Glacial Geomorphology
Prof. Pitambar Pati
Department of Earth Science
Indian Institute of Technology, Roorkee

Lecture- 53
Glacial Geomorphology

So, friends, welcome to this lecture series of geomorphology and today we will discuss about this glacier geomorphology. First of all we should think, why the glacier geomorphology is important for you. See, we have already discussed about these geomorphic agents, the weathering agents, one is your river, then Aeolian system is by wind. Then we have studied the coastal geomorphology and this glacier is one of this important geomorphic agent which is mainly working at this higher latitudes and higher altitudes.

And glacier, it is though it is confined to a particular geographic region. But it is geomorphic work like it is erosion and transportation and deposition, it plays a significant role in the geological past. And we know, then in the last few million years, starting from this Precambrian to recents, this earth has been many times glaciated and deglaciated. And particularly, sometimes the whole earth or this major region of this earth surface was glaciated, and sometimes part of its glaciated and deglaciated.

So we have glacial times and interglacial times, glacial periods and interglacial periods. In the present time, we are moving through an interglacial period and then approaching to the glacial system in geological future. So, now the question arises, if the glaciation and deglaciation has occurred in the geological past, we should have evidences for it otherwise talking about this the earth was glaciated, so it is of no meaning.

So that we have that evidences, and we are searching for more and more evidences for determining whether number of glacial or interglacial periods are more or not. So, during glaciation there is particular types of environment particular type of depositional environment, erosional environments occur. And if you remember when we were talking about this initial time of modelling and the initial time introduction to geomorphology we are talking about this earth surface peneplanation.

And this geographical change due to glaciation and due to overloading. So during glaciation, there are overloading occurs on the earth's surface so that there are depressions are formed and during deglaciations, once this system removed or the glacial removed this earth it cannot come or could not come to it is original position so that some depressions are lying still there and this is called isostatic compensation or it is under compensation. So, during this deglaciation time, this type of topographical changes occurred.

And during glacial movement, some of these topography are changed because glacier though they are restricted to a particular geographical environment, their erosion is at deeper level as compared to other geomorphic agents. Rivers they erode to certain meters from this earth's surface, aeolian system, they remain there on the surface or near surface, but glacier as their density is this a material it is very heavy, a glacial body it is very heavy glacial mass it is more.

So, its movement, it creates its own channel sometimes and it is the part of this earth a few meters it erodes that means at a deeper level of erosion that is characterized by glacial topography or glacial process. Similarly, deposition also when this glacier melts, it is not able to carry this huge sediment further, so that it deposits the material as Moraines. So, it is the geological terminology. It is called Moraines.

So, that means, there will be depositional topography, there will be erosional topography, and similarly during this moment within that glacial body, this some of this geomorphological features there occur. So that has to be covered in this topic. And second thing that when there is glacier, which interacts either the lake or the ocean or some of this glacier ice sheets, they are floating on the systems.

And these glaciers, though contain some boulders, pebbles cover some sediments by melting they drop down there and is coming then forming these drop stones. So, that means there are pure glacial environments, glacio fluvial environment, glacio aeolian environment. So, different types of environment in combination of glaciers, they form different type of geomorphic features.

So, in this class, we are going to discuss about how the glacier system forms, how they move and what is the mechanism of movement, what is the, what velocity they move. If they are

moving, what are the different topographic changes that occur within their path, and what are the different topographical changes that occurred when the glacier melts. So, these type of systems and these types of topographic combinations that will be covered in this present class.

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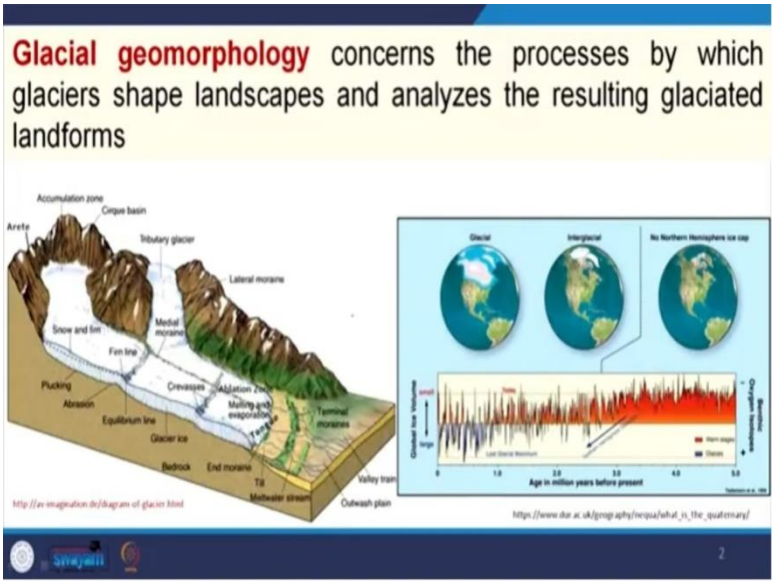

