Engineering Geology
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Lecture - 33
Geologic Hazards – Seismicity and Volcanism

Hello everyone and welcome back. Today, we are going to talk about geologic hazards connected with seismicity and volcanism.

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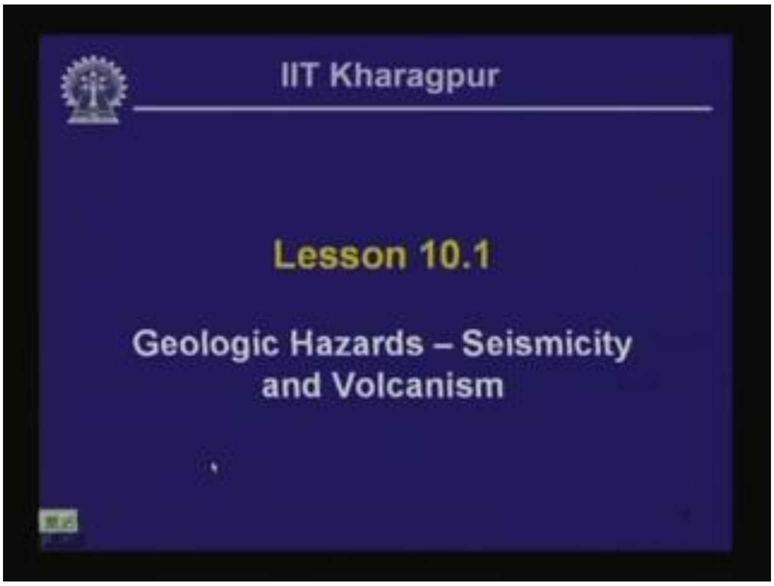

We have been discussing about earthquakes and earthquake hazards for the last little bit. We are just going to complete or formalize the notions that we have already developed in those lessons in this one, and then move on with the discussion on geologic hazards related to volcanism, okay.

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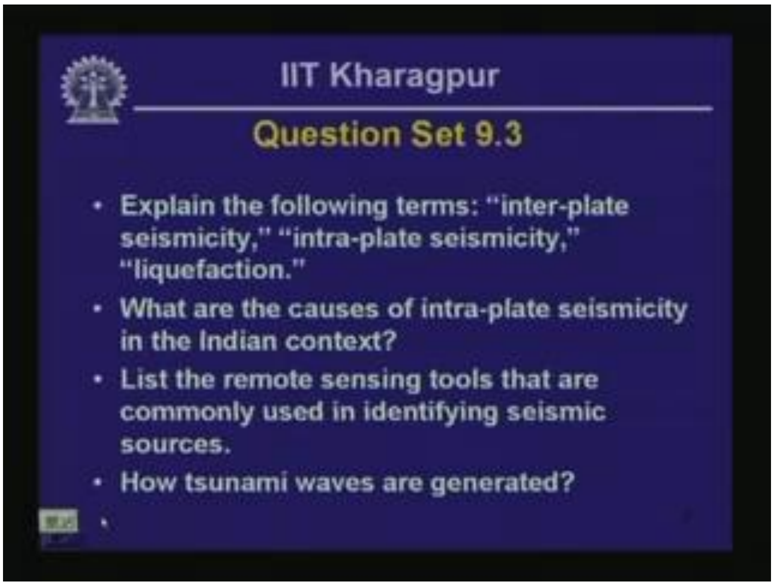

Before we do that, though, we are going to look back at the question set of the previous lesson, and here are the questions. The first question that I asked was explain the following terms intra-plate seismicity or inter-plate seismicity rather intra-plate seismicity and liquefaction, okay. Inter-plate seismicity are the earthquakes basically that are triggered by the dislocation of rock mass at the plate boundaries. Similarly, intra-plate seismicity is the earthquakes that are triggered by dislocation of rock masses near the middle or away rather from the plate boundaries.

And then the third one was that I asked was liquefaction. Liquefaction is what is meant by that term is that when earthquakes occur in case of loose sands and soft fine grain sediments. The pore water pressure tends to go up as the shaking progresses and it may so happen that the rising pore water pressure may actually become equal to the original in-situ total stress. So, then what happens if you recall from the discussion that we had some time back, the effective stress becomes zero.

And in that situation frictional soils which derive most of their shear strength or coarse grained sediments which derive most of their shear strength from inter-particle friction or interlocking, those types of soils loose a substantial proportion of their shear strength. And when shear strength is lost, then the soil starts behaving like a very thick viscous fluid. Actually that type of phenomenon is referred to as liquefaction.

Now that is not to say that liquefaction is triggered only because of earthquake in many situations, because liquefaction can also be triggered statically if the pore water pressure goes up because of rapid static loading or if there is a gradient in the groundwater and the groundwater is moving in the upward direction, then that also can lead to liquefaction. So, liquefaction can be triggered by an earthquake as well as statically.

Second question that I asked was what are the causes of intra-plate seismicity in the Indian context? This is actually in the forefront of research really at the present time; people are coming up with a lot of different lot of different types of explanations for intra-plate seismicity in different parts of the globe. And in the Indian context, what has been suggested is that perhaps the seismicity is being triggered along pre-existing plains of weaknesses such as rifts because of the bend because of the intra-plate stresses that is developing near or away from boundaries of the Indian plate. So, that has been suggested as the cause of intra-plate seismicity in many places within the Indian plate.

Okay, the third question that I asked was listing of remote sensing tools that are commonly used in identifying seismic sources. The tools that are commonly used are LIDAR light detection and ranging. We talked about this particular remote sensing procedure sometime back in this course in a very briefly really not at great length. And there is another tool that is used also in this context is IFSAR that is interferometric synthetic aperture radar.

These two tools have been used in recent years to detect seismic sources. Interferometric synthetic aperture radar, some people actually call that particular tool by a different acronym than that we have been using in this course. We have been using the acronym IFSAR I f s a r; some people called it INSAR or i n s a r. So, these are the tools to give you a little bit more flavor of what is being done in this case. In the north-western corner of USA that particular area of the globe is seismically very active; although, it is actually understood to be seismically very active, although, in that area, all the faults seismogenic faults are not detected. And that area, in fact, receives a huge amount of rainfall.

So, what happens because of rainfall, there is thick forest cover in that area which really impedes the detection process of any existing fault. So, in that situation in that context, LIDAR became very handy, because LIDAR can to some extent penetrate forest cover. And you could actually develop bare earth model using LIDAR which gives the features of the ground surface which is masked to a great extent by existing forest cover. And from the topographic features, a fault has been detected across the city of Seattle actually in recent years; it is called Seattle fault using this technique.

The fourth question that I asked was how tsunami waves are generated? Tsunami waves can be generated by any disturbance on the seafloor, and that disturbance could be because of fault break near the seafloor, or because of a underground landslide or slope failure or even if there is a volcanic eruption at the sea floor that also can trigger tsunami. So, these are the causes of tsunami and that takes care of the question set, and now we move on with today's subject matter.

