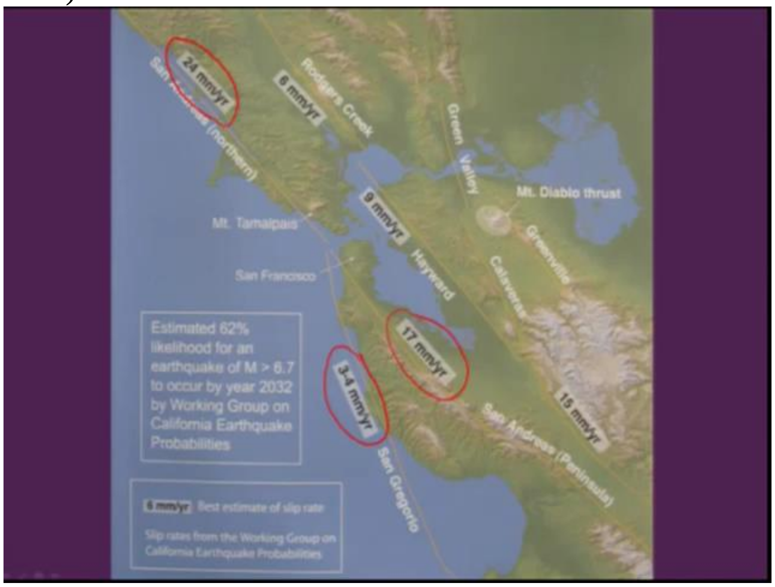

And now as I told that there is a, it is extremely important to identify the fault lines, this is an map **of** from US. Very famous fault system has been shown here. This is what we call as the San Andreas fault system. So we have multiple fault lines on the surface which have been identified by US geological survey and other research groups in US okay.

Now what the numbers if you look at here okay, what it says is very, these are the numbers which says about the talk about the slip per year along this particular fault segment okay. So you have different slip like 3 to 4 mm and 17 mm, 9 mm, 6 mm, 24 mm. Now we need to have for India we are trying to come up with such maps in Himalaya as well as in Kutch region and try to know the slip rates.

That is what we call the slip rate along the particular fault okay. So have the slip rate, the chances of having earthquakes, more earthquakes, more frequent earthquakes increases here okay. So the interval between 2 or earthquakes will be shorter here whereas the interval between the 2 earthquakes in this region where the slip rate is low will be less okay. So the interval will be sorry larger here. And here you will have the interval will be much shorter.

So we need to have such information to reduce the seismic hazard in the region like Himalayas and all and in Kutch.

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Now this is another example which has been given that how these different fault lines slip and why you are having different slip along the different fault lines okay. So for example, this has been given in like what they did is that if you can take the plane card set and then and try to put the pressure on either side, so what happens that the plane cards, each plane card you consider that they are the contact is a fault line okay.

So they will slip at different rate okay. They will not slip at the same rate. So that that is what is happening in nature also. So you are having, the example is from here where where the Pacific plate sliding or subducting below the North American plate and then the slip along the different fault lines is different, it is not the same. So that is best explained if you can do this experiment on your own and try to understand that how the each card or the contact between the each card slips okay.

That is your fault line. Here the movement is right lateral where the right side is coming towards us and the left is moving away from us okay. So **so** this has been explaining how how these slips okay. So it will not slip everyday but it will accommodate the strain along those weak zones okay.

So strain is getting accommodated or accumulated along these weak zones and the time will come, after it crosses the threshold limit, it will break or it will slip. And that will result into the earthquake.