So glacial geomorphology concerns the process by which glacier shape landscapes and analyze the resulting glaciated landforms. So glaciers they shape the landscapes, they erode the landscapes, they transport the material from one place to another, they deposit where the glacier melts, so that the earth surface in particular, the higher reaches and higher latitudes. So, where change their topographic due to glacial effect.

For example, now, if you are confining yourself in the Indian context, many of these glaciers they are in the Himalayan terrain, they are moving, moving and these glaciers they are the source for this major rivers in India like Ganga, Yamuna, Brahmaputra, Ghaghara, Kosi. So, many of these glaciers they are feeding this rivers 24x7 and forming the perennial river systems.

And glaciated landforms that landform means erosional landform, depositional landform, during transportation there are also some landforms are formed, that will also be covered in this present class. So, if you analyze this figure here, there are age in million years before present. Here, if you see maximum part, it is glacial, it is interglacial. That means, you see the

maximum part of this American North American continent that was glaciated about 1 million years back.

And now, if you coming, that is 2 million years back there, this is interglacial period, only the northern part they are having glaciers. Similarly, if you are going more down only this part are glaciers. So that means due to this glaciation and deglaciation in this geological past many time major part of this landform, major part of this landscapes has been changed, and these changes will well recorded in the rock record. Now we say it is tillites or it is directite and mostly they are preserved in the rock record in the sedimentary rocks.

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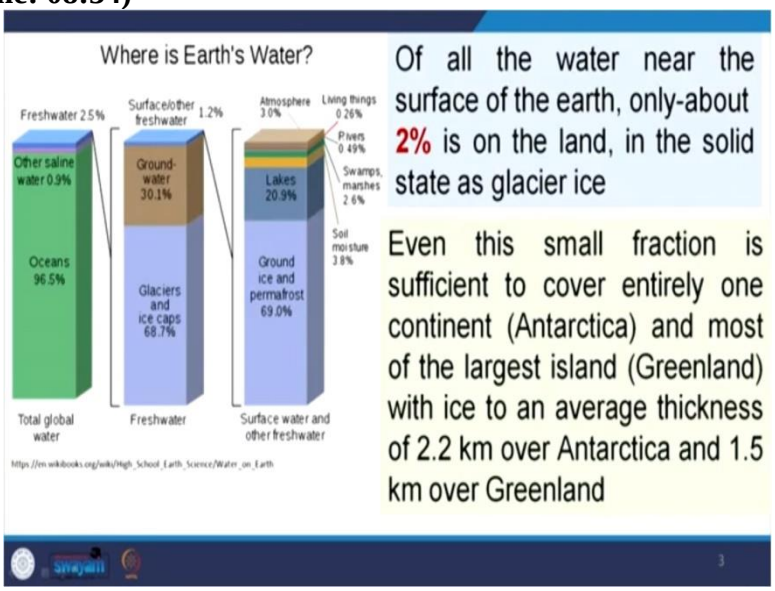

Now if we compare the water budget of this glacial system. Of all this water near the surface of the earth, only about 2% is on the land and in the solid state as the glacier ice. So here, this budget is given 96.5 it is ocean. Then other saline water is also 0.9%. But here this 2.5 is freshwater out of 2.5 freshwater, it is 68.7% glacier and ice cap and 31.1, 30.1% it is groundwater then out of this here if you see ground ice permafrost that is this much lake is this much.

So, that is this complete water budget of this earth crust. So, we can say here, this glacier it only occupies 2% of this land water 2% of this water and they are confined in the confined as solid state in the form of glacier ice. Even this negligible percent of this water, this is 2% this small fraction is sufficient to cover entire one continent that is Antarctica and another continent is Greenland, in the ice. The average thickness of 2.2 kilometers in Antarctica and 1.5 kilometers in Greenland.

