Glacial Geomorphology
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Lecture- 54
Glacial Geomorphology – II, Valley Glacier

So, friends, welcome to this lecture series of geomorphology and in this class we will continue with this valley glacier that we are talking in the last class. So, valley glacier or ice sheets are 2 different modes of glaciations, ice sheet that means it is covering entire area and its thickness is about 2 kilometers in average. And this movement is due to its own weight. And valley glaciers they are confined within this valleys in the mountains.

And are continuously fed from this ice field which is adjacent to this valley glaciers. And if you see this photograph, so, this is, this is a valley glacier and this entire is representing the ice field. So ice field continuously provide glacier ice to this glacier to maintain its velocity, to maintain its continuity, otherwise it will be in the ablation zone. So, as a thumb rule about 65% area of this valley glacier falls in the zone of ice field. So that means, less is in form of valley glacier, more its in form of ice field. So that it accumulates more ice and continuously supplying to this valley as valley glaciers.

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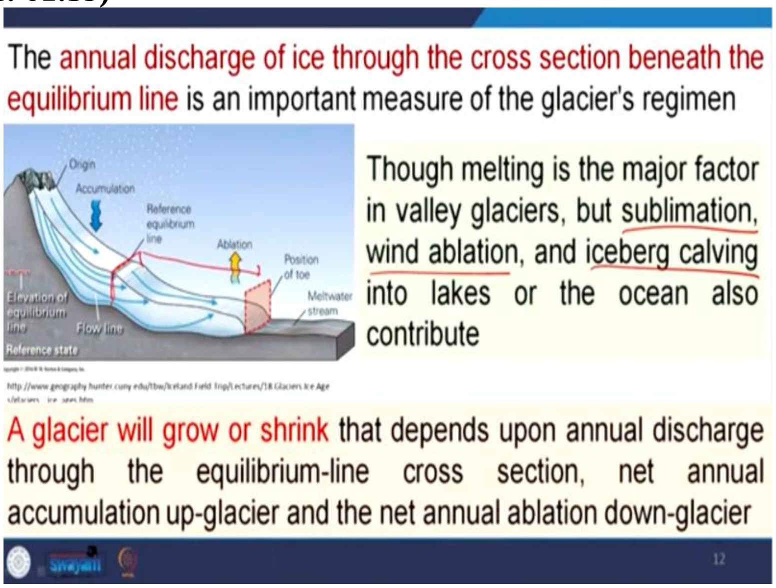

An annual discharge of ice through this cross section beneath the equilibrium line is an important measure of glacial regimen. Though melting is the major factor in the valley glaciers, but sublimation, wind ablation and iceberg calving are also takes into account for the contribution to ablation. So, that means, we have different ways of losing of ice. One is this, this ablation zone is due to sublimation is there, then the wind ablation is there, then iceberg calving is there erosion is there. So, that means by these are the ways this ice mass reduces gradually.

A glacier will grow or sink, that depends upon annual discharge through this equilibrium line cross section, net annual accumulation of glaciers and the net annual ablation in the down glaciers. So, to what extent the glacier will sustain? It will what extent it will continue whether it will remain there or it will melt that depends any observation is made this cross section, along this cross section through this equilibrium line.

Like we, they calculate the discharge, river discharge, the sediment discharge during this at different gauging stations. Similarly, this equilibrium line is one gauging station of this glacier at where we calculate how much glacier ice is being transported down glacier side, and how much it is accumulated at up glacier side, how much it is moving per day or whatever this unit you take. So, this measurement here is defines whether the glacier will or glacier will melt.

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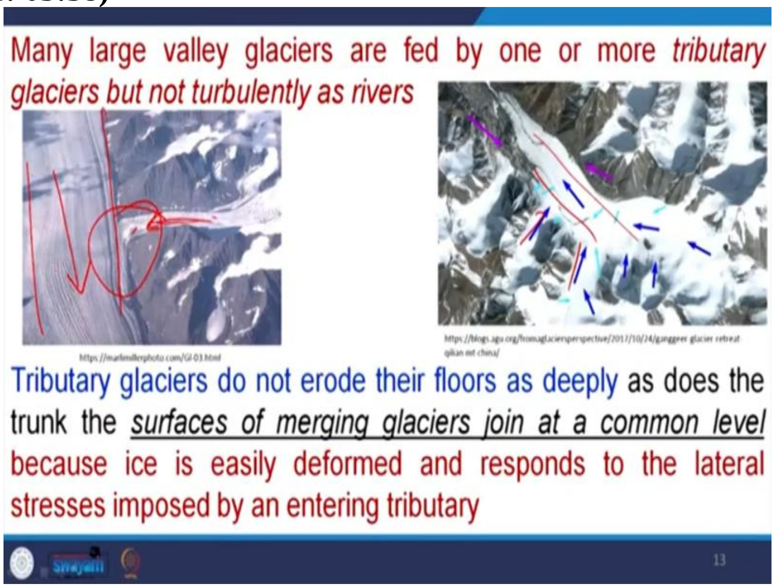

So, many large valley glaciers are fed by one or more tributary glaciers, but not turbulently as rivers. So, it is very interesting fact. So, there are 2 different levels tributary glaciers they remain at this higher level and the trunk glaciers they remain somewhat at lower level and though they contribute their ice at to from, from a higher level to a lower level, but at this confluence, this system, this level is same, this is due to the deformation.