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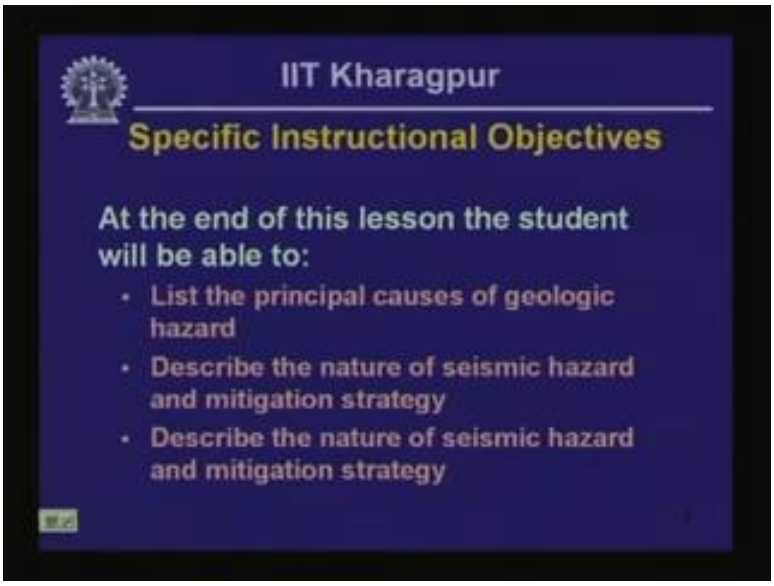

The objectives of this particular lesson are the following. At the end of this lesson, we would like to able to list the principles causes of geologic hazards. Describe the nature of seismic hazard and list the mitigation strategy, and describe the nature of actually volcanic hazard this thing. The second one will be volcanic hazard and the mitigation strategy for volcanic hazard, okay.

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Now geologic hazards basically could originate from many different factors, and some of the principle factors that give rise to geologic hazards are the following; earthquakes, volcanism, tsunami, landslides, subsidence, and expansive and collapsible soils. So, we are going to discuss at length the first five in this particular lecture set. We are going to talk about earthquake hazard, volcanism, hazards due to volcanism, tsunami, landslides and subsidence. And we are also going to look at the areas or the areas that were affected by hazards due to expansive and collapsible soils in the Indian context.

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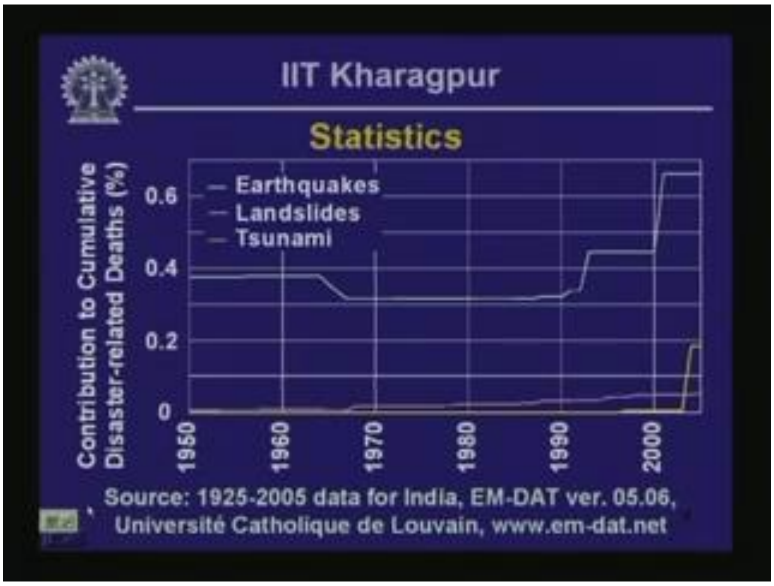

Now with that set it is of interest or in order to set the stage, let us look at the statistics from the past approximately 75 years or actually 80 years for the cumulative deaths because of different causes of geologic hazards. And what we look at in order to get a feel for the relative importance of these various types of hazards; we normalize the contribution of each individual hazards, contributions to human causality related to earthquakes, landslides and tsunami in this particular case with the total disaster related deaths cumulative disaster related deaths recorded from 1925 to 2005.

Now you can see that by far, the contribution of each one these hazards is relatively small, because you are looking at the most 0.6 percent of contribution to the total disaster related casualties from any one of this individual geologic hazards and that is earthquake.

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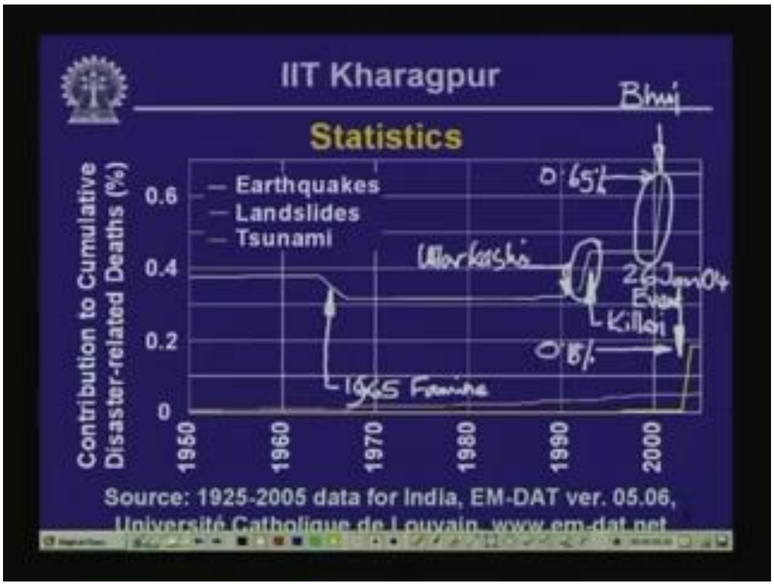

So, here for instance, here we are looking at we are looking at approximately 0.65 percent of total deaths that is due to all disasters combined. And natural disasters include drought, flood and everything; all other causes that are not really related to geologic factors which are not within thus not within the scope of this particular course. So, what we see here is that the contribution is relatively modest even when you consider the worst or even when you consider the highest individual contribution to disaster related deaths.

Now in spite of that, what I would suggest is that it is important to study these hazards because this gives us tools which allows which will allow systematic reduction of the damage caused by the geologic factors damage to the economy or damage to human life that are causes by these geologically triggered disasters. Here what we see in this particular plot is that the tsunami related causes are even less of a factor when you consider it as a percentage of the total disaster related deaths.

And here we are looking at a contribution of approximately 0.18 percent, and you can see that there was a remarkable rise at this particular point. And before that tsunami was really considered to be a non-factor in the Indian context and this was the 26th January, 2004 event tsunami event near Sumatra and Andaman Nicobar islands, okay. And you can similarly see that there are some jumps in the relative contribution of the earthquake related deaths. And this one here this this jump is because of the recent earthquake that occurred near the city of Bhuj in Gujarat.