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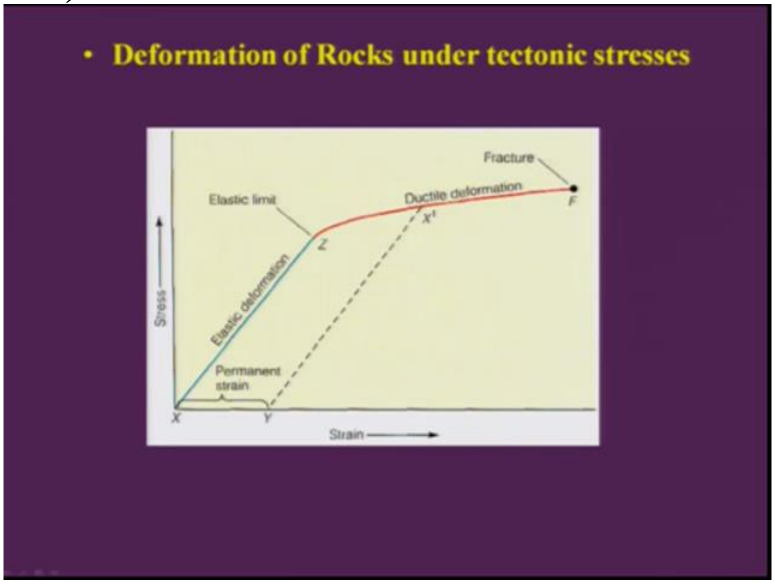

So not deformation of rocks under tectonic stresses. So it is a simple stressed-strain diagram which explains that that if you keep on increasing the stress okay, eventually at one point of time, it will break okay. So initially the material, all material within the earth is an elastic has an elastic property okay.

And then initially they deformed up to an elastic limit and then there will be a ductile deformation which will go on and finally it will break okay or the fracture. Now this fracturing or the point where it breaks is your earthquake. Now this is an very well understood.

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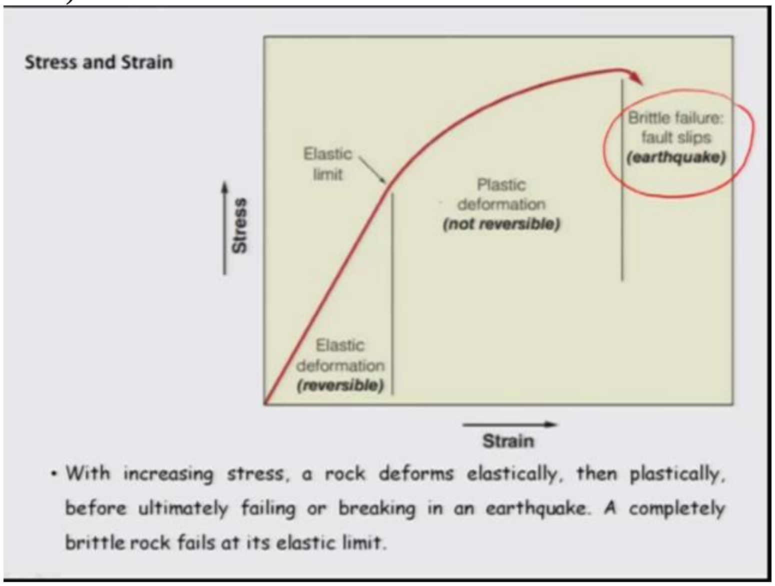

So you keep on increasing the stress. A rock deforms elastically. Then plastically before ultimate failing or breaking in an earthquake okay. So this point or the breaking is your earthquake okay. So a complete brittle rock fails **as** at its elastic limit. So each material has a different elastic limit. But what ensure we want to understand here is that all material will eventually break at one point of time okay.