That means this glacier can easily be deform, so that this level becomes equal. So, tributary glaciers do not erode their floor as deeply as does by these trunk glaciers. The surface of merging glaciers join at the common level, because ice is easily deform and respond to this lateral stress imposed by an entering tributary. For example, if you see in this figure here, these are the deformation.

Now see, these are the tributary glaciers and it is contributing this main glacier, valley glacier here, these are the deformation line these are the deformation line. So, that means, the ice can easily deform, ice can easily adjust themselves. So, here if you see here these are the deformation lines. So, that means the contribution from this tributary glacier and once it is mixing with the main glacier, the main deformation zone is here. So, due to deformation, the level changes and the level become equal to join at the uniform levels.

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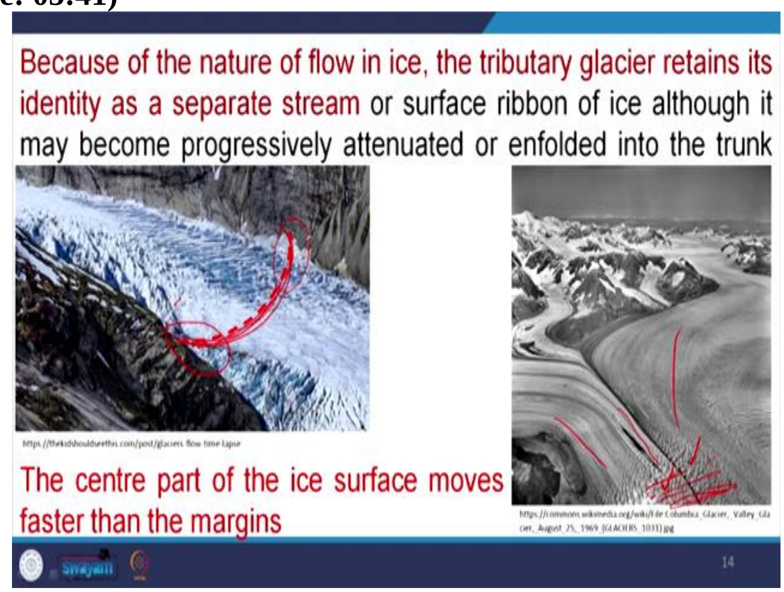

Because of this nature of flow of ice, the tributary glaciers remains there, retains its identity as a separate stream or surface river of this ice, although it may becomes progressively attenuated and enfolded into the trunk. So, that you see here suppose this is the valley glacier and this is the trunk glacier. Now, 2 glaciers they are merging together, but you see there separate identities there, you can distinguish this glaciers from this glaciers.

So, this is this identity, it continues for kilometers, for few kilometers and gradually these 2 glaciers merge and finally becomes one. So, this is due to this rheidity of these glaciers. This central part of this ice surface move faster than this margin. Very interesting fact here, if you see this in the valley glacier, and it is moving, the center part is moving at a higher velocity as compared to its side.

So, this is due to dragging effect. Here it is interacting with this valley here it is interacting with the valley and they, once you say this interaction is there, so, there will be dragging mechanism, but here it is free to move. So, that this cross section of velocity will be on the surface velocity will be like this crecent. So, that is convex towards the downstream.

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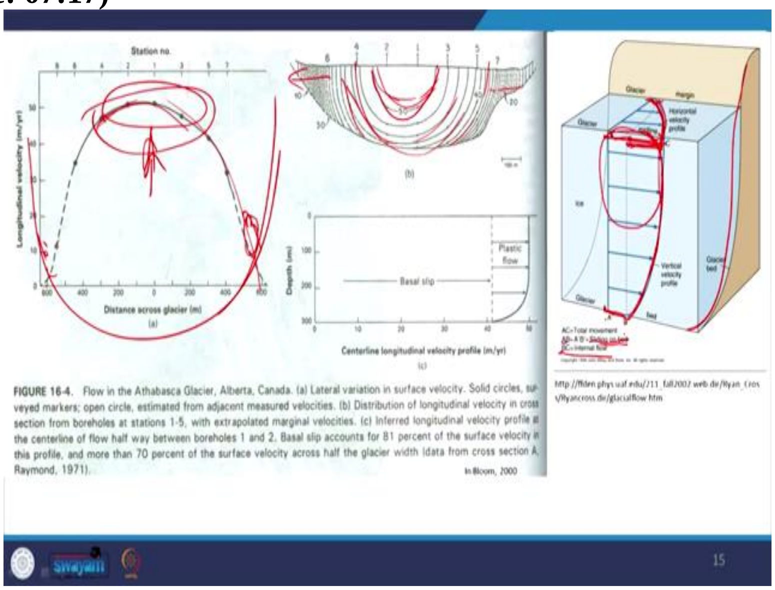

Now, here if you see these figures are given representing this surface velocity as well as the internal velocity of these glaciers. Here, this is the surface velocity it is given and the surface velocity if you see the surface, the middle part of this glacier, it is moving at a higher velocity as compared to the valley side. So, this is the valley if you see, at this valley, due to dragging effect, this velocity decreases, but at this middle part, the velocity is more.

Similarly, if we go through this cross section, this, through this cross section you will see this velocity is more here and gradually it is decreasing and decreasing. The same thing also, if you remember, when we were talking about this fluvial geomorphology, the same thing as the rivers. The rivers velocity here it is maximum and gradually it is go down and down and here it is towards the side of this valley, it is also reduces.