This one here is is the central Indian earthquake Killari earthquake, and this slight blimp, this slight bump here is the Uttarkashi earthquake. And you can see that near around 1965, there was a decrease of the relative contribution of earthquakes in the total disaster related deaths, and this was the famine of 1965. Many people died as a result of that particular famine. So, the contribution until 1965 because of earthquakes in the total disaster related deaths actually showed some decline around that particular time frame, okay.

So, that actually sets the stage. So, relatively speaking earthquakes are much more important than landslides and tsunami, if you consider only geologically triggered natural disasters, but still even then the contributions of each one of these factors is relatively modest if you consider the total amount of disaster related causalities, okay.

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With that set, let us get into earthquake hazards; we have discussed some of it in the previous set of lessons. Earthquake hazards are mainly caused by ground deformation; we know some of these effects already. Liquefaction, liquefaction can trigger subsidence and uneven settlement, floatation of underground facilities that is because if you have got say for example, an underground water tank and if the partially filled underground water tank and if the soil around this water tank liquefies, then those types of water tanks tend to float to the surface if they are not properly anchored.

And that is because when the soil liquefies, it behaves as a very thick viscous fluid which has got a unique rate of around 20 kiloNewton per meter cube equal to the total unit rate of the medium that liquefied. And since, the unit rate is approximately twice as much as the unit rate of water, the buoyant force that is going to be encountered for a body stuck inside the liquefied deposit will be about twice as much as it would have otherwise encountered or it would have to withstand if it was to float or if it was to be constructed underwater. So, the buoyant force is going to be also twice as high.

And if the fact that the surrounding soil may liquefy, if it was not considered in the original design, then the underground water tank may actually float to the ground surface. Then there could be slope failure and lateral spreading which is a phenomenon associated with the waterfront slopes or waterfront open phases if liquefaction is triggered near the shore of that waterfront, then the slope phase tends to move towards the water.

So, these are the contributions or these are the different damages, these are the different factors which may cause damages to the constructive facilities are natural features because of liquefaction. Then because of earthquake, slope instability can also be triggered, and landslides may result; there could be rock fall, and there could be tsunami. We are going to discuss tsunami separately, and in this particular lesson, we are going to talk about the first four or the first three rather factors Rock fall we are not going to discuss separately and we discussed the mitigation measures for rock fall sometimes back if you recall in one of the previous lessons, okay.

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So, a few photographs; what are the damages that could be caused by ground deformation? These photos were taken from United States geological survey, and they pertain to the earthquake of November, the 3rd 2002 in Alaska, it was a magnitude 7.9 earthquake that was triggered because of a right lateral strike slip fault movement. And you can see consequences of that fault movement on the highway shown in this particular photograph. This highway is called the Richardson highway, and you can see near the bottom centre of this particular photograph, the highway has been damaged. And that particular damage is, because of the right lateral fault movement.

At this location, the fault movement was approximately 2.5 meters. And you can see towards the left of this particular highway is the Alaska pipeline. This particular pipeline was specially designed to account for this particular fault by constructing the pipeline on roller supports, and the roller supports are near the left centre of this photograph where the pipeline shows a kink. In spite of the measures of placing the pipeline on roller supports, this pipeline was damaged slightly by this fault movement, okay.

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Now the fault movement took place like this. This was the sense of motion, and as I mentioned, the roller supports are in that area of the pipeline to account for this type of fault movement that largely mitigated the problem, but still there were some minor damages to the pipeline, okay.

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This shows a close up of the damage that we looked at in the aerial photograph shown in the previous slide. And here you can see the fault movement or the damage caused by the fault movement more clearly from the alignment of the central line marking or the divider marking of this particular highway.

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This one this photograph shows the damage that could be caused by liquefaction. This photograph was again picked up from the United States geological survey, and this pertains to the earthquake of October the 17th, 1989, Loma Prieta earthquake. This one was of magnitude 7.1 in state of California in Western United States. And here, what you can see is that because of liquefaction, the sand underneath this waterfront port structure was blown out, and lot of sand has come to the surface by being blown up by the upwelling of water that typically occurs during liquefaction.

And because of the upwelling because of the sand ejected, you can see that there is a relative downward or there is an uneven settlement between this location and this location. Actually, the bottom right portion of the photograph actually sunk downward because of the ejected sand. In this type of situation also what happens, the triggering of liquefaction sometimes pushes the key walls, the walls that support the waterfront facilities outward towards the water. And this type of movement leads to damages of cranes of and other port structures of port facilities. And that type of damage was widely observed during the recent Hyogoken-Nanbu earthquake near Osaka in the port of Kobe in Japan. So, these are the consequences of liquefaction.

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Another photograph, and this photograph again comes from the 2002 Denali earthquake in Alaska, and this one shows the consequences of liquefaction lateral spreading that is caused by liquefaction. And the affected area is near the bottom of this photograph, and you can see some of the structures have unevenly pushed upward such as the one near the bottom centre of this particular photograph this one here.

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This structure was pushed up unevenly, and the cause of that is liquefaction and flotation that results from liquefaction, okay.

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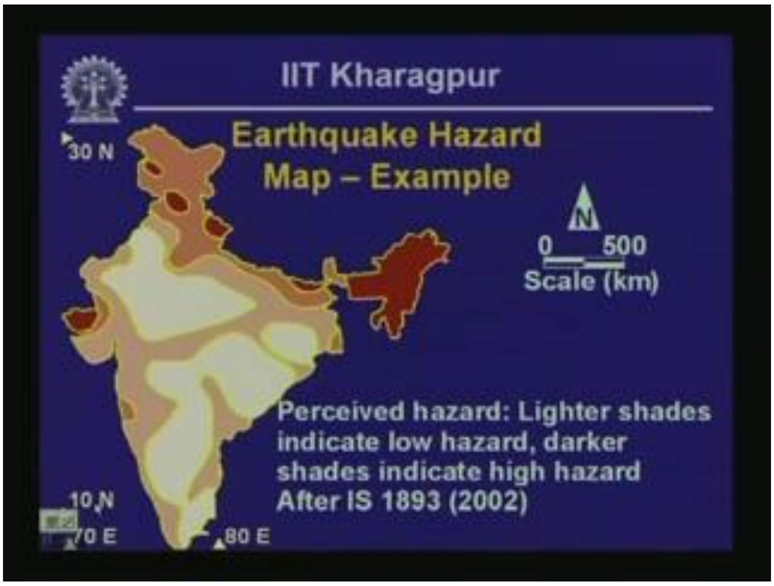

Now earthquake we know from the previous lessons is that the earthquake hazard is mainly addressed by designing facilities for the hazard that is expected in a particular area of a country. And this map here actually shows the relative hazard of different parts of India. And what is here in order to read the map let me tell you this it that the deeper colors here indicate greater hazard while the lighter colors represent lower perceived hazard.

This map is a part of the Indian standard code 1893 of 2002 which is used by structural engineers for designing civil engineering structures. So, you can see that the hazard is remarkably high near the northern part of the country near the Himalayas and near the foot hills of the Himalayas and near the western fringes of the country predominantly that is the case. And that is because of the proximity of these areas to the earthquake sources as you may recall from the previous lessons.