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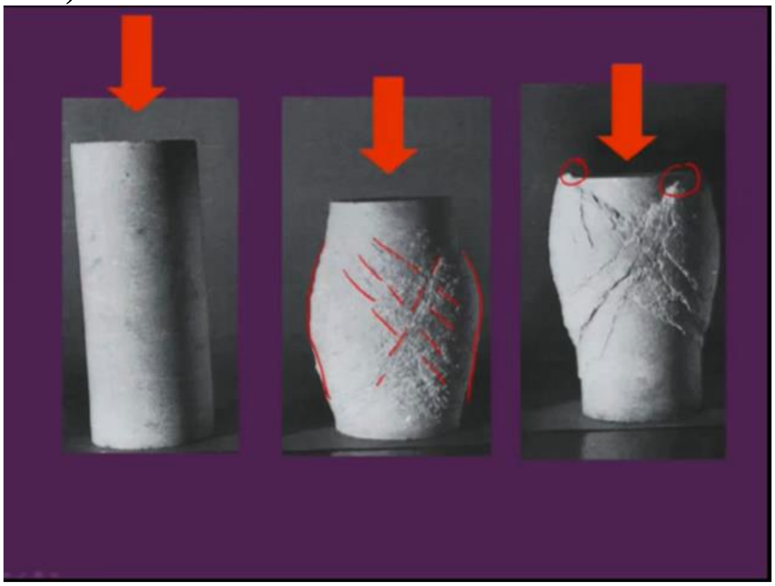

So for example, if you take a rock block then you are applying pressure here. So it will initially it will deform okay. And then, some very blurred lines are coming up, these are the weak zones actually. So this is what happens within the earth also okay, earth's crust. So these are the weak zones which are coming up and finally if you keep on applying whatever, it will break. So there is a displacement, if you can see here, this is displaced okay.

So this is seen on the surface or it is preserved on the surface whenever there is an displacement which occurs along the and this is what we call either the fracture or we can say as conjugate joins okay. And in a broader sense, we can also talk and say that this is a kind of a fault which has occurred okay.

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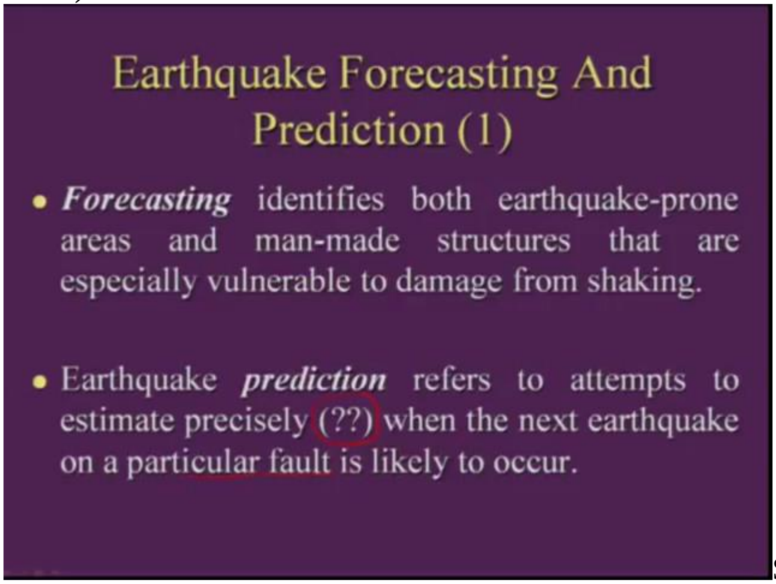

So earthquake forecasting and prediction particularly. The forecasting identifies both earthquake prone areas and man-made structures that are especially vulnerable to the damage from shaking okay because what happens at the time of earthquake is as we have discussed about that mostly you will observe different types of waves which are generated and those waves will result into strong seismic shaking.

And we need to understand that what will be the magnitude of the earthquake, how far it will be triggered, that is the source, how far is the source? Where we are living? So **so** the man-made structures which are vulnerable to such shakings. So whether the earthquake shaking will be strong in our area or not, that we have to understand okay.

Then earthquake prediction refers to the attempt to estimate precisely okay with the next earthquake on a particular fault, so these are the weak those which we are calling faults, is likely to occur. Now I have a question here because I keep, this is not we cannot do very precisely prediction of an earthquake okay. It is difficult.

But we can have a range where weekends say that okay fine the earthquake may occur within 25 years or 50 years or 100 years. But it is difficult to say that precisely. But of course we can predict that when the next large earthquake is expected on a particular fault okay. So that at least we can talk about.