And this is an interesting figure, which represents both this lateral that means surface velocity as well as the internal velocity, the sliding frictions, and this internal deformations or internal flow. If you see here, this is the valley, and this filled with, this blue one is filled with ice. Here once you are coming away from this valley side, this is valley and once we are coming away from this very side, this velocity is increasing.

Similarly, if we are moving towards the bedrock toward this base of this valley this velocities decreasing. So, this means these are this area where we are encountering maximum velocity of glaciers. So, here this A C is the total movement, this is A and C, this is total movement is here, then AB A’ B’ this A’ B’ here. This is due to this A’ B’ and AB, it is due to slide on this bed, this slide on this bed is this much, this must and what is BC, this is the internal flow here, this is the internal flow.

So, that means that particular instance you see, here, this BC is more than AB that means here internal flow within the glacier is more as compared to its slide on this bed. So, slide in this bed the velocity acquired by sliding on the bed is less as compared to its internal flow. So, that that means glacier movement in a particular direction at a particular place or a particular side is more due to its internal flow as compared to its sliding on the bed.

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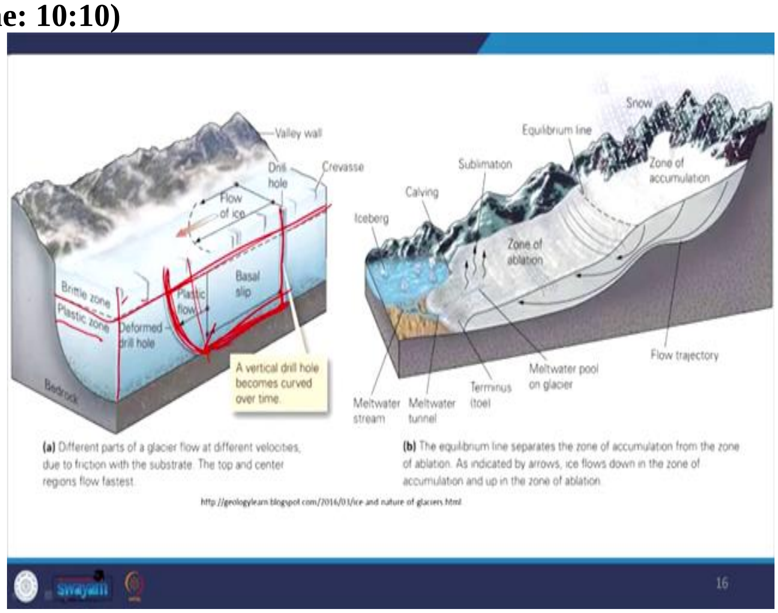

So, here an experiment was carried out by inserting a drill hole here, if you see this is the drill hole, and this drill pipe was here after few time, after some time, if you see this system is here, but the shape of this this point has migrated to this place, but the shape of this drill pipe is bending like this. So, this is due to this internal flow and this is due to sliding on this bed and this is this much this sliding on the bed if you remove this sliding on the bed, this is due to internal flow.

So that means internal flow is always more than the sliding flow on the bed. And if you move downward from the surface to this bedrock level, gradually, these characteristics of the rheology of this glacier, it changes. At this upper part here we are getting the brittle zone and below that it is plastic zone. So, that means at the upper part, the glacier can be broken into pieces, it is brittle, it fragments, but later on once we are going downward, it is plastic deformation is there. So, that means, the rheology changes with depth, the internal velocity changes this frictional, sliding friction with this bed is less as compared to its internal flow.

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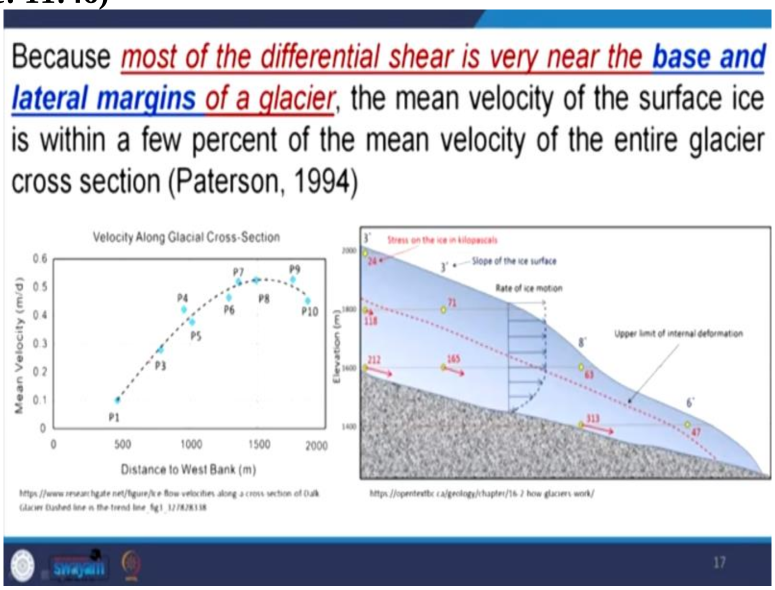

Because most of this differential shear is very near to the base and lateral margins of this glaciers. The mean velocity of the surface ice is within a few percent of this mean velocity of this entire glacier. So, that means, this glacier, it is moving at a faster rate at a surface level as compared to the sub surface level.