Now this one a similar map can be prepared from the exercise of probabilistic seismic hazard assessment. This particular map does not originate from a rigorous probabilistic seismic hazard assessment, but a similar map can be developed from a rigorous probabilistic seismic hazard assessment, where the contours that crisscross a geographic area may represent various levels of peak horizontal ground acceleration; for instance, related to an earthquake that has got ten percent probability of occurrence in 50 years as you may recall from the discussion on design basis that we had in our earlier lessons.

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Okay, earthquake hazard mitigation, what are the procedures for earthquake hazard mitigation is discussed here. First of all, you need to realize that earthquakes cannot be predicted. So, hazard is handled in a statistical sense. What I mean by that is that you look at the historic seismicity of a particular site; you look at the proximity of the given site from different active sources. And from that you can in a statistical sense say whether a particular site is relatively more hazardous in comparison with another site.

For instance, if we recall the map that I showed in the previous slide, then you could say qualitatively that the areas which are on the Himalayas or near the foot hills of the Himalayas, they are going to be relatively more hazardous in comparison with the site which is located within the stable peninsular shield. Second aspect that you need to consider here which we already discussed is that near source steep topography and soft soil, these types of sites they generally in those sites, they typically are more hazardous than the sources or the sites that are far away from the earthquake sources sites that are underlain by stiff or stiff soils or hard rock and the sites that are that are located in areas with a flat topography.

Thirdly and as a consequence of the first points really, design is based on the notion of acceptable risk; what is meant by that? What is meant by that is you have to go for a more stringent design or more stringent requirement is placed on the facilities that are to be constructed in areas that are more hazardous in comparison with areas that are relatively less hazardous. And secondly, if you have got a facility which has got a greater importance than another facility such as, say, nuclear power plant, the design requirement for such facilities are going to be more stringent in comparison with another facility that is relatively unimportant such as a rural highway.

So, in order to accomplish this, design is sometimes carried out for an earthquake that has got a low probability of exceedance; by low what I mean is typically a number of ten percent is considered internationally low probability of exceedance during the service life, say, 50 years of the structure. So, that is the design strategy for earthquake loads or this is the strategy that is considered for mitigating earthquake hazards, okay.

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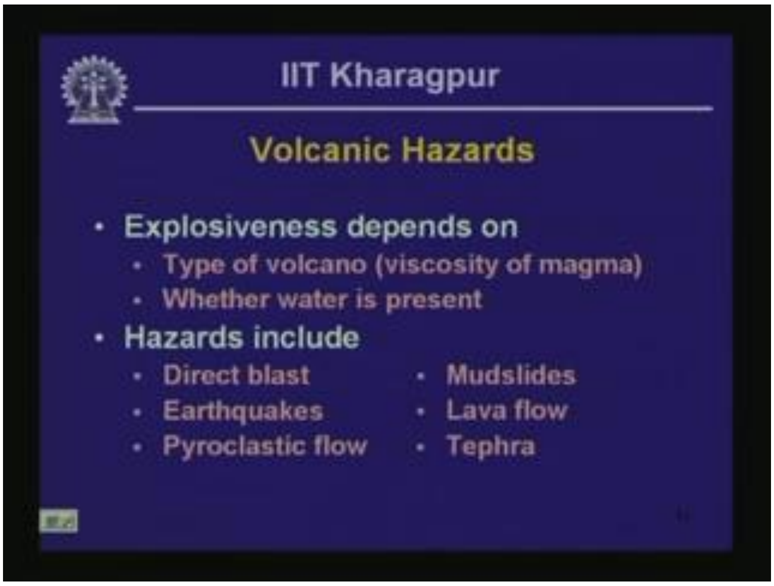

So, that is in a nutshell the strategy that is adopted or the course of action that is adopted in order to minimize earthquake hazard. Now the second type of geologic hazard that we are going to consider now in this lesson is the volcanic hazard. And by volcanic hazard, what we are going to discuss here is the hazards that arise, because of a volcanic eruption or the processes that originate because of volcanic eruption.

Now you can recall that it is difficult actually to consider these individual hazards separately from others, because volcanism generally triggers earthquakes order of small magnitude that may affect significantly the the areas that are located in the vicinity of the volcanic activity. Now in order to consider volcanic hazard first of the things first of the points that we need to consider is the explosiveness of the source.

If the source is assessed to be of greater explosiveness, then the hazard is going to be far greater than the sources that are relatively less explosive. So, that will require classification of different type of volcanoes, and really, we have to look at the viscosity of the magma that is causing the volcanism. And the second aspect that is important in this context is whether water is present in close proximity where the volcanism is taking place. What kind of hazards? That we need to consider here they include direct blast, earthquakes, pyroclastic flow, mudslides, lava flow and tephra.

Now before we go ahead, we need to define a few terms here which you might not have encountered before. The first one is pyroclastic flow. What is meant by pyroclastic flow is really it is a flow like phenomenon that is comprised in which movement of pyroclastic material takes place. Now what is pyroclastic material? Pyroclastic material is essentially a mixture of lithic crust and hot gases. They are highly mobile, very hot, and they tend to flow down the down slope from the volcano, and that type of flow is called a pyroclastic flow.

The second term that is appearing for the first time here is tephra. By tephra what is meant? It is really a mixture of different type of pyroclastic material which varies in grain size to a great extent. There could be very large grain sizes which is called a bomb to to very fine material which is called volcanic ash. A volcanic ash is it could be as small as clay size particles, whereas bombs could be as large as boulders. So, that takes care of the definitions, okay.

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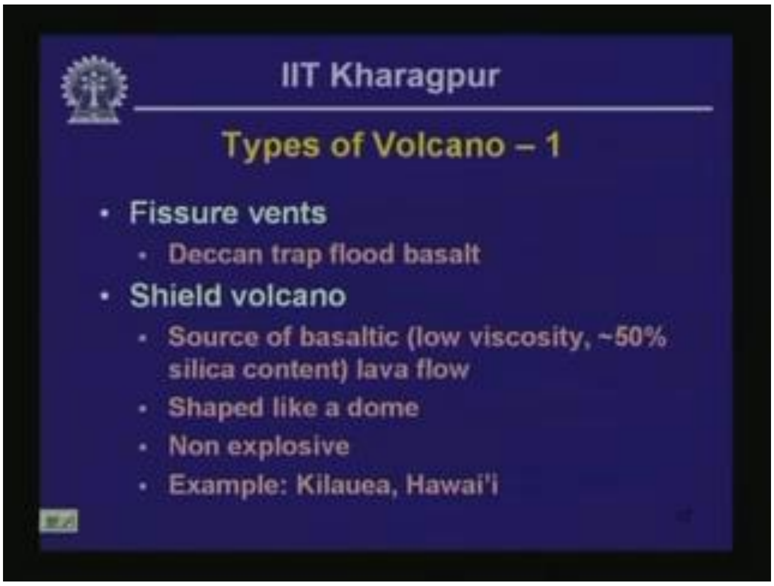

Now as we have noticed earlier is that one of the factors that is very important in assessing the damage due to a volcanic eruption is the explosiveness of a volcano, and what govern the explosiveness of volcano is the types of a particular volcano. So, here we consider the different classes of volcano. The first one is called a fissure vent. Here what you have got is a crack at the surface of the earth from which the lava is oozing out that is called a fissure vent; it is a linear structure typically, linear geomorphologic feature typically.

