Geomorphology
Prof. Pitambar Pati
Department of Earth Sciences
Indian Institute of Technology-Roorkee

Lecture-03
Energy Flow in Geomorphic System and Role of Uniformitarianism Vs Catastrophism

Ok friends today in the geomorphology class, we will discuss about this energy flow in geomorphic system and role of uniformitarianism versus catastrophism. What does it mean, in geomorphic system if you remember our last classes, we are talking something about the geomorphic processes, it may be fluvial process, it may be eolian process, it may be glacial process or any process is involved and weathering and erosion is involved.

So, we need energy flow from one form to another form, and we need material, either a material has to be added or is to be removed in any case, we need energy and material together and in geomorphic system to sustain for a long time, this energy and this material has to be balanced, if it is not balanced, what will happen. For example, suppose, we have more energy available in the system, but less material.

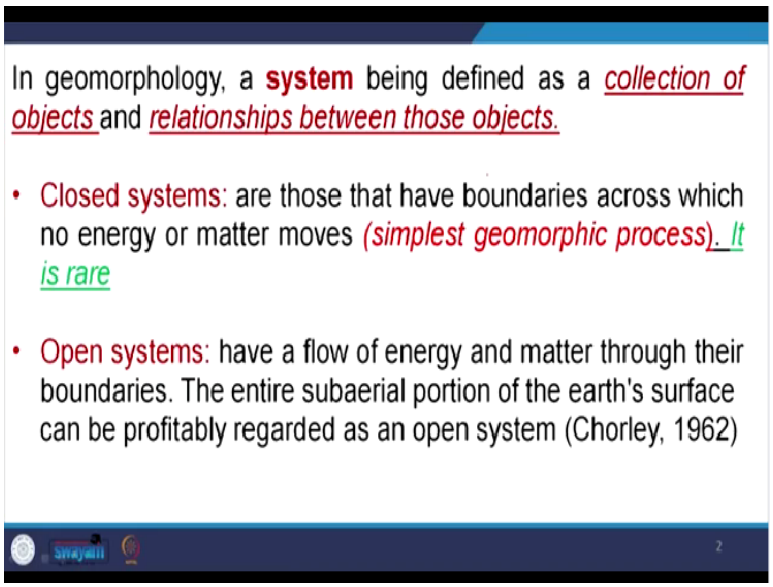
So, there will be dissipation of energy, there will be loss of energy and there will be less work done. Similarly, suppose we have more amount of material available, but less amount of energy available. So, the system will not work, the system will be not long lived it will short live and one system will be segmented into different subsystems. So, that means I want to say to sustain a system in a geomorphic system for a long time, we should have a balance between these energy and material together.

And whatever the geomorphic features, so far we have discussed. So, some of these geomorphic systems or some of these geomorphic features that were formed uniformitarianism process that means, it is a gradual process, gradual process it will take long time to form, it will take a long time to come into balance and some of the systems which are called catastrophic systems. Catastrophic system means within a minute, within hour, within a day it will happen.

For example, suppose we want to create a mountain system which is relict mountain system for example eastern ghat. Eastern ghat is the relict mountain system and it is this uniformitarian approach if we move that means it has taken a long time to form, but in terms of our Himalayan system is concerned, Himalayan system it is catastrophic process that means a tectonic process within a long geological time involved a lot of energy, a lot of material is being added to this surface of this earth.

So, therefore, it is a catastrophic system. So, in today's class, we will talk in detail how the energy flow occurs in a geomorphic system and the role of uniformitarianism and catastrophism how they work together or separately to modify a geomorphic system and to modify these topographic processes. So, what does it mean. So, far we are talking about the system and system, what is system in geomorphology is concerned. System, it is a collection of objects.

(Refer Slide Time: 03:50)



And those objects has to be related to one another with some process. For example, we have fluvial system. Fluvial system means there is river involved, within river there is erosional topographic, erosional landforms there involved. There are depositional involved, depositional topography and depositional features are involved. So erosional landforms and depositional landforms, the fluvial process, the river, the streams, the floods, they are related to each other.