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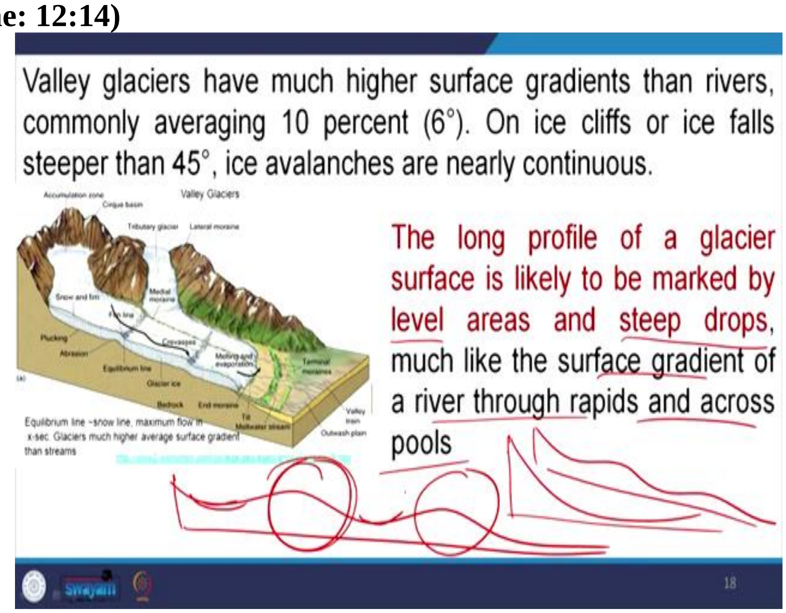

Valley glaciers have much higher surface gradient than rivers. Commonly average of 10% or 6 degree. On ice cliffs or ice falls, it is steeper than 45 degree, then in ice avalanches it is nearly continuous. The long profile of a glacier surface is like this river profile. So, here is marked by some steep drops and marked by some levels, areas of steep drops much like this gradient of this river through rapid and across pools that means, in ideal cross section, in ideal river profile, it is like this.

That means concave upward and if you, we have some rapids, some lakes, some other types of local base level is there. So, we get a changes like this is not it. So, similarly, in the glacier surface also, if we are taking this cross section, it is like this. And these are, these areas where we can say this is the, the bedrock is exposed, the latches of bedrocks are exposed and this area is represented by extensional flow and these areas are represented by compressional flow.

So, that means, within this movement from head to mouth, within the glacier, the flow velocity does not remain same. Similarly, there are certain areas where there are compression within the glacial mass and some areas where extension in glacial mass. So, this extensional mass is represented by particular type of deformation that is called crevasses.

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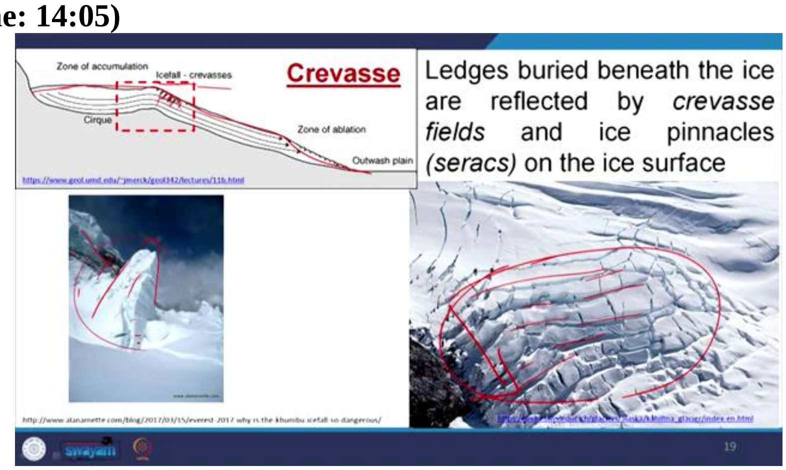

So, what are the crevasses if you see here, this is this profile of glacial surface and if you see the glacial surface is not as smooth as river wall. Here, these are the areas where ice fall or crevasses and you see these fractures. So, if you zoom it, real field photographs, here, these are these fractures and these fractures if you see there are more or less parallel with each other. And this is the direction of the glacier movement and these fractures are produced, where there are latches up bedrock exposed to these surface.

So that here we are getting this extension and we are putting this extensional cracks. So crevasses they are these extensional cracks within that ice surface. So, ledges buried beneath this ice are reflected by crevasses fields and ice pinnacles on this ice surface. These are this ice pinnacles and this, this here we are getting some extensional cracks and these ice pinnacles and crevasses, they represent the extensional regime within that glacier surface.

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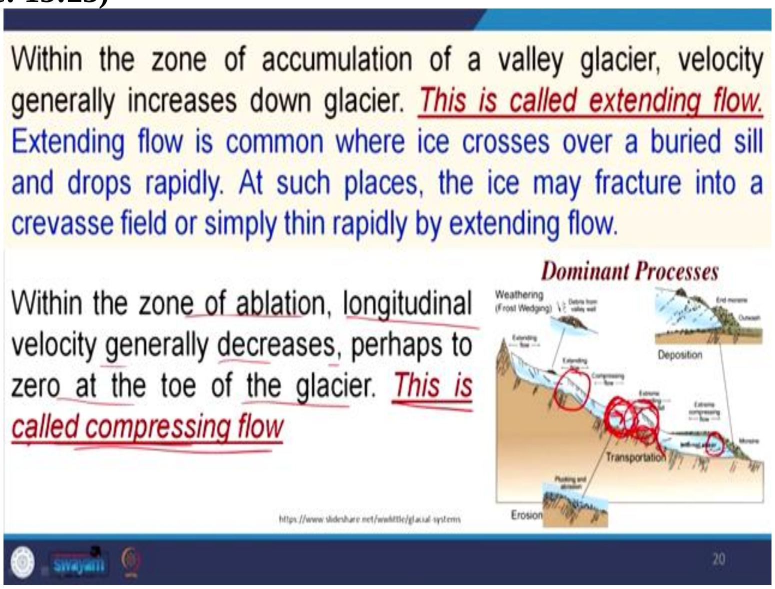