And a fissure vent, the undersea spreading boundaries you could consider them as in many situations, they are fissure vents where lava is oozing out, and pillow basalts formed as a result of that type of underwater volcanic activity. Deccan trap which covers a large part of south western or north western Indian peninsular; that area to the Deccan trap is essentially a result of activities that took place in geologic pass through fissure vents it is presumed.

Second type of volcano is called shield volcano. Shield volcano is a source of basaltic magma. Basaltic magma is a low viscosity magma which consists of about 50 percent silica. Now these volcanoes are typically shaped like a dome. They are non-explosive in which lava flow typically occurs in a very gentle manner. It flows out of the vent, and the flow velocity is typically less than the velocity at which a person walks across a field for that matter. Example of a shield volcano is the Kilauea volcano in the state of Hawaii in Southern Pacific of United States.

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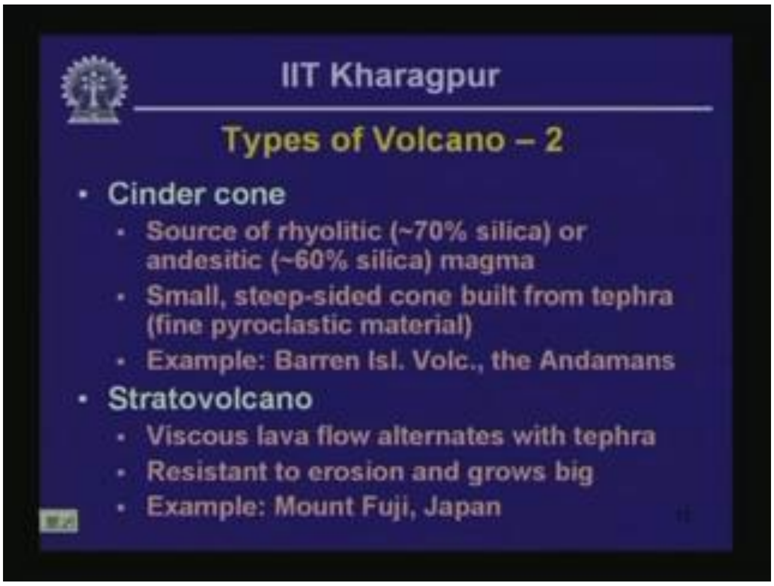

We have got two more clauses of volcanoes to consider. First one is the cinder cone. It is typically a small feature; it is source of rhyolitic or andesitic magma. Rhyolitic magma is typically 70 percent; it has got 70 percent silica content and andesitic magma has typically 60 percent silica content. And if you recall from the discussion that we had on volcanism earlier, with silica the viscosity of magma typically changes with silica content. And as silica content goes up, the magma or lava becomes more and more viscous and the volcanism associated with such magma is more explosive in nature typically in comparison with volcanism associated with lava or magma that is what a smaller silica content.

By lava actually just to jog in your memory by lava what is meant is the partly moultant rock forming material that is at the surface, whereas magma is when the partly moultant material is deep underneath the surface of the earth. So, that is the distinction between lava and magma if you recall from what we discussed in our earlier lessons. Now cinder cones are typically small as I indicated earlier; they are steep-sided cones built from tephra fine pyroclastic material typically.

Example of a cinder cone is the Barren island volcano in the Andaman's; that is actually one of the two active volcanoes that one can find within the jurisdiction of India. The fourth type of volcano, this is the huge feature actually; this type of volcano is called stratovolcano. Here viscous lava flow alternates with tephra and resistant to erosion that is imparted because of alternation of lava flow and tephra fault, and this type of feature can grow very big indeed and examples being mount Fuji in Japan. Let us take a look at a few photographs because then the scale that we are talking about may become a little bit more clear.

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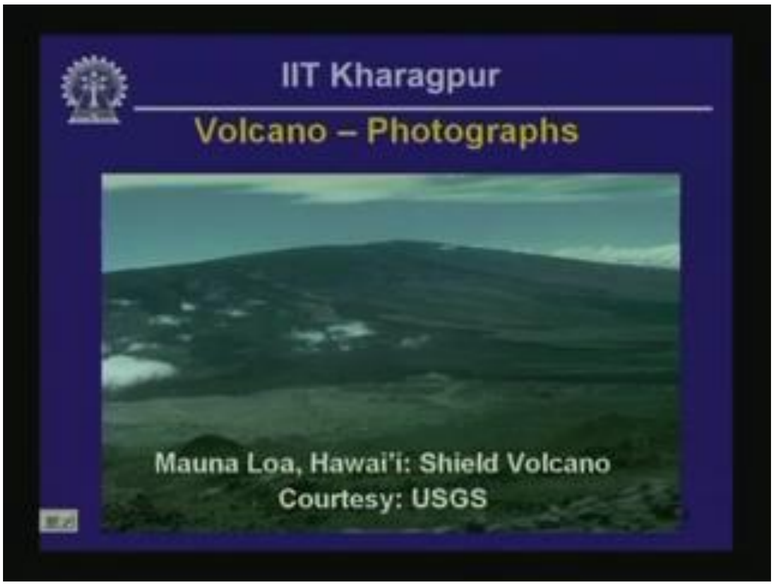

This one here is a photograph of a shield volcano, and this one is a photograph of the Mauna Loa volcano in the island chain of Hawaii. Photograph was picked up from USGS as earlier.

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This one is another photograph showing the volcanic eruption of Mount St Helens that took place in the year 1980. This particular volcano is a stratovolcano in the North Western United States in the state of Washington. Now you can see that this is a huge feature.

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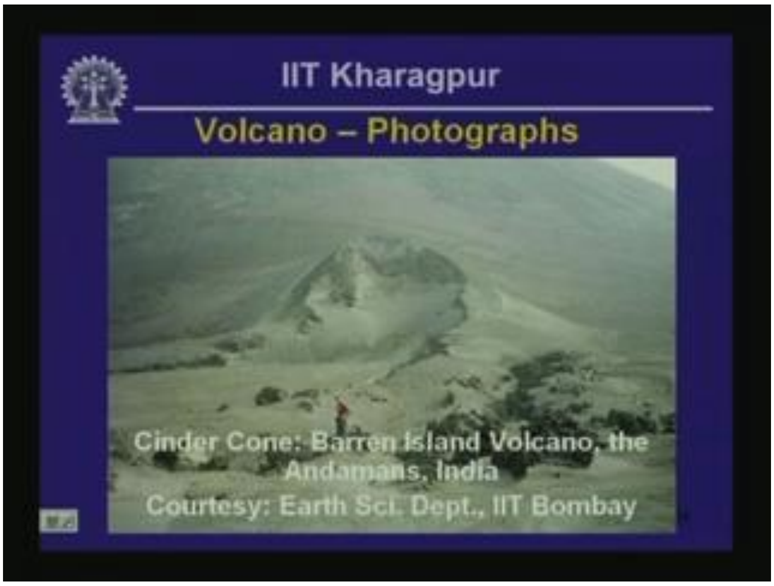

Then this picture shows the cinder cone. This photograph was obtained from the Earth Sciences Department of IIT Bombay, and this one is the Barren Island volcano of the Andaman’s, and as is apparent that this type of feature is much smaller in comparison with a stratovolcano.