So this is an attempt we can do and there is a field or the branch of Earth sciences which deals with such type of studies are termed as it is known as paleoseismology. So if time permits, I will talk I will give one lecture on paleoseismology and the type of work we are doing in Himalaya and how we have identified the signatures of the old earthquakes or the ancient earthquakes which are preserved on the surface in Himalaya region and in Kutch region.

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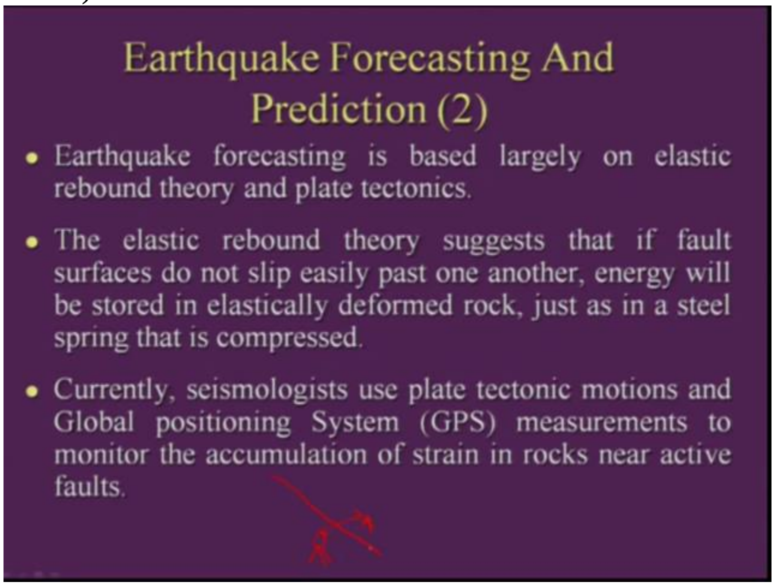

So further, the earthquake is based largely on elastic rebound theory and plate tectonics okay. So the elastic rebound theory here suggest that that if the fault surface do not slip easily pass one another, energy will be stored in elastically deformed rocks okay. So energy will get as we were talking about that these strain will get developed or will get preserved within the rocks. So if it it keeps on slipping or if it slips continuously then no energy will be stored.

But it if it is not it does not slip okay, the energy will will be stored in an elastically deformed rocks okay. Just as in a steel spring, so try to compress and then finally when it is been released, it will result into the vibrations. So currently, seismologists use plate tectonics motions okay. So as I was talking initially that we have now the GPS, global positioning systems, where we can measure the movement of the plates at a millimetre accuracy okay.

So this also again we are doing in India. With the help of Ministry of Earth science, we are putting a lot many GPS stations in Himalaya to know and to measure the crustal deformation which is going on in that area okay. So the measurements to monitor the accumulation of strain in rocks near the active faults.

So we identify for example on surface the fault lines and then we try to put the GPS station on either side of this and try to understand that what is the deformation which is going on between these 2 points okay. So that what we are doing in Himalaya and this is the…

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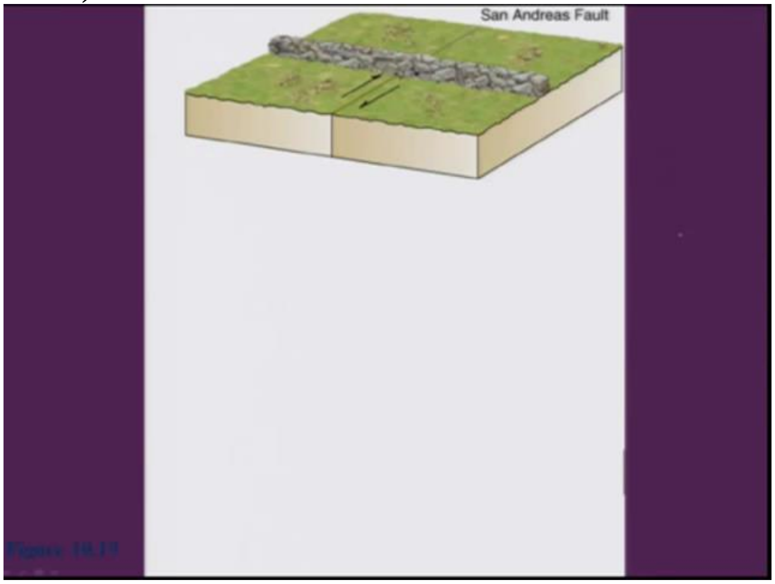