Within the zone of accumulation of valley glacier, velocity generally increases down glacier. This is called extending flow. Extending flow is common, where this cross, ice crosses over the buried sill and drops rapidly. At such places the ice may fracture into crevasses, crevasses field, crevasse field or simply within the rapid by extending flow. So, that means there are 2 types of flow one is extending flow, here we are getting some extending flows and some areas just backs up this extending flow, we are getting some compressional flow.

Why compressional flow occurs. Now within the zone of ablation, longitudinal velocity generally decreases, perhaps 0 at the toe of the glacier. This is called compressional flow. Here, where we are getting some compressional flow. Similarly, if we have some latches like this, so here, this is this, this area, here, compression occurs. Because this becomes a speed breaker, so that ice mass accumulates here, it thickens here. So here, this is the compressional flow, and here extensional flow. So that means within the ice mass there are differential movement.

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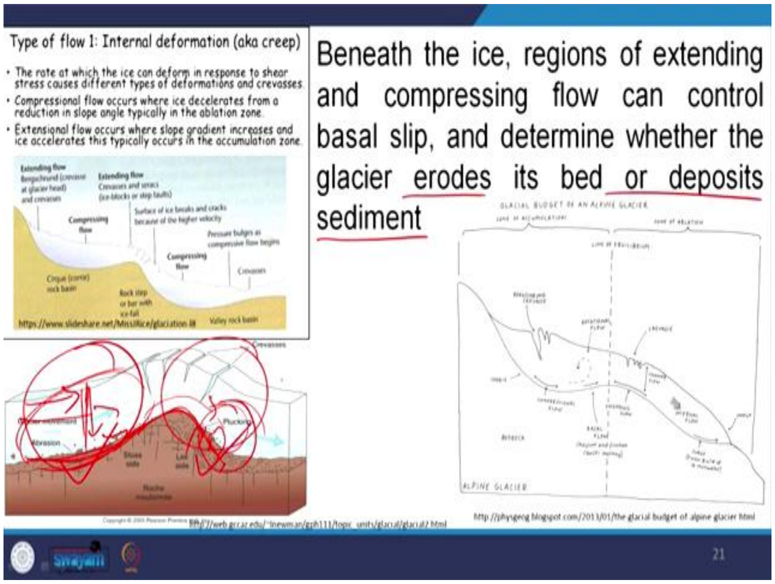

Beneath the ice, regions of extending and compressing flow can control basal slip, and determine whether the glacier erode its bed or deposit sediment. It is very interesting to see. Within that glacier movement, whether these glaciers erode material or deposit that depends upon this which type of flow is associated. For example, if you see here, this is glacier movement, and this area is representing compressional flow, and this area is representing extensional flow.

So, once were moving glacier in this direction, and were restricting its movement by this, so, here ice accumulation occurs. So the thickness of ice becomes more. And due to this ice mass accumulates here, it shear stress is such as moving here, shearing on this bedrock surface is more, so that abrasion occurs, more abrasive topography, more abrasion topography will be confined in here.

But once it is moving here, it that means here ice is extending extensional flow. So here, plucking occurs. So that means whatever the fractures are, what fractures are there, through the fractures, these plucking of material occurs, the blocks, they are plucked by this glacier and this is due to plucking, erosion occurs at this side of this downside of these ledges. So, that means here we have compressional system, here we are getting extensional system. Here due to abrasion, here due to plucking so 2 different types of geomorphic work is there.

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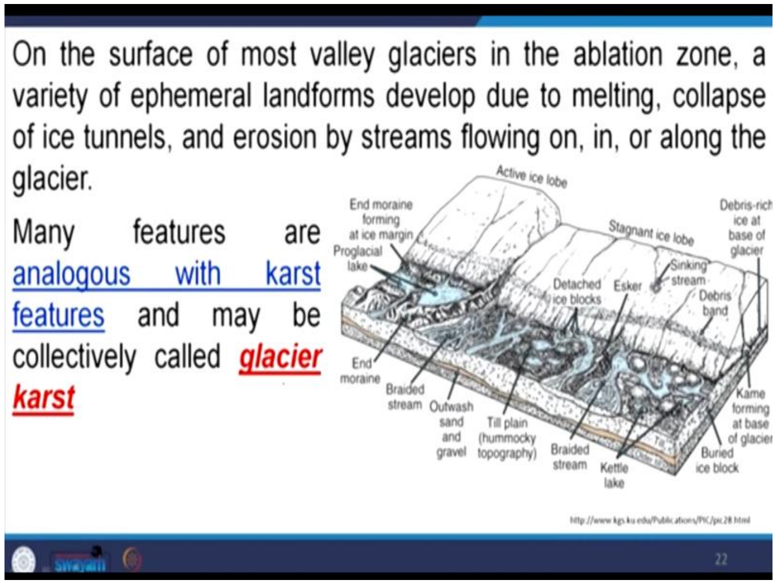

On the surface of most valley glaciers in the ablation zone, a variety of ephemeral landforms develop due to melting, collapse of ice tunnels and erosion by stream flows on it and along these glaciers. Many features are analogous to this karst topography and the karst features and maybe called at glacial karst. So if you see here, once a glacier is accumulated at a place in the ablation zone.