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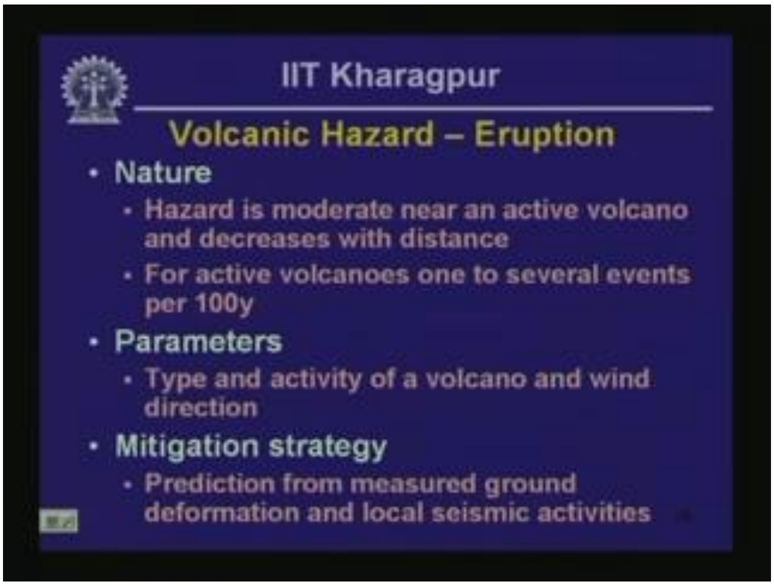

Now with that set, we can get into we can formalize the concepts of volcanic hazard. So, first volcanic hazard that we consider here is the volcanic hazard due to eruption. We are going to consider the nature of this type of hazard, parameters associated with the hazard and the mitigation strategy, and that is the format that we are going to follow for all other types of volcanic hazard. So, the nature of volcanic hazard associated with eruption is the following.

The hazard is moderate near active volcano and decreases with distance, and that is because the fall of pyroclastic material near the volcano could be much larger in size than the pyroclastic material of tephra that is going to fall way out in the distance from the location of the volcanic eruption. For active volcano, there is typically one to several events per hundred years, and for relatively inactive ones, you can expect one event per one thousand years. So, that gives you a sense of the return period that are associated with this type of hazard.

Parameters include type of volcano and the activity of a volcano as well as the wind direction which will blow the pyroclastic material to a distance. We are going to look at the details here. I am going to give an example later on to explain these factors more in detail. Mitigation strategy in this regard includes prediction from measured ground deformation, prediction of when eruption is going to occur or approximate time frame when an eruption is likely and local. So, the prediction is typically done based on ground deformation measurement, tilt measurement and local seismic activities.

What happens; what figures typically a seismic eruption is building up of magma underneath the ground surface, and because of that building up, typically the ground surface topography changes and ground surface tilts in certain direction. So, from the tilt measurement, it is possible actually in many situations to predict when a volcanic eruption is eminent. And that is confirmed from local earthquake activity that is triggered by failure of small rock masses because of intrusion of magma, okay. So, when a volcanic eruption is predicted or eminent volcanic eruption is anticipated, then appropriate evacuation measures is typically undertaken to mitigate loss of human life.

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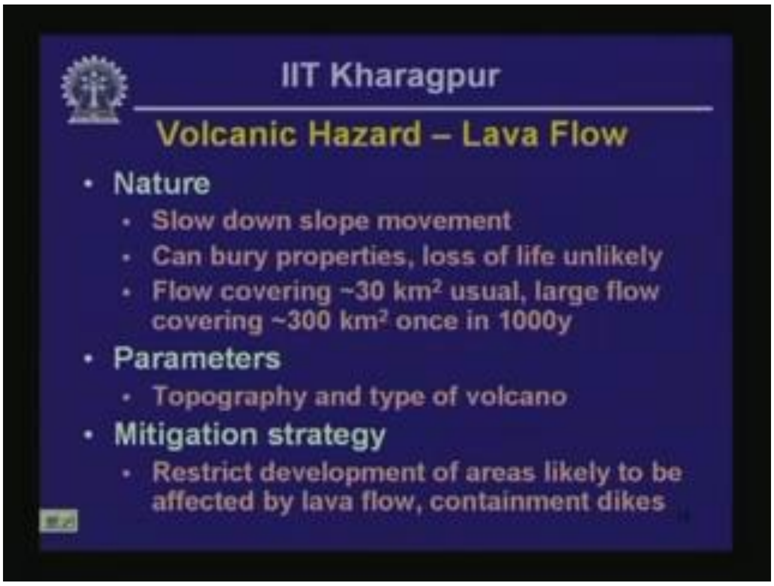

Volcanic hazard due to lava flow, the feature of this type of hazard includes slow down slope movement. The lava flow is typically slow, and it can be out faced relatively easily. Lava flow can bury properties; loss of life is is generally unlikely is because of slow moving nature of the lava. Typically flow covers a few tens of kilometers and large flows covering areas as large as few hundred kilometers are also likely with the return period of about one thousand years.

Parameters that govern the hazard in this particular case are topography and the type of volcano. Mitigation strategy in this case includes restricted development of the areas likely to be overrun by lava flow and containment dike in order to confine the lava flow movement.

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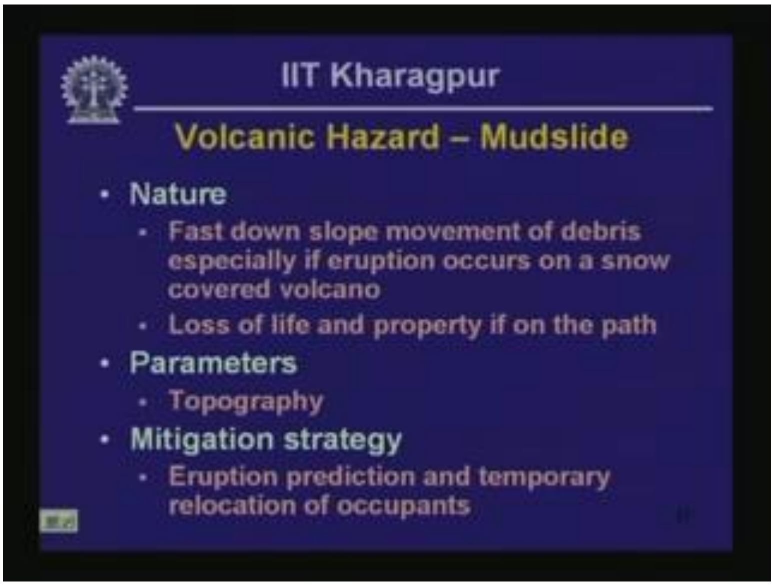

Third type of volcanic hazard, this one is due to mud slide. This is typically fast down slope movement of debris rock fragments soil mixed up with melt water, and this is especially this particular thing happens if eruption occurs on a snow covered volcano. Loss of life is a distinct possibility here loss of life and property because the mud slide is so fast that it cannot be out run by any stress of imagination. So, loss of life and property is a distinct possibility if human occupants are on the path of the mud slide. Parameters include topography. Mitigation strategy in this case includes prediction of eruption and temporary relocation of occupants away from the anticipated path of mudslide.