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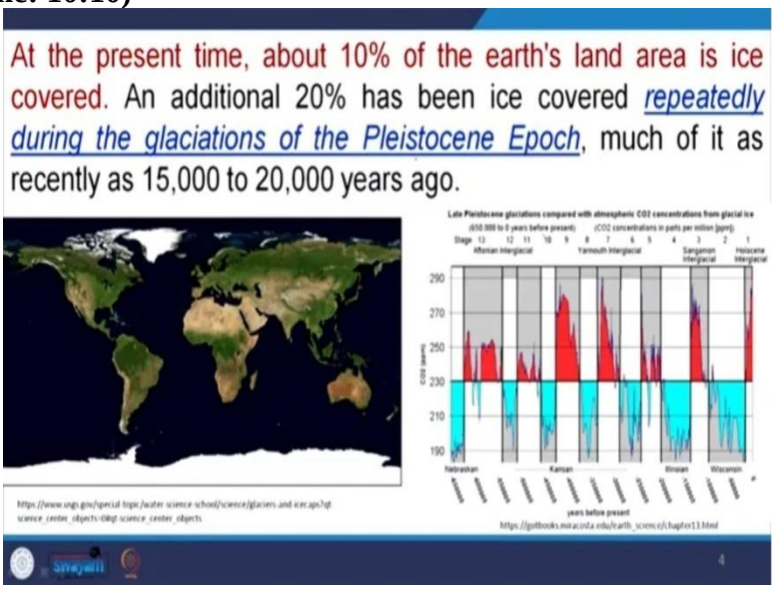

So that means this 2% water content in the glacier, it is covering the one entire Antarctica continent it is covered with ice. Greenland, Iceland, they are covered with ice. Similarly, the ice peaks in this higher reaches like this Himalayas, the Alps, the Andes so they are also glaciated. At the present time, about 10% of this earth land area is ice covered in additional 20% has been ice covered repeatedly during these glaciation of the Pleistocene Epoch, most of it as recently as 15,000 to 20,000 years back.

So that means here you see there are glaciations very recent times, it is 15,000 years back to 20,000 years back, we have glaciated surface. So, we have glacier effect very recently. So, the Pleistocene glacial is it is climate change Pleistocene glaciation Pleistocene climate change, we have already discussed in our initial classes when talking about the introduction to geomorphology.

So, that we can say very recently the earth was recovered from glaciation and the land surface is exposed. And if you see, when we are talking about this the coastal geomorphology also we are talking that a near to the coast in last glaciation time the sea level was in below 100 meters or so. So that the entire shelf was exposed and the rivers was debouching their sediments much deeper level as compared to the present. So, that means glacial time many what most of this water remains in the glaciated form and so, that the ocean level decreases, the sea level decrease and this entire surface is exposed.

So, that means it is a geomorphic modification. That means other geomorphic agents they get a chance to work in a wide area as compared to this present. So that means glacier, not only itself affecting the system, geomorphic system, it also allowing the other agents to affect very effectively in exposed surface.

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Glaciation has been the dominant factor in shaping the present landscape of North America northward of the Ohio and Missouri rivers in the Eurasia northward of a line from this Dublin, Eastern through Berlin and Moscow and beyond the Urals. So that means I want to say, major part of this Europe, European system is nowadays also glaciated and glacier is taking it is, glacier is working very effectively to change the landscape in that region.

In addition, mountains and plateaus in all latitudes has been glaciated to altitude about 1000 to 1500 meters lower than this present snow line. What is snow line. Snow line is an imaginary line, here is an arbitrary line where we know around this line there will be very less melt of the loss of this glaciers. So, here this snow line it changes with time, with climate change, with the seasons. So, here the snow line suppose for example, in this part, this is the snow line. So, here the mountains and this higher reaches of this mountains like this Alps, the Himalayas, they are also occupied by glacial ice.