So anyways like this is one one very important part. Now if you look at the elastic rebound theory what we see here okay. So we see that the 1st figure which shows the original that we are having the fencing and then we are having a fault line over here which crosses this one, so because of the ongoing tectonic movement, the deformation starts of course it is elastically deformed here okay. It is not displaced but it is elastically deformed here.

So if you are having GPS stations on the either side, one can easily make out that how much displacement has occurred here okay. So initial points we are having here and then we are having here but you will see that that there are some displacements. So GPS will keep on taking 24 x 7 the coordinates of that particular point. And finally the land ruptures and releases the energy okay.

So this is the roster process and the release of energy is your earthquake here okay. So when the rock rebounds to the original and deformed shape okay. So this this was an elastically deformed here along with the displacement but then finally it goes back okay. So this portion is finally going back to its original okay. And again the process is repeated. Again along this fault line or the week zone the strain will start developing okay.

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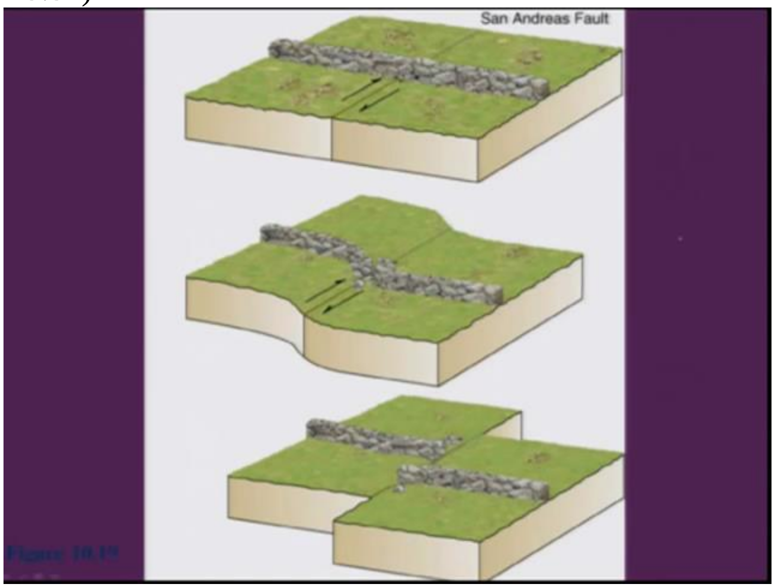

So the same for example the San Andreas Fault system is again shown here. So initially it deforms elastically and then finally it is released here.

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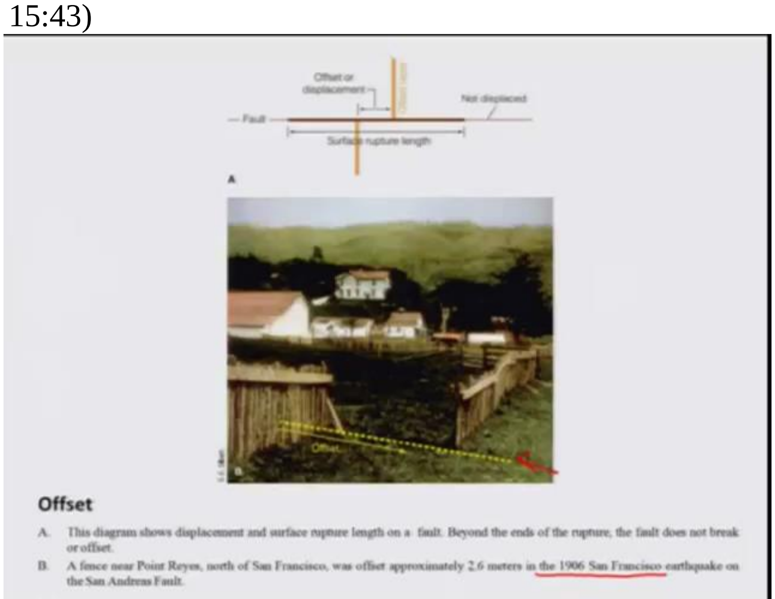