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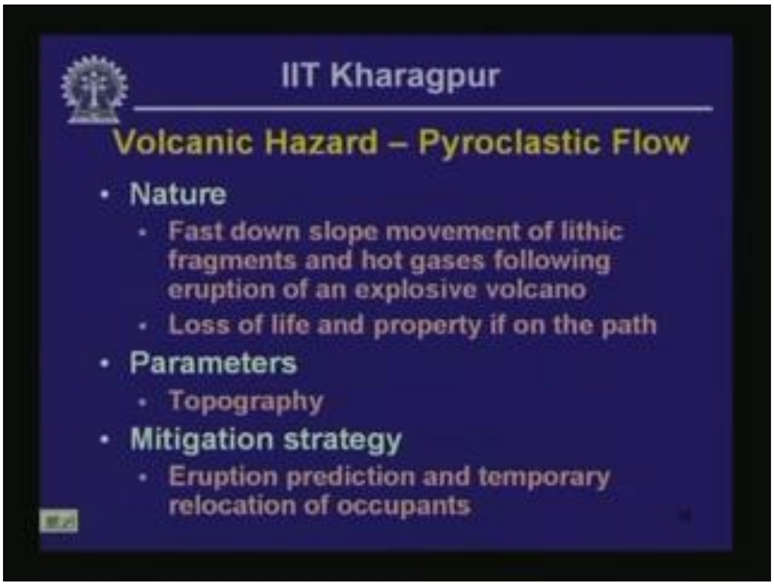

Pyroclastic flow is very similar in nature to mudslide in other aspects except for the fact that here you are looking at the flow of lithic fragments mixed with hot gases following eruption of an explosive volcano. Loss of life and property is a distinct possibility in this particular case as well. And parameter in this case is topography as well as the type of volcano, and here again we have the mitigation strategy revolves around eruption prediction and temporary relocation of occupants away from the anticipated path of pyroclastic flow.

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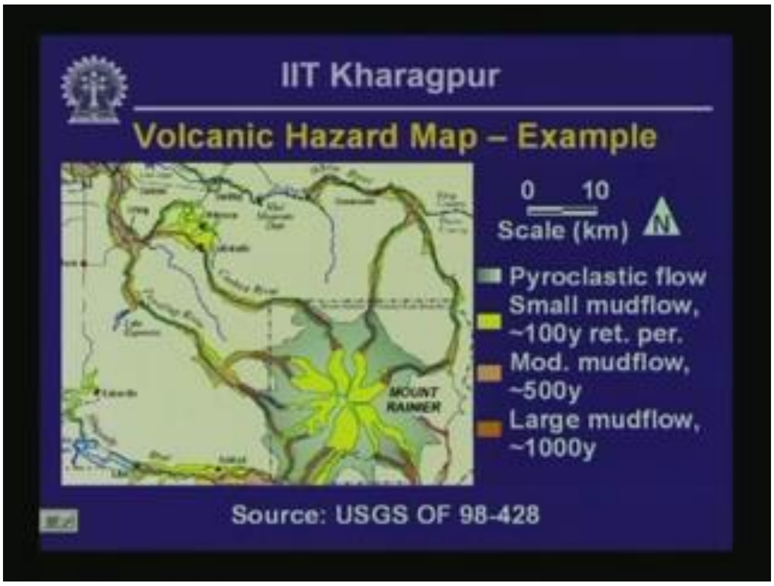

This one here is a volcanic hazard map of a volcano in the state of Washington in North Western United States prepared by the United States geological survey. You can see the locations of the pyroclastic flow hazard, then the areas that are likely to be affected by small mud flows with 100 year return period moderate size mud flow with a 500 year return period and deep color indicates large mud flow with 1000 year return period.

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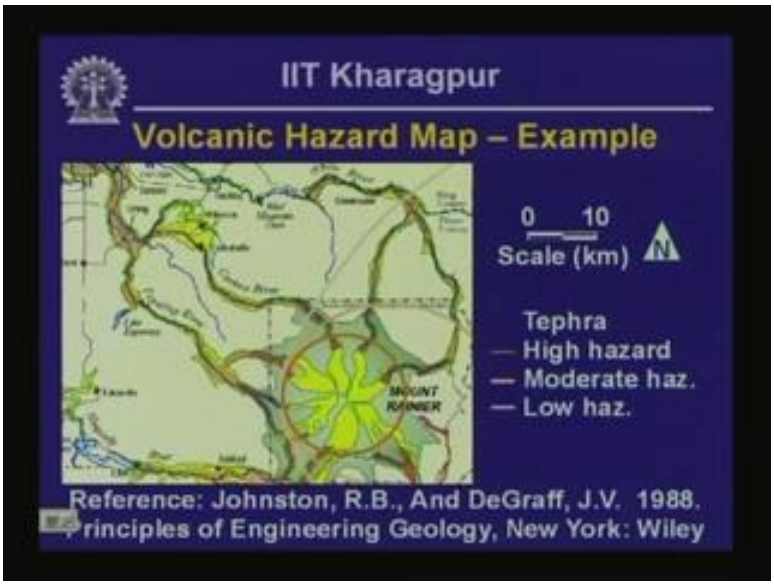

Super imposed on this one are the tephra fall hazard; you can see that the hazard actually decreases with the distance from the location of the volcano. And in this case, the direction of the wind movement you can easily say that the direction of the wind movement is towards the east. And as a result, the hazard is also oriented in that particular direction.