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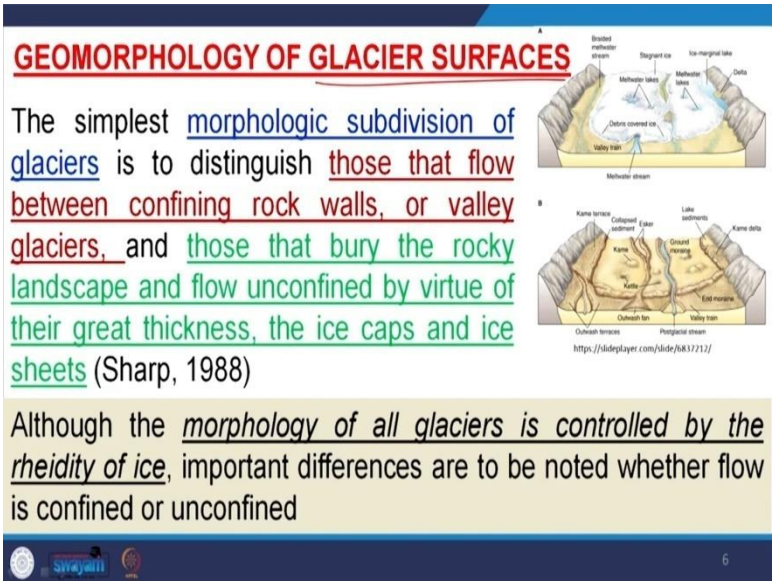

Now, we will discuss about geomorphology of glacier surface. Glacier surface here need to understand here that means, once we are forming a glacier, the glacier surface has certain geomorphology that means it is highly smooth or it is fractured or it is only undulated. If it is, so, then why what are the reason behind it? What is the, how this glacier moves within that surface, what is their internal behavior of this glaciers that is will be discussed in this present point.

That is geomorphology of glacier surface. So, the simplest morphologic subdivision of glacier is to distinguish those that flow between confining rock walls or valley glaciers and those that bury this rocky landscapes and flow unconfined by virtue of their great thickness, the ice caps and ice sheets. So, that means once we say it is glacier, it always comes in your mind that it should be Antarctic like that, it is that means it is ice sheet.

So ice sheet they also move but their movement is due to its own weight. So we are we are pressurizing it, its weight is increasing with more and more ice we are adding so it will move in which direction, it is moving in all direction. So if you see its plan view, this ice sheet movement, it is a radial in nature, it is moving in all directions. But there are glaciers mostly which are confined in the hilly terrains in the upper reaches, they are called valley glaciers.

Why? Because they are confined within this valley they are confinement within 2 walls of this valley that is that is called valley glaciers. So, these natures of work of ice sheet and valley glaciers are totally different. The ice sheets, they are unconfined, because they are

only when they are burying out this undulation of undulating topographies. But this valley glaciers they are confined within this within the topographic boundaries.

So that valley glaciers they are restricted movement within valley. Their work is confined within the valley only. But ice sheet is whole area, the whole entire area will be worked by this ice sheets. Although the morphology of all glaciers is controlled by the heredity of ice important differences are to be noted whether flow is confined or unconfined. Mostly it is says this rheidity that means, this rheidity of this glacier mass that defines this morphology of this glacier surface.

However, this either it is a confined system or it is a unconfined system that defines what type of topography will appear on the glacier surface.

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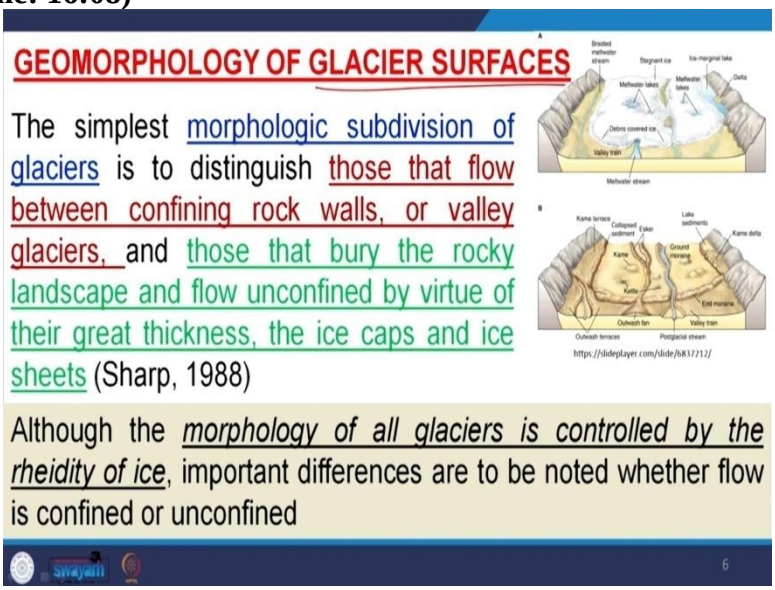

Either it is elongated or it will be radial, it will sheet like, it is moving in a zigzag pattern or moving smoothly, how at what speed or what velocity it is moving. So, all that that depends upon the rheidity of the system and this valley glaciers and this ice sheet they behave differently.