So, this is a complete system, which is called fluvial system. Similarly, take another example about the glacial system, it is the glacier is the medium, the glacier topography, either it is depositional or it is maybe erosional. All those they placed side by side at the upper reaches the erosional topography will be dominant the erosional topographic features will be dominant and the lower reaches where the glacier melts down the depositional features and depositional topography will reflect.

So, it is complete system, it is complete a glacial system. So that means system means, it is a collection of objects placed side by side, and they are related to each other. So, now the question arises if this is so, the system can be divided into 2 parts, one is called the closed system, closed system that means material and energy they are restricted that means material cannot be transformed or transferred to a boundary beyond that, that is called closed system.

Similarly, energy cannot be transferred from this system beyond that boundary, that is called closed system. Generally in geomorphology closed system are very, rarely found, even if they are closed systems are there, they are not long lived. So, that means with time if closed systems are there with time with subsequent geomorphic modification, these will not sustain. So, they will divided into small and small and small systems.

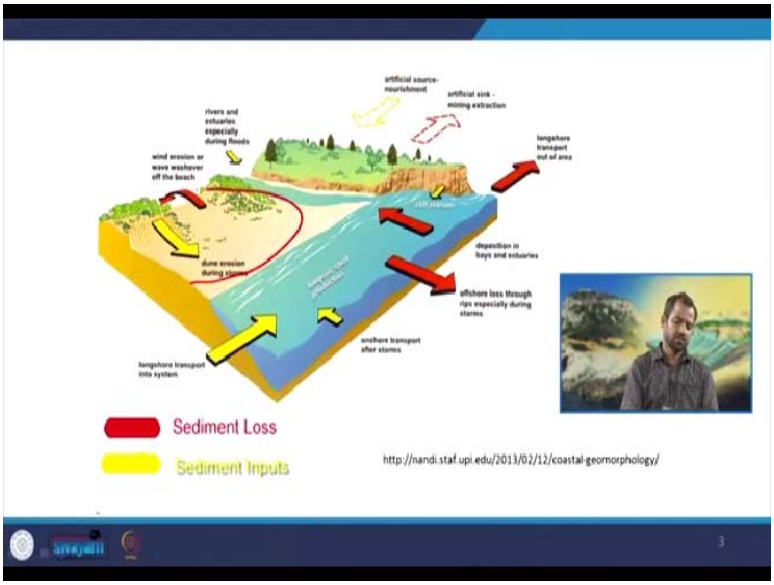
Finally, that will not sustain and will be vanished from the earthcrust. So that is why I want to say though close system has been defined, they are very rare, simplest geomorphic processes, they are the closed system and it is very rare. Now open system, open system means both energy can be transferred, but material can be transferred, for example, we have a fluvial system, from fluvial system we have rivers, they are debouching their water to the sea.

They are transporting their sediment from the upper reaches from the surroundings and some of these sediments that are deposited in the flood plain some of the sediments that are deposited within the riverbed, some of the sediments they are going into the sea. So, finally, we are having a open system that means from the upper reaches to the open sea, this system is any changes in the sea, any fluctuation in the water level in the sea it will affect the fluvial system.

It will affect the sediment production, it will affect the sediment transport, it will affect the sediment deposition, that means one system if it is changing its position one system if it is changing with the property, it is affecting to the another system. So these are called the open systems and many of the geomorphic systems and the geomorphological domain its concern many are whether most of the systems they are open system.

And closed systems they are very rarely present here. Now here these examples are given, the systems if you see here, these are the desert systems.