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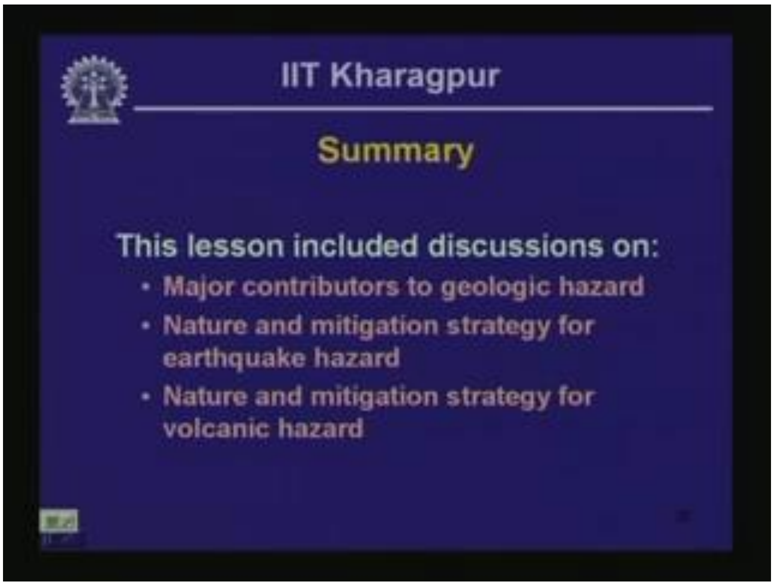

To summarize what we learnt in this lesson, we learnt the major contributors to geologic hazard, nature and mitigation strategy for earthquake hazard and nature and mitigation strategy for volcanic hazards.

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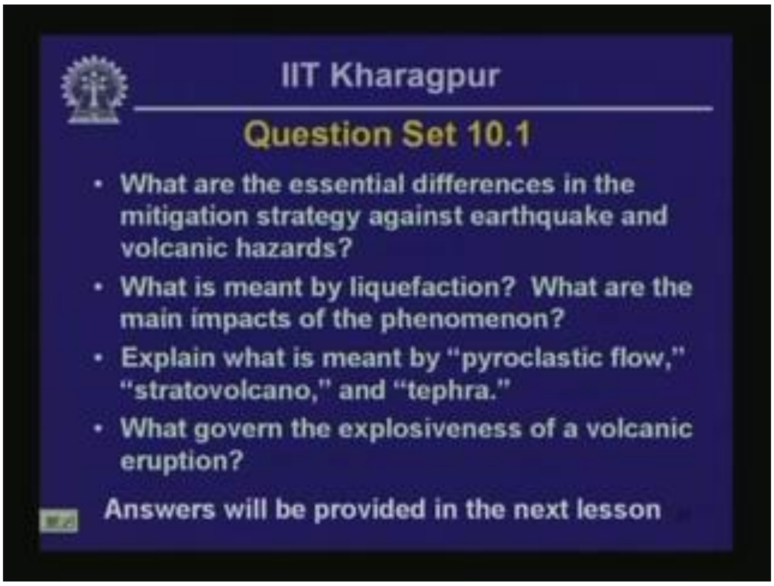

We wrap up this particular lesson with this question set. The first one is that what are the essential differences in the mitigation strategy against earthquake hazards and volcanic hazards? What is meant by liquefaction? What are the main impacts of the phenomenon? Explain what is meant by pyroclastic flow, stratovolcano and tephra? What govern the explosiveness of a volcanic eruption? Try to answer the questions at your leisure. I will give you my answers when we meet with the next lesson; so, until then bye for now.

Thank you very much.

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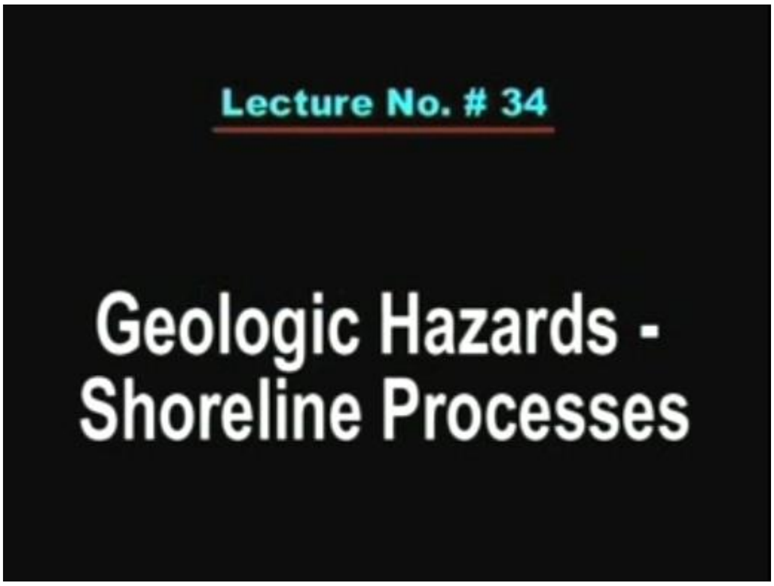

Hello everyone and welcome back today we are going to talk about a new kind of geologic hazard that arises because of different shoreline processes such as wave action or tsunami waves, but before we go ahead with the today's lesson, let us look back at the question set of the previous lesson.

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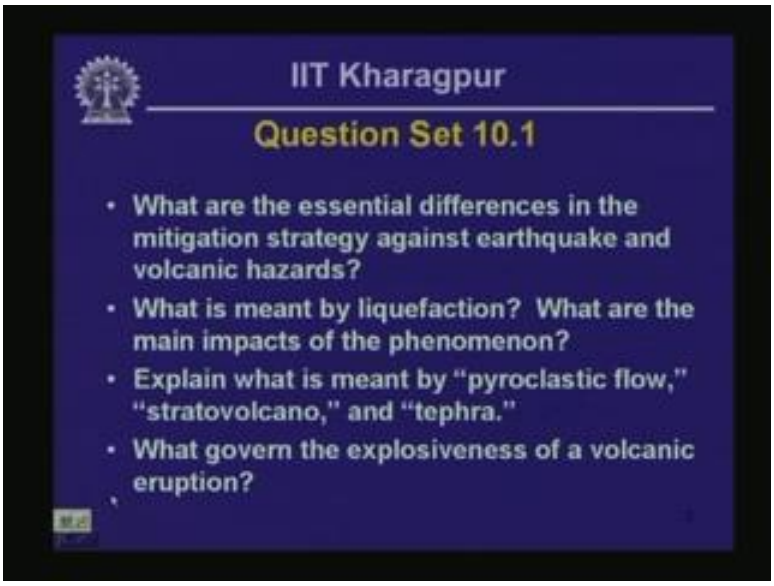

Here are the questions. The first one that i asked was what are the essential differences in the mitigation strategy against earthquake and volcanic hazards? Now if you recall what became apparent from the discussion that we were having in the previous lessons is that the process of earthquakes cannot be predicted. On the other hand, in many cases the likelihood or the timing of volcanic eruption to some extent can be predicted.

So, the mitigation of earthquake hazard is basically done by managing the risk involved depending on the statistics of the past earthquakes recorded in a given region. On the other hand, volcanic hazard to a great extent is managed by by predicting the timing of a volcanic eruption and removing people from the areas that are likely to be affected by different kinds of volcanic hazards. So, this is basically the main difference between the mitigation strategies associated against earthquake and volcanic hazards

The second question that I asked was what is meant by liquefaction, and what are the main impacts of the phenomenon? Now liquefaction is primarily a phenomenon associated with elevation of pore water pressure within the matrix of relatively coarse grain soils which derive most of their strength from frictional interaction between different individual particles that compose the media. Now because of pore water pressure increase, the grain to grain contact force measured by the effective stress is largely reduced.