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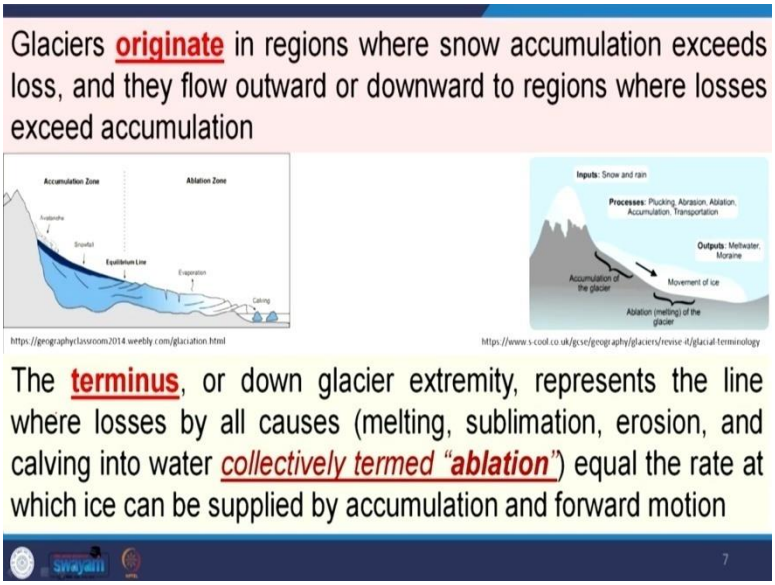

The glaciers originate in regions where snow accumulation exceeds the loss here is snow accumulation exceeds the loss. And they flow outward or downward to regions where loss exceeds accumulations, here 2 contrasting environment. It is forms where this excess snowfall is there or excess mass will be there, then it is a loss. And once they move to these regions where loss is more than their accumulations, so, 2 contrasting environment at the 2 different end to end of this glacier system.

Here if you see this photograph on this diagram, see, this is called accumulation zone. Accumulation zone, here, the loss is less as compared to accumulation. But here it is called ablation zone. Ablation zone means, here loss is more as compared to accumulations. So, that means, here we are adding the ice mass and due to its own weight, due to slope, this ice sheet is moving downward and here it is coming to this environment, where it is loss more as compared to its accumulation.

So, that is called ablation zone that is called accumulation zone. In between there is a line that is called equilibrium line. Equilibrium line that means, it says the loss and gain or the accumulation and loss is compensated. So, that is called equilibrium line. So, the terminus or down glacier extremity represents the line where losses by all causes it is all causes mean by melting, sublimation, erosion and calving into water collective term of ablation.

So, equal to the rate at which ice can be supplied by accumulation and forward motion. So, here in the terminus, that, this end of this glacier is defined only in the ablation zone, it is defined by many terminologies by, due to, it is when main work is here, the glacier is losing

its strength, it is losing its mass. So, this losing when we due to melting of ice, it may be due to sublimation, it may be due to erosion.

It may be due to calving. Calving means detaching sheets of ice, detaching blocks of ice from the main ice body or main glacier body to this water, to this, either it is to the ocean or to this lake where glacier melts. So, that is called Calving. So, this is all this terminologies they are collectively called ablation. So, ablation means loss. That means, the glacial mass of the glacier body is losing its strength, its losing its mass. So, the losing may be due to melting. So, these are the points through which the glacier lose its ice sheets, ice material, ice mass.