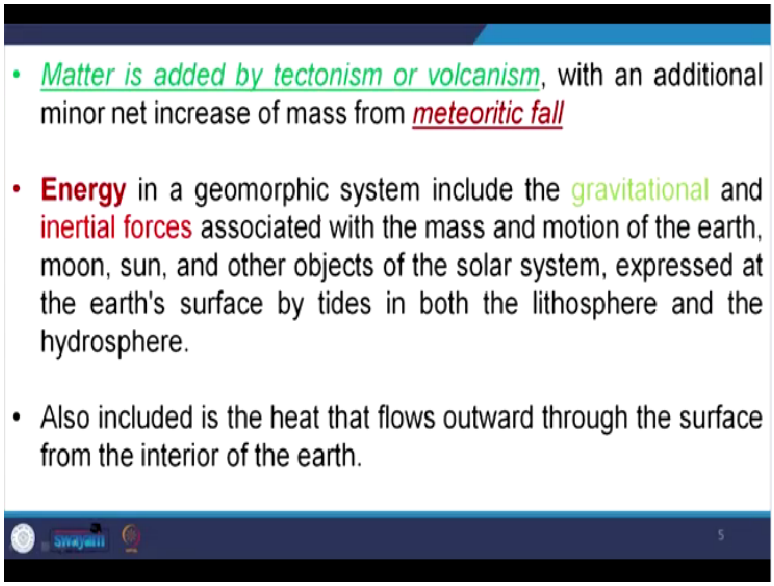
(Refer Slide Time: 07:41)



This side the desert system, desert system means desert geomorphology is concerned. Here we can expect the dunes, the different types of dunes, the barchans the star dunes, the longitudinal, the transverse, similar the ripples and this erosional topography the yardangs, the gala, whatever maybe it is. So this is completely a geomorphic system which is isolated. Similarly, this side it is fluvial systems, this side we have marine systems.

So, these are the system they are independent in their domains, closed system landscape with wetland, esturine, lakes, they are the closed systems.

(Refer Slide Time: 08:22)



So now, we are talking about material and energy management within the system. So, we see material, material is being added by tectonism or volcanism and very small amount by meteorite fall. Tectonism we know Himalayan system, it formed by tectonism, tectonic process, eastern ghat, western ghat many all mountain systems in the world. Not many all mountain systems in the world. They are formed by tectonic process in geological time.

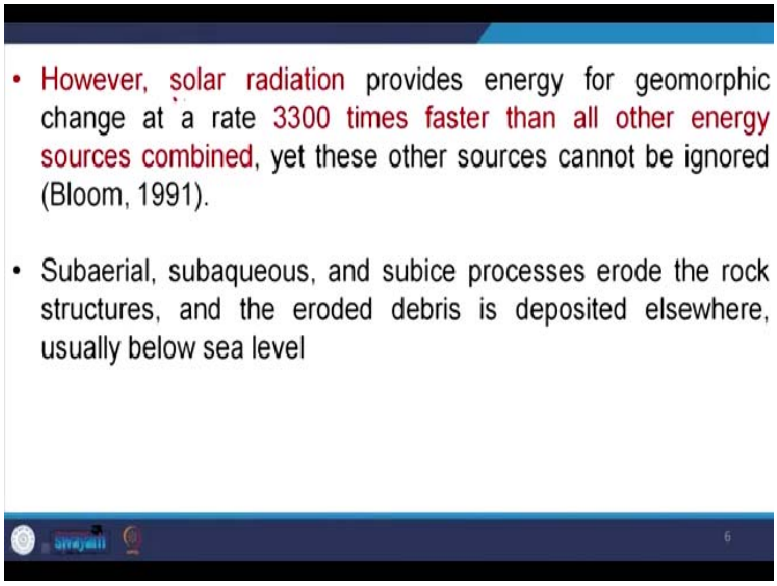
So the main work or the main theme of tectonism is it adds materials on the earth surface, it takes from below it adds on the earth's surface and creating a topography. So, that means it is a geomorphic it is creating a separate geomorphic system within the surrounding. Similarly meteoritic fall though it adds material in this geomorphic system, but its contribution is very, very, very, very small.