So this again a very famous photograph of the displacement of the fence okay where the fence got offseted along the fault lines. So this is the fault fault line over here and this happened in during an earthquake of 1906 San Francisco where the displacement was measured around 2.6 m okay.

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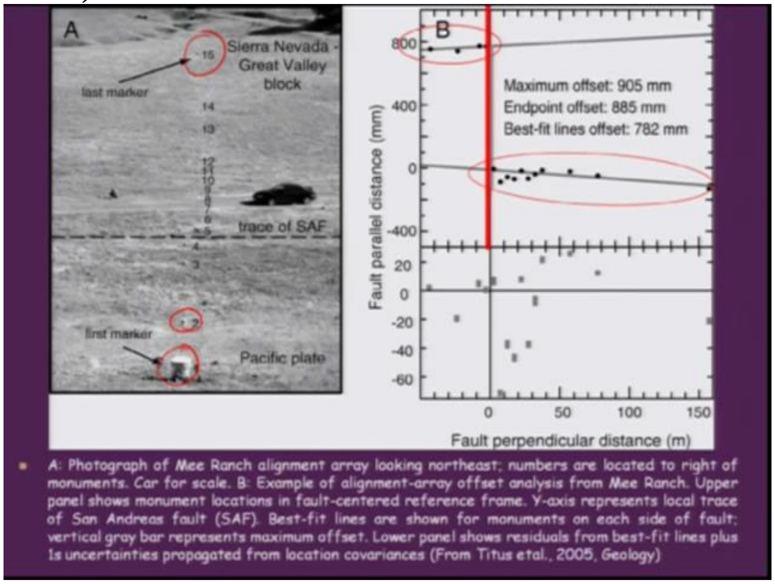

Again this is an example of San Andreas Fault system where what they did was across the fault line here okay, they put several GPS stations. So you can see these GPS stations here and then so what they wanted to measure is that they wanted to see how this displacement is we can measure okay and how much will be the displacement close to the fault and how much will be the displacement away from the fault.

So they have measured this and this photograph is the is showing the alignment of a rare looking north-west number of so this basically it shows the locations of the GPS and you can understand the scale based on the scale that what is the distance here okay. So what they did? This is the fault and then we have the different points here. And then maximum offset which they we found okay was around 900 mm where the end point offset they found was around 885 mm.

The best fit line suggests that the average displacement was around 782 mm. So this, one can measure if you are having a very precise location of the fault and then you put more GPS stations. So you can have the close array of GPS station which can measure the amount of displacement or total amount of movement which is taking place and the amount of strain which is developed or or stored along this fault plane and you can you can have the prediction that when will be the next earthquake here okay.

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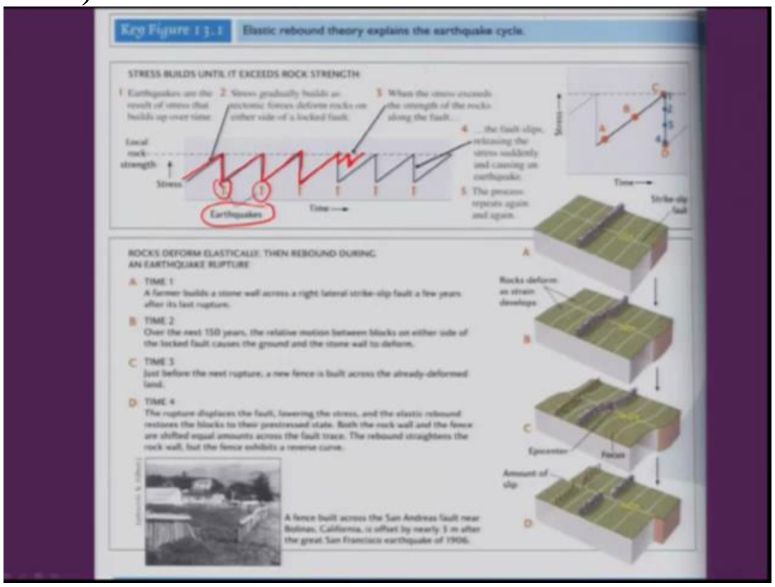

