Geomorphic Processes: Landforms and Landscapes
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Lecture - 29
Glacial Landforms (Part II)

So welcome back, so as we were talking in the previous lecture that mainly the cycles, which we discussed the glacial and interglacial cycles will keep happening because of the changes which we discussed in the Milankovitch theory and that is obliquity, precession and eccentricity. So these are the and then they have different time periods, there in which those changes will take place.

And because of this changes we will also have change in the climate because the distance between the or the radiation, which we are receiving from the Sun that distance will keep varying and also when we were discussing the plate tectonics part we also talked about that the India was a part of the Gondwanaland which was located in the southern hemisphere which had an glacial environment in the past.

And suppose if you change the polarity where the north will become the south pole and south pole becomes the north pole. So in that case also you will have different climate and different locations.

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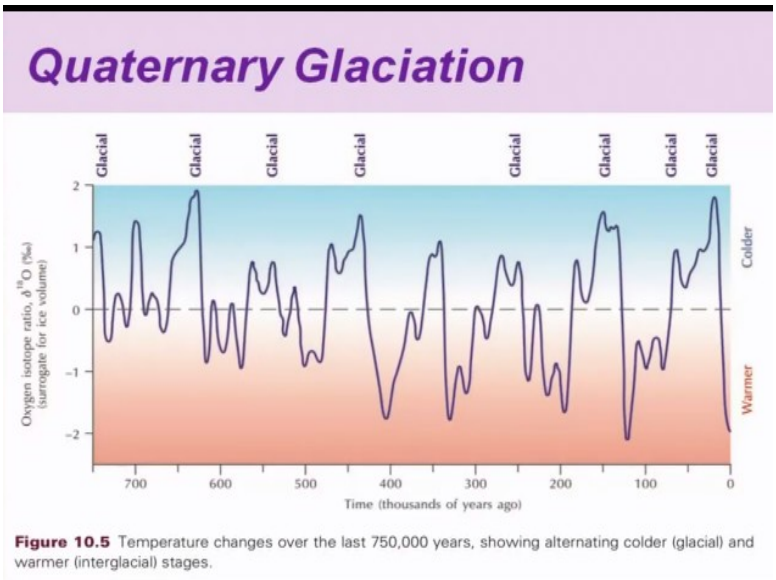

Figure 10.5 Temperature changes over the last 750,000 years, showing alternating colder (glacial) and warmer (interglacial) stages.

Now moving ahead with the understanding what we discussed in the previous lecture, the quaternary period shows much of the fluctuation in terms of the glacial cycles and that is glacial and interglacial cycles.

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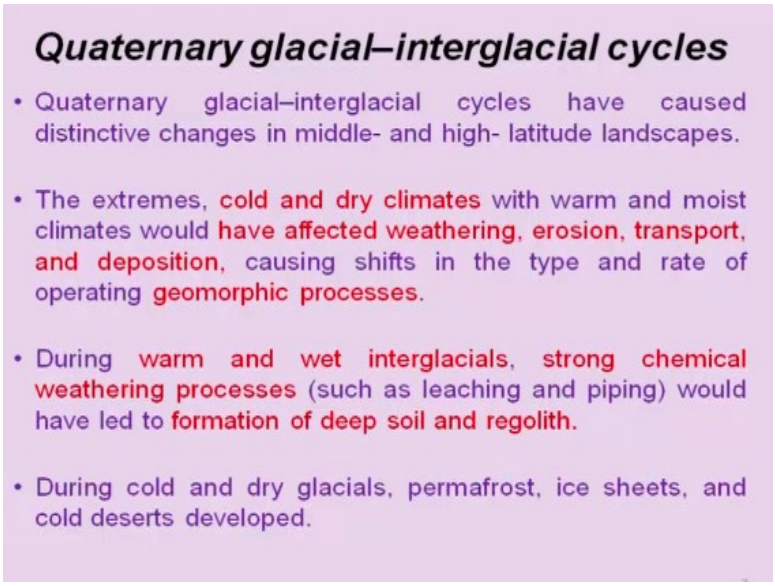

So quaternary glacial and interglacial cycles have caused distinctive changes in middle and high latitude landscape. So studying this landscapes helped us in understanding the climate change also. The extremes cold and dry climates with warm and moist climates, climate phases would have affected weathering, erosion, transport and deposition causing shifts in the type and rate of operating geomorphic processes.

So this is one another important point which helps us or we can say that why understanding of glacial landforms are important because if you move towards the warmer climate then you are melting snow or they will be in glacial retreat. So more water on Earth's surface, which will affect weathering of the material on the Earth's surface, which will lead to erosion which will lead more sediment supply.

So this will also create into loading and unloading of the areas as well as increase or we can say sea-level rise also. So overall geomorphic processes will be affected during warm and wet interglacials, strong chemical weathering process such as leaching and piping would have led to the formation of deep soil and regolith, whereas during cold and dry glaciers, permafrost, ice sheets and cold deserts developed.

So there is a difference which is seen in terms of the different climatic regimes, glacial and interglacial either it is cold and dry climate or warm and wet climate, which will trigger the operation of geomorphic processes and will result in to the formation of or sculpturing of different type of landscape.

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