Some meteoritic fall they are of varies form vary size or vary weight from kilos and some grams or so. So it is in matters that means though it is meteoritic fall though it is adding mass to the system, but as compared to the large mass of the geomorphology is concerned, it is very negligible. Then it comes to energy, what should be the source of energy to sustain a geomorphic system. Mostly the energy involved in a geomorphic system, it is the gravitational energy.

So gravitational energy means its source is sun, the moon is not it, in the solar system is the gravitational of energy, then the inertial force associated with the mass of the motion, then some

internal energy, internal energy means is the heat dissipation, it is the movement of this mental, so, this also providing energy to the system. So, that means mass and energy both are related, both are available within this earth, very less amount of material is being added from the extra terrestrial systems. If you see, and you compare the energy systems available from different source, you can see the solar radiation.

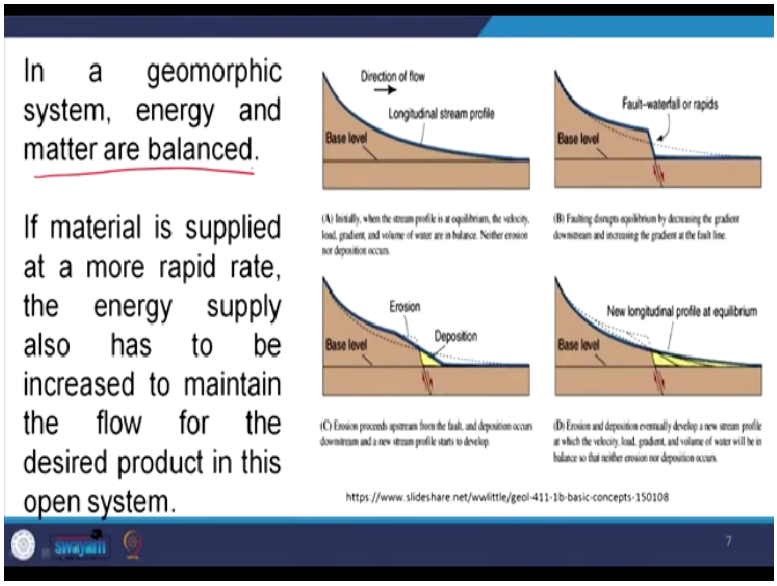
(Refer Slide Time: 10:42)



If you see, note down here, the solar radiation provides the energy for a geomorphic changes at a rate 3300 times faster than all other energy source. So, to sustain a geomorphic system for a long time, solar energy is very much required. Then subaqueous, subaerial, sub-sea processes erode the rocks from one place to another. So, erode the debris deposited somewhere else, this also needs some energy.

That energy is that means solar energy is divided into different forms and all other forms of energy, they also provide to the geomorphic system to move the material from one place to another. So, this is the management of energy and matter within a geomorphic system, as we have discussed earlier also in a geomorphic system, the matter and the energy must be balanced.

(Refer Slide Time: 11:35)



If it is not balanced, that means, the geomorphic system will not sustain forever, it is of short life for example, if you see here notice here, this is a longitudinal profile of river, it is in steady state, it is attained equilibrium that means to sustain this river to flow it has to be this riverbed geometry should be like this. But if you see here suppose there is fault in between so, that means it is creating it is adding material here.