Now this is a very important part which talks about the stress building blocks and released periodically okay. Now this is a very simple and very straightforward diagram which talks about the stress here on the y-axis and the time on the x-axis okay. And it says that over the time that is 1st if you take the earthquakes are the result of stress that build up over the time okay. And this stress gradually builds as tectonic forces.

So this is the this is the period or the time where the stress is building up okay. And the time will come, it will break. So this sudden braking or release of the energy is your earthquakes okay. So this is the threshold limit of this region which will after there will be an sudden slip of the rock locks okay. Now the point is that, the question remains whether this is so periodic as we have we are looking here that all the earthquakes are systematic earthquakes or there are some some changes because this this most of the time what now we have found is that this is not very systematic okay.

Otherwise you can easily predicted the earthquake when will be the next one okay in terms of the time you have okay. So this is the time of quiescence where no activity will be seen along this one and the strain will keep on developing and finally it will drop out. That is the event okay.

So these are the events of which we see are the earthquakes here. But now most of the places what we have found is that this is not exactly the same but it will some places it will release, the earthquakes are been, smaller magnitude earthquakes have been seen which have been triggered between the 2 major one okay. So this is one example which has been given okay. Now if suppose there is an the slip which is or the which is continuously seen what we call creeping okay, then you will not have the major earthquake along that fault okay.

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So one of the example of the creek which has been observed along the Hayward fault which is an part of the San Andreas fault system, what you see here is a in the people live on fault and they have houses on fault.

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So this is a fault line which crosses from here. So people are staying on fault and they are having houses on fault but they understand and they know that this fault is creeping and they also know that when is the expected next earthquake in this region. But now after the precise mapping of the Hayward fault, no other construction is allowed on this fault line.

But people understand because their utilities like pipeline, water pipeline or drainage pipeline or gas pipeline, they are getting the formed if they are crossing this fault line and periodically they will have to get it repaired and they keep monitoring that whenever it is ruptured okay. So they need to fix up those things because their pipelines or their houses are sitting right on the fault okay.

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So this creeps. Now you can see here, the fault passes through this part over here okay and you can see the offset of the pedestrian boundary here. So this is an offset here, the fault passes. So the movement is somewhat like this okay.

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Again another one. Let me remove this one. So here, the fault is running across this part here. It goes along this one over here. And these are all the cracks which are very much common which which which are formed when there is a right lateral movement okay. So movement is like this and if you if you see the close up of this one, you will realise that how that it creeps okay every time.

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So this is an again a creep which is very well observed. So every time what they do is this is over several years this slip has occurred okay. So you can see the offset here of this one. So this, it was here and this is here. So this is the amount offset we are having. So this is the result of a creep. So every time they will like repair this because they know that this cannot be stopped okay.