So, that means it is losing this glacier mass. So, this losing maybe due to ablation and due to sublimation, due to calving, so that means part of a glacier body, part of the ice body, it detached from this main body and its going. Similarly, due to melting water is coming from inside of this glacier. So, this water coming through proper channels and it is creating a tunnel within the glacier body. So, within this tunnel, if there will be a collapse of tunnel, so, that means part of the glacier mass is removed.

So, that means, I want to say very irregular topography is formed, very irregular topography within that glacial body. So, this is equivalent to karst region.

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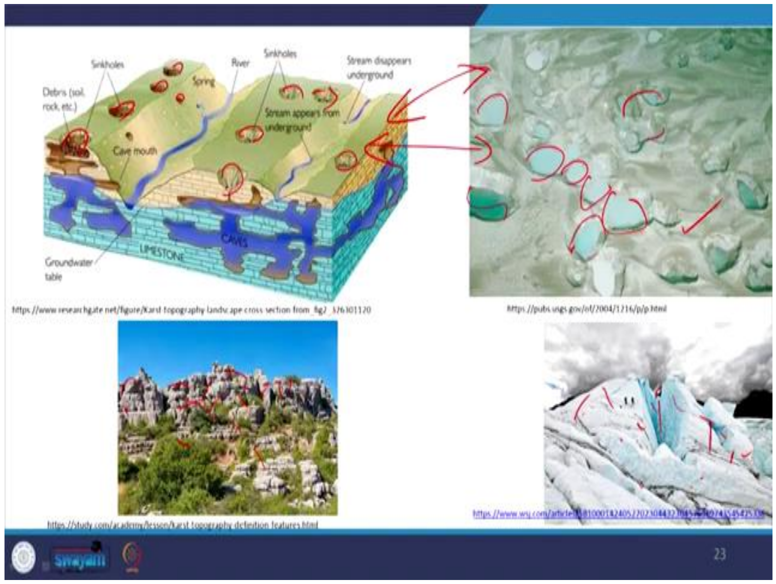

For example, if you see these photographs, this is the mass of the glacier and some fractures like this, some topography you see these are this pits and here this within that glacier, this is the whole entire photograph is representing glaciated surface. So, here there are some of this pond type accumulation of water is there and if you compare this similarity of this with this, this karst region. See, along this karst region, there are uvalas, sinkholes.

So, other types of this blind valleys, caverns. So, there are many types of topographic, many types of geomorphological features out there. So, that means, look wise and geometry wise, these 2 topographies they are looking similar. So, that is why it is called glacial karst and here if you see the karst topography, how irregular topographic how irregular arrangement is there. Similarly, here some irregular arrangement is there, not this profile is not as smooth. So, that is why this system is called karst topography or this glacial karst in terms of glacier is concerned.

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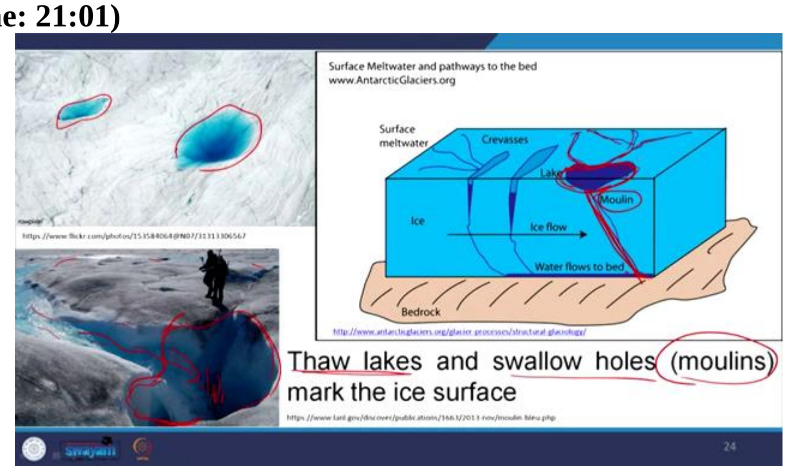

And there are 2 other types of features that are found in this glacier system one is called Thaw lakes and Shallow holes, this is called terminology which is called moulin, so marks the ice surface. See here, thaw lake, here it is the thaw lake. Thaw lake means, it is a lake, it is a pond, accumulation of water, but below it is not, it is not connected with the bedrock through fracture or throw any holes or so, it is that means, it is a zone of water accumulation, it is called Thaw lake.

But, once it is, it is connected to this through this fracture to this bedrock, here, if you see there is a hole, there is a sink hole type in terms of karst topography there is a sinkhole type so that means this water is gradually down to the system, it is percolating down this is the ice surface or the glacial surface. And here due to melt water is coming and it is percolating down through this hole and it is equivalent to the sink hole of karst topography.