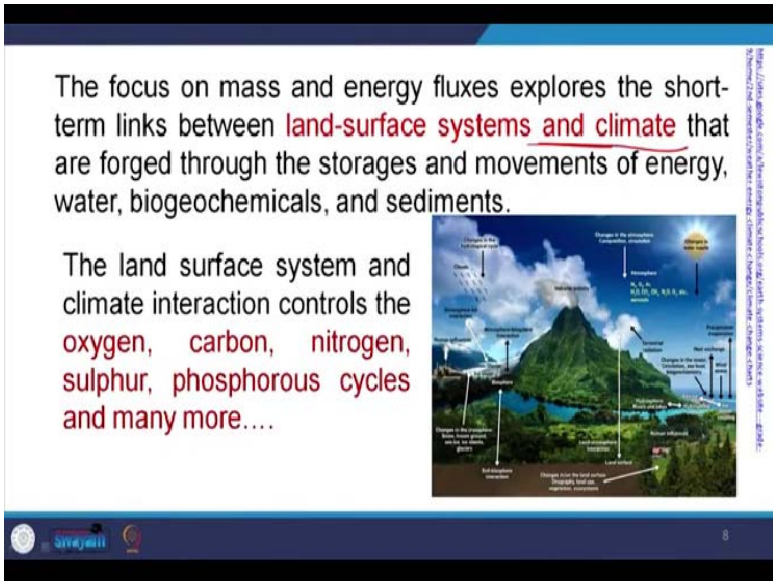
And nature has a property that it will not keep this surface uneven, always 24X7, the natural processes, natural agents they are acting 24X 7 to make the surface peneplain. So, that is why if you see here, gradually there will be erosion. So, due to erosion, this side erodes and the material produced here that will be deposited here. So, with time this part, this mass is totally eroded out, and this eroded material is being deposited here.

And finally, this is the longitudinal river profile occurs. So, that means, earlier it was started and it ended with like this. So, in between there will be imbalance and that is called temporary imbalance in a geomorphic system. So, temporary imbalance means it is not long term, it is a very short term as compared to geological time is concern, sometime means geological time is concerned, it may be 1000 of years, it maybe millions of year depending upon the terrain as you discussed earlier.

If this happens in a fluvial system, which is very alluvial system unconsolidated material this unevenness will not sustain for a long time even if 100 of years or 1000 of year the system will peneplain it. But if same happens in a hard rock terrain like Peninsular system, the system will continue for millions of years, this unevenness of new geomorphic system will remain there for millions of years or for lakhs of year so.

So, that is why these things these are temporarily available or temporarily sustaining, but in long term geomorphological system is concerned this says no place, so it means nature always wants by its natural agents to make its surface peneplain.

(Refer Slide Time: 14:07)



If you see here, climate change, it also plays a major role in modifying the geomorphic system. For example, suppose we are talking about the geological time when the arid climate was concerned or arid climate was dominant or we are talking something in geological time, when the humid climates were dominant, we know in humid climate more rainfall, more sediment production, more weathering erosion, is not it.

So, that means material will be more, energy will be more and that will be transported from one system to another system. So within a system from one end to another end. So if it is arid system, it is a cold desert, cold in there will be no rain material will be produced by physical weathering

what will remain there, no transportation because energy is not available. So, that means climate change also affect the geomorphic system to such an extent.

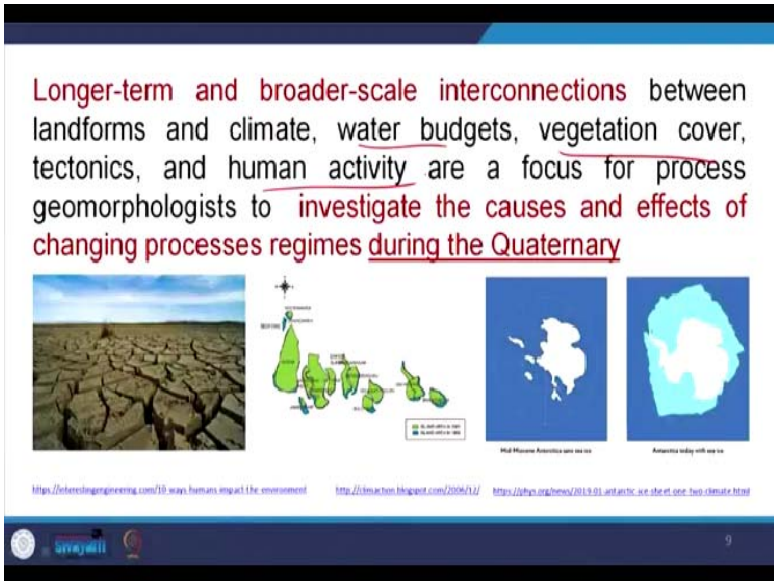
And its role is very prominent. There are many climate change records have been noticed and they are preserved in the rock body, it has been noticed during this humid climate conditions, the peneplanation system of the earth is uniform. However, during this arid system, either it is cold arid or it hot arid some of this geomorphic processes they are restricted in some geographical environment. So, this energy and material distribution on the earthcrust is not uniform.