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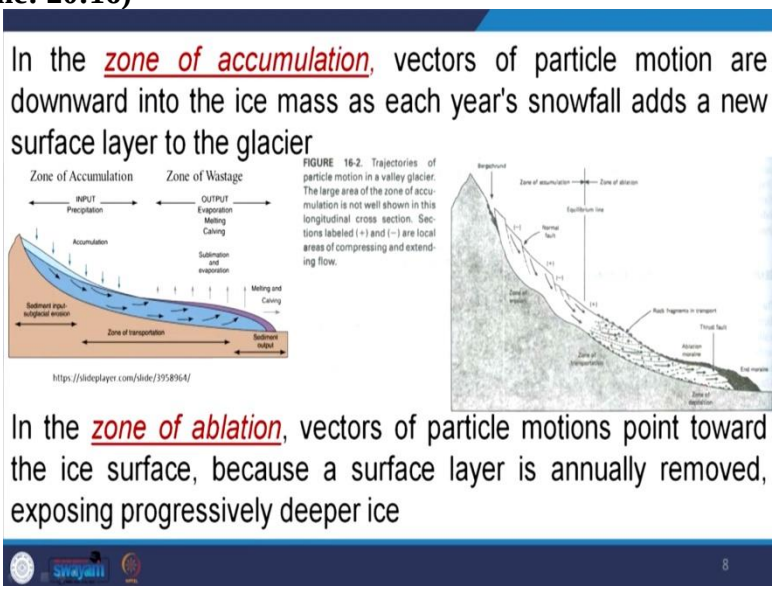

In the zone of accumulation, vectors of particle motion are downward into this ice mass as each year snowfall adds a new surface layer to this glacier. Here, this point to be understood, at the zone of accumulation that means we are accumulating ice. So we are adding one layer with another one layer with another. So the movement is downward. So for example, suppose here, earlier, this point was here.

And after one year, we are accumulating more ice here. So that means due to compaction, this it is moving here. So similarly its own weight, it is moving also downward. So in the zone of accumulation the vector of particle motion or a downward into ice mass is each year snowfall adds new surface layer to the glacier. So, here we are moving downward direction, so in the zone of ablation the zone of loss, vector of particle motion points toward the ice surface, because a surface layer is annually removed, exposing progressively deeper ice.

So if you see here, the vector is upward, it is system is upward, but here it is downward. So, this is due to addition of ice, annual addition of ice due to annual snow fall. Here due to removal of ice sheets one layer is removed. So, that deeper level material a deeper level ice is exposed to the surface. So here, net movement is upward, here net movement is downward. The vector that means the movement of this vector of this movement.

So, here if you see this in this figure, it is written the trajectories of particle motion in a valley glacier, the large area of zone of accumulation is not well shown in this longitude across this section. Some sections leveled at the plus and a minus are local areas of compression extending flow. So, here that means, the net movement is downward, here the net movement is upward. So, the zone of ablation and zone of accumulation can be distinguished.

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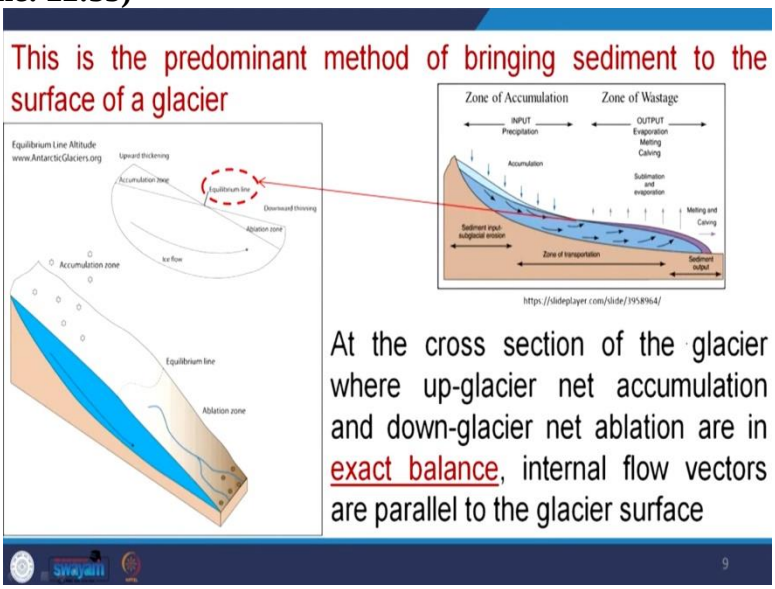

This is the predominant method of bringing sediment to the surface of this glaciers. So, the surface of the glacier, how because glacier, once it is moving, it is taking the sediments with it and eroding this material. Now, it should be below that glacier that means the interface of this glacier and this bedrock, but glacier come, this sediment comes to the surface and why it is sediment is coming to the surface, because of this gradual removal from this ice sheet. So, once at the ablation zone, we are removing the ice from the top, top level.