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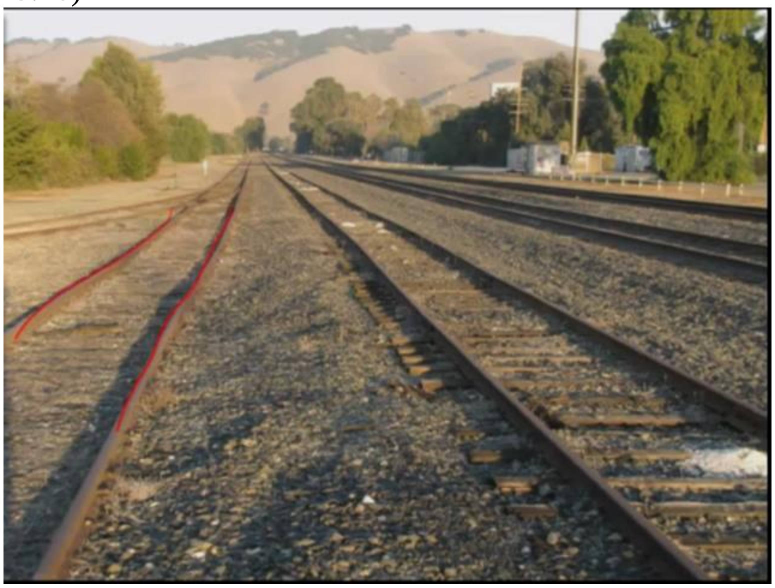

So this is an example of creep again on the railway track okay. So this is an example you can see on the railway track. And this offset is over here. So if you take this, it comes here and then it goes like this okay. Now this, they have abandoned this railway tracks. The fault runs from here. So they have abandoned and these are the 2 new railway tracks which were been constructed.

So over the time, they keep on replacing this because to avoid the accidents in the area okay. So they keep on since they are having the understanding of this, so it is they try to minimise the risk in this area okay. So that is what I was talking. It is extremely important to know where the fault passes through and what is the type of motion or the pattern of deformation along that particular fault.

Either it is laterally deforming or it is moving up and down. So you need to know that part okay. And how frequently it moves, that is also important. So this is an best example of the creeping which is taking place along the San Andreas fault system. That is one of the fault of San Andreas Fault system known as Hayward fault.

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This is another close up of this. You can easily look at the offset here okay cause there is an deformation which is going on again here. So they keep on replacing these and these are the new ones okay.

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So this is an offset which was been measured in 2004 here and this is an offset in 2006, Hayward fault.

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Again as I told that the utilities are getting deformed. So this is an example of the water duct which is displaced along the Hayward fault okay because of the creeping.

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So they know that a giant crack in the earth which passes through the city. So this is an example of Seattle where they understand that there is an the fault which passes through their city okay. So tis is very important that we need to know that from where which place the fault passes.

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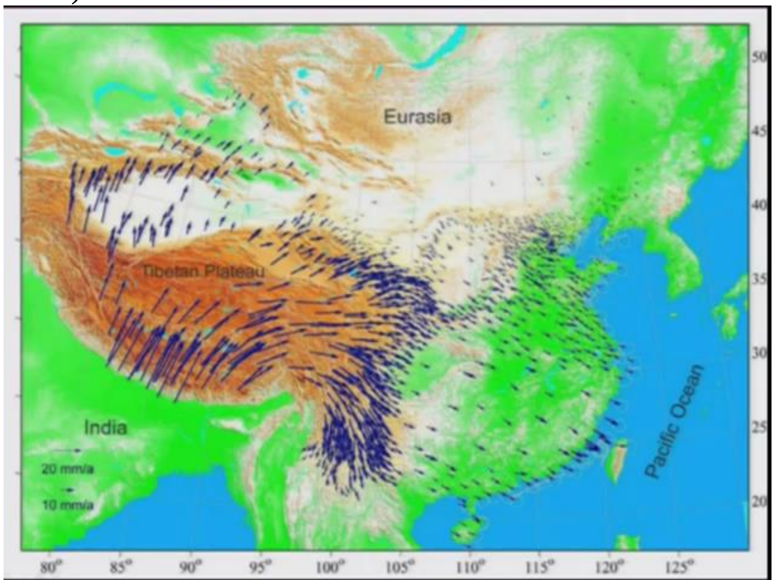

Now coming to the Indian subcontinent part, we have some information which is available which talks about the deformation and the motion of the Indian plate which goes on. So so maybe I can now we can continue this in the next lecture. I will stop here. Thank you very much.