In their cluster form, the energy is dissipated, the energy is used and it is cluster for the material is transport. But if it is humid climate, it is warm and humid climate there will be uniform distribution of energy and material throughout the time. So, this climate change it affect our oxygen cycle our carbon cycle, nitrogen cycle, sulfur cycles and many more. So, that means by one way or other the geomorphic system is being affected.

So, that climate plays a major role in modifying the geomorphic system. Now, we see long term and broad scale interactions between landforms and climate. Suppose, we are allowing the climate to interact the land for long time, again long time means what type of climate with which we are dealing with, if it is arid system or arid or arid hot arid or it is that is cold arid we are producing sediments, we are producing materials.

But the material will remain there, material will not be transported, if it is cold arid if the glacial system is there, then glacier will transport this material to certain extent. But glacier has its own limit, it cannot transport to nth extent, it has certain own limit, is not it. So, that means, I want to say the climate change that affect the system, the geomorphic system that affect the water budget, that affect the vegetation cover, that affects the human activities.

(Refer Slide Time: 17:23)



All those things they affect our geomorphic system. For example, if you see this figure in arid climate, these are the indicators the mud cracks, this aridity, we have rock record within which mud cracks are very well preserved. That means here the geomorphic system is affected, here if you see we have Sundarban delta. There are many delta have been submerged. If you see here this map in Island in 1969 island position in 2001.

That means substantial changes in area why this is due to the climate change. So the climate change affect our marine system, this affect our continental system. Similarly, they affect our glacial system also, if you see here mid oceanic Atlantic ice here, Antarctica today in the sea ice. So if you see, this ice percentage is from here to here, there will be a drastic change. This is due to climate change. And due to climate change, if we are restricting our geomorphic environment, we are squeezing our geomorphic environment to certain domains.

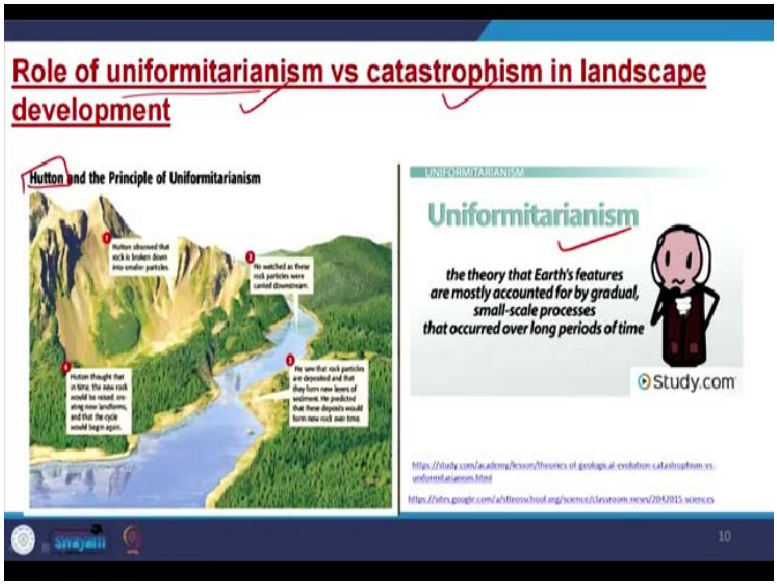
So, that means within it one domain, we are creating small, small sub domains. Earlier if you see this was the position where this glacial system was dominant. Now, the glacier system is dominant here, but what about the rest of this area. This is by the marine system. So the means with time, with the change in climate, with change in topography, with change in tectonism, one system dominate over other one system takes away any regions from other.