So, below whatever this sediments was accumulated and it is exposed, so that the sediment is transported from one place to another and its exposed to the surface. So, at the cross section of glacier where up glacier net accumulation and a down glacier net ablation are in exact balance, internal flow vectors are parallel to the glacier surface. So, that means here we can

say, one is here, it is moving downward, here it is moving upward, but here it is parallel. So, that means here this is the 3 vector which we can represent the glacier movement.

In the zone of accumulation, the vector is pointing downward, the zone of ablation the vector is pointing upward and this equilibrium with this vector is parallel to this interface or parallel to this glacier surface. And this is red line it is the equilibrium line here this equilibrium line is here and this equilibrium zone, see, this vector is parallel to the system.

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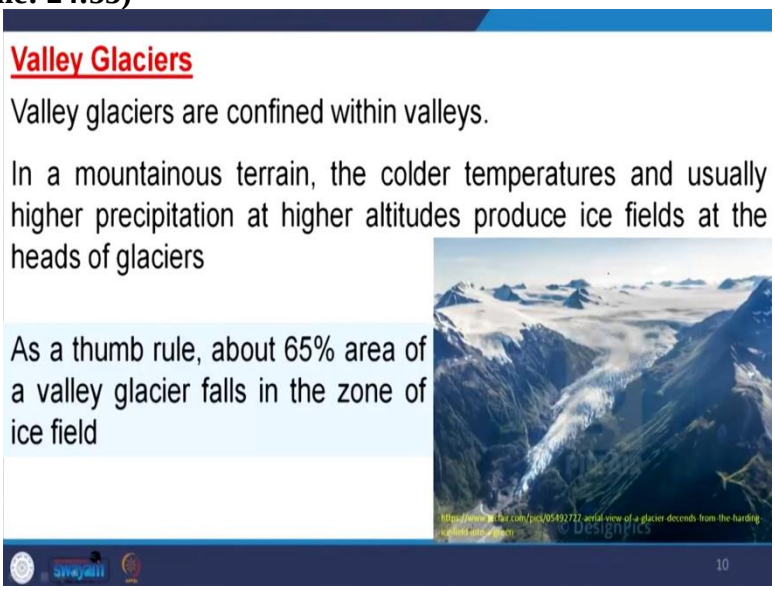

Valley glaciers, so we will talk about that we know this we have 2 types of glacier one is valley glacier, another is ice sheet. So we will talk about these valley glaciers. So valley glaciers are confined within valleys. That means here if you see this photograph, here this is this ice field. This is called ice field. That means it is accumulating ice and this ice field, it is lying somehow this, this is the contour line.

This is the contour line above this contour above this particular contour, this ice is accumulating and this is representing the snow line, this representing snow line. So, once the glacier field or the ice field, the glacier is accumulated here. Due to more and more accumulation, it weight increases. So, once this weight is increasing, due to its own weight, the glacier will try to move.

Now, what are the pathways to move. So once the glacier is moving towards different directions, wherever its getting a valley, it will follow this valley and move to downward directions. And if you remember when the last class we are talking something about this

valley wall modification on valley size or shape modification were talking the river valley may be occupied by glacier valleys in at certain times.

So, the river valleys as we know it is up for V shape and once it is occupied by glacier this valley is modified the cross section is modified and is converted to U shape. So, this, this is the evolution of the mountain valley system. So, in a mountainous terrain, the colder temperature and usually higher precipitation at higher altitudes produce ice fields at the heads of these glaciers. These are the ice fields that mean these are this background or these are this ground, hunting ground for this glacier to accumulate.

So, glacier, there fed ice from this ice fields. As a thumb rule, about 65% area of these valley glaciers falls in the zone of ice field. So here, the ice field plays a major role. Because to fed a valley glacier we need to continuous supply of ice otherwise it will, it will that means ablation will occur, this valley glacier will finally it is vanish. So that means to continuous supply this ice to this valley glacier, this ice fields this plays a major role in the continuous supply ice to this ice field to the to the valley glacier.

So that the valley glaciers becomes active and remain active throughout its movement through this valley. So, I think we should stop here. And in the next class we will talk in detail about these valley glaciers, its characteristics, how they move, what are their behaviors during movement, and how, what are these landscapes they form during their movement. So thank you very much. We will meet in the next class.