So, this type of topo or these types of features, this ponds and its subsurface, it is connected to this bedrock through the fracture or through hole, so, number of fractures, so, that it behaves as water accumulation zone. Here, you see the streams there are supplying water to this moulin system and it is associated with the bedrock then this terminology moulin is used. So, the difference between this terminology Moulin and Thaw lake is that, thaw lake it is not associated anyway to this bedrock through fractures, but moulin it is associated with bedrock through fractures.

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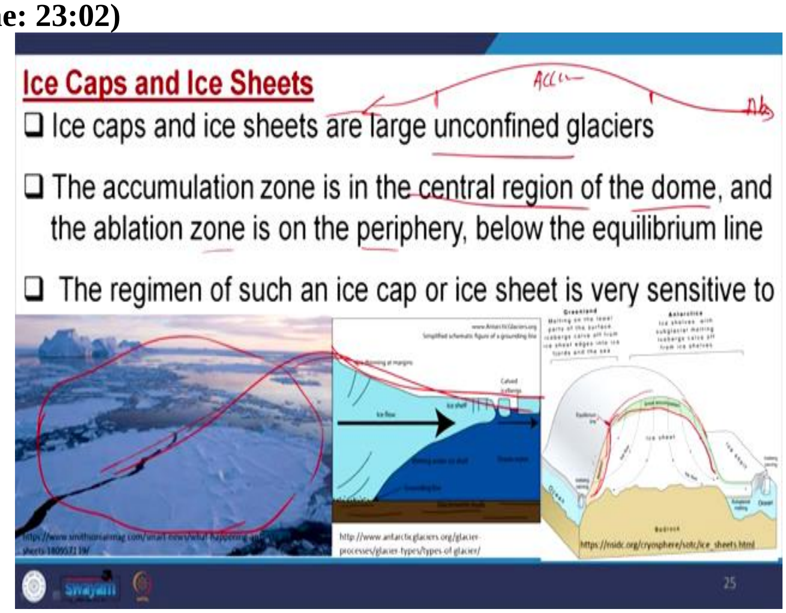

Ice caps and ice sheets. So, so far we are discussing about this valley glaciers. So, valley glaciers, they are confined within the valley. Now, we will talk about this second part of this ice system that is called ice caps. So, that means here this topography is near about smooth and it is the thickness is about to 1.5 kilometers or 2 kilometers on average. And this glacier movement is due to its own weight. Ice caps and ice sheets are large, unconfined glaciers.

Here it is large unconfined glaciers. It is not confined it is free from any sides, all sides. The accumulation zone is the central region of this dome and the ablation zone at the periphery, below the equilibrium line. But in the valley glacier we have the equilibrium line, which is a cross section on the valley, but here as we see it is ice sheet. So, here this may be, this may be this equilibrium line.

So, that means, here it is the unconfined system, here the accumulation zone is at the center it is that means, if we are talking a cross section, it is looking like this similarly, other side it will move like this. So, that means, in a cross section, this ice sheet will be like this. So, the center part this is the accumulation zone and this side they all side you are looking a cross section with all side it is ablation zone and somewhere here maybe the equilibrium line.

So, that means the accumulation zone at the central region of this dome and the ablation zone at this periphery below the equilibrium line. If you see here, this is the accumulation zone this green color, this is the accumulation zone and this side is the ablation zone. And here this is the equilibrium line, the regimen of such an ice cap or ice sheep is very sensitive to temperatures. So, that means with increase of temperature, this ice sheet, it melts, the equilibrium line shifts and this cross section also changes.

Both vertically it is go down and laterally it sinks. So that means it is as it is unconfined the system. So this shrinkage is from all sides. And similarly, at the from the top and from the 4 sides or all sides of the system. Any increase in accumulation will increase the height and therefore, the area of accumulation zone related to this ablation zone resulting in further acrated growth, acrated growth. Acrated means addition. Acration means addition.

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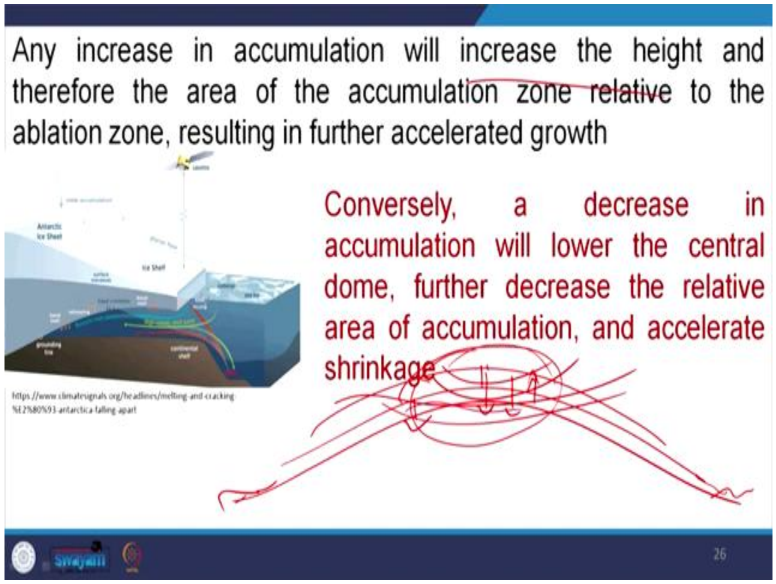

So any increase in accumulation will increase the height. Because we know that this surface it is looking like this cross section is looking like this. And these are these regions of accumulation. So once we are adding the ice here on the adding, that means we are increasing the height of this dome. So increase the height of the dome in the accumulation zone and resulting in accreted growth. So accreted, that means we are adding the system.