So well nowadays arid climate is continuing in geological past you can say there is cold climate was continued there. So that is why these things are this evidences are preserved within the rock record. So that is why I repeatedly say if we are able to unravel, decode this geomorphic systems from this rock record, you can unravel the geomorphological history of that region. Then whatever the energy, whatever this material it is used energy from one form or another.

Material from one place to another, does this energy work repeatedly into 24X 7 or the rate of energy flow is the same throughout the geological time. If you see here, there are 2 schools of thoughts, one is theory of uniformitarianism, another is Catastrophism, what is uniformitarianism, the school says the whatever the geomorphic topography we have nowadays either it is erosional topography or it depositional topography.

These topography they form gradually, gradually it takes a long time to form. This is the uniformitarianism approach.

(Refer Slide Time: 20:42)

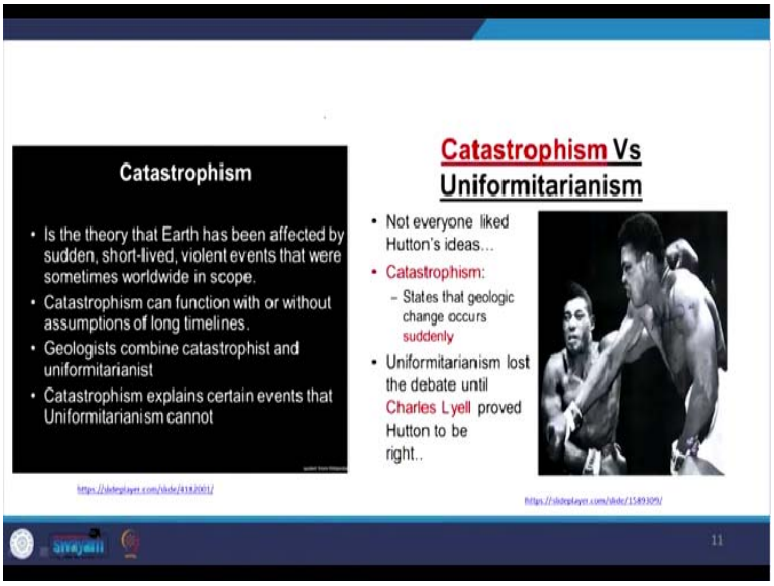


This theory of uniformitarianism it was proposed by James Hutton. So, James Hutton he noticed first he observed that the rock is broken down into small particles. Then he watched these rock particles are carried down downstream. He saw the rock particles are deposited and that they form new layers of sediment. He predicted these deposited sediment will form new rock in

future. Then Hutton thought that in time, new rock would be raised, creating new landforms that this cycle will continue.

So, that means it was the theory of uniformitarianism or uniformitarianism approach that all those landforms they were form gradually with taking long time.

(Refer Slide Time: 21:33)



But catastrophism is another school of thought. It says that, no, no, no, this uniformitarianism approach is wrong. Many of this landforms are the landforms, they occur overnight. Within a small time, you will find huge landforms. So earth has been affected by sudden short life, violent events that are sometimes worldwide in scope. So this catastrophism can function without or with assumption of long time.

So that means catastrophic events they are short lived event. suppose there is a earthquake there will be a fracture, there will be huge mountain building systems, huge mountain will build up within a minute, within an hour. So that means catastrophism versus uniformitarianism if you say, catastrophism says it is the landforms occur suddenly. But uniformitarianism says the landforms occurs gradually with time.

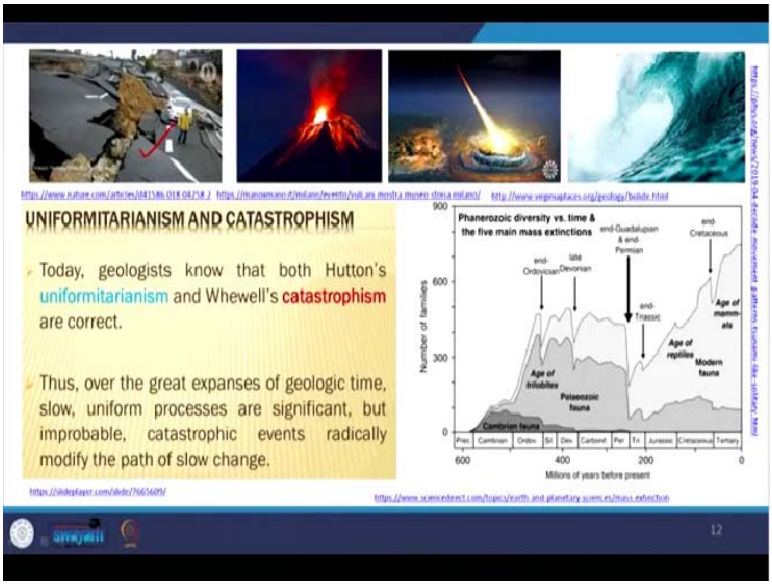
Uniformitarianism lost the debate until Charles Lyell proved Hutton to be right. This Charles Lyell was the key partner of the geomorphology, he supported the James Hutton theory and

argued yes, Hutton was right. Then many of this landforms they occur gradually that does not mean there is no catastrophic event. There is catastrophic event suppose earthquakes, volcanism, landslides, they are catastrophic events.

They occur but many of this landforms, many of the landforms they were form gradually. That is why this uniformitarian approach. So, that means, if you take a long time span in a geological timescale, suppose you take for example, thousands of year of for millions of year in a time span within the time span, the graph will move smoothly within that smoothness there will be some zigzag that will affect these uniformitaric approach to catastrophic approach.

So, those are the catastrophic events which are responsible for modifying the system. So, here are some examples of catastrophic event.

(Refer Slide Time: 23:57)



It is photographs from Nepal earthquake, after Nepal earthquake these are the systems of roads that position of the road, you can see there is a depression, there is a landform, small landform form. Similarly, we have volcanoes, it is catastrophic event, meteorite impact it is a catastrophic event, tsunami, it is a catastrophic event. All those events, they transport material from one place to another, they release huge amount of energy.

So, both energy is present and material is present. So, that is why they create new landform within a small time. Similarly, if you see this geological time scale from 0 to 600 million years, so we will say here they are the catastrophic event PT boundary, KT boundary, NQ boundary, Precambrian-cambrian boundary, these are occupied or these are characterized by catastrophic event.

So, that means there are smoothness in a curve within the smoothness there are catastrophic event they are short lived. And finally, they release huge amount of energy, huge amount of material and forms landforms within that. So, within a gradual approach, we have catastrophic approach too. So that means we can say both catastrophism and uniformitarianism they both are responsible for modifying and formation of the landform on the earthcrust.

(Refer Slide Time: 25:31)

So, now if you see if you compare these 3, one is catastrophism, another is uniformitarianism, and in between it is called gradualism. That means where catastrophic. We have some catastrophic events, volcanoes, floods, earthquakes, landslides. Once they form the geomorphic system takes a long time to respond. One event is there but to respond the geomorphic system to that event, it takes a long time.

So, this is called gradualism. So, gradualism means it is the junction or it is the transition between this catastrophism and uniformitarianism. So, mostly it is the time taken for this, the

compensation or it is time taken for the response of the geomorphic system to that catastrophic event. So, this is all about. So if we can conclude this class here, we have 3 approaches, one is called catastrophic approach another is called uniformitarianism approach.

And in between we have gradualism approach. So, catastrophism it is the sudden events, they create the landforms, uniformitarianism it is the slow processes that creates the landforms, but this gradualism approaches in between, which is the transition between the 2, which said the response time That means to catastrophic system geomorphic system respond to come to a uniformitarian approach in between this time span, it is called the gradualism approach.

So whatever the event is there, whatever the geomorphic system responds to within that time that is called gradualism approach. So it is the conclusion and we will meet in the next class. Thank you.