Conversely, a decrease in accumulation will lower the central dome further decrease the relative area of accumulation and accelerate shrinkage. So that means once we are removing the system, we are also decreasing the system like this. So that means addition and deletion or addition or loss and that means accumulation and ablation that occurs at these zones. So that means, once we are got ablation on this that means once we decrease the accumulation. So this dome height will decrease, but a ablation zone will be this side and the side. Here, we are decreasing the accumulation. So that means the dome height was decreasing.

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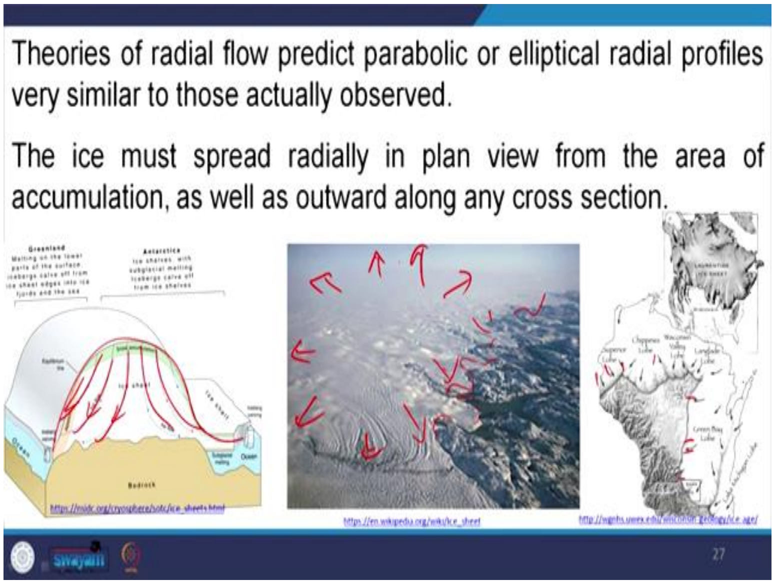

Theories of radial flows predict parabolic or elliptical radial profiles very similar to those actually observed. The ice must spread radially in plan view from this area of accumulation as well as outward along this cross section. So now you see here, we are talking here, we are talking about a cross section. Here you see this system; it is shifting that means from outward. This movement is from the central part to outward.

Similarly if you see here, these are the different lobes of this ice sheets and this ice it is moving outward. So, this is radial flow that means, if you see here, in all sides, this glacier mass, it is from all sides it is moving down. So, that means here it will move here, here. So, that means ice sheet the movement is for every sides on that means from all sides of this system from the central part, and in a cross section, we can say it is from outward from central part to outward.

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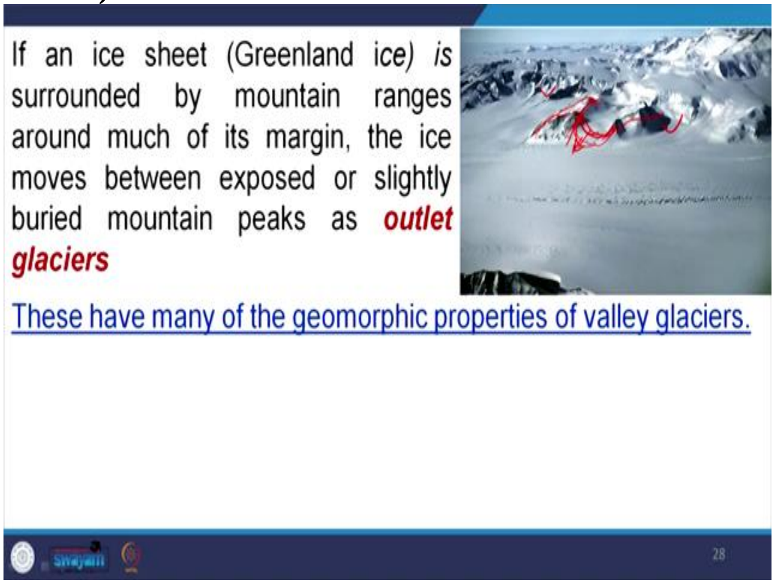

If an ice sheet suppose in Greenland, it is surrounded by mountain ranges around much of its margin, the ice moves between exposed or slightly buried mountain peaks that is called outlet glaciers. And these have many of these geomorphic properties similar to valley glaciers. So, that means suppose a ice sheet is forming and that ice sheets within this mountain system, this is burying a mountain system and within that valley, there are difference, differential movements.

And here suppose these valleys of this mountain peaks are not completely buried. So, that means, here this part, this part, this part, this whatever the movement of glacier is there, it is similar to this movement of a valley glacier, but because in locally this part of this glacier, it is behaving like a valley glaciers. And these type of glaciers, a part of this main glacier or the ice sheet, but at the periphery or at the certain valleys where these peaks are not totally covered along these different peaks the glacier is moving in a confined.

This movement is a confined movement and its properties it is similar to that of this property of valley glaciers. So, that means the ice sheet though it is continuing a large covering a large area, which thicknesses is more at this central part, it is spreading sideway from this central region. But at this periphery, it is if or within that body if the peaks are there, which are not covered by ice and this glacier or this ice sheet is moving through this different peaks.

So, it local this behaves as valley glaciers. So, that means I should stop here. And we will meet in the next class. We will talk about more about this glacier sheets or something else. Thank you very much. We will meet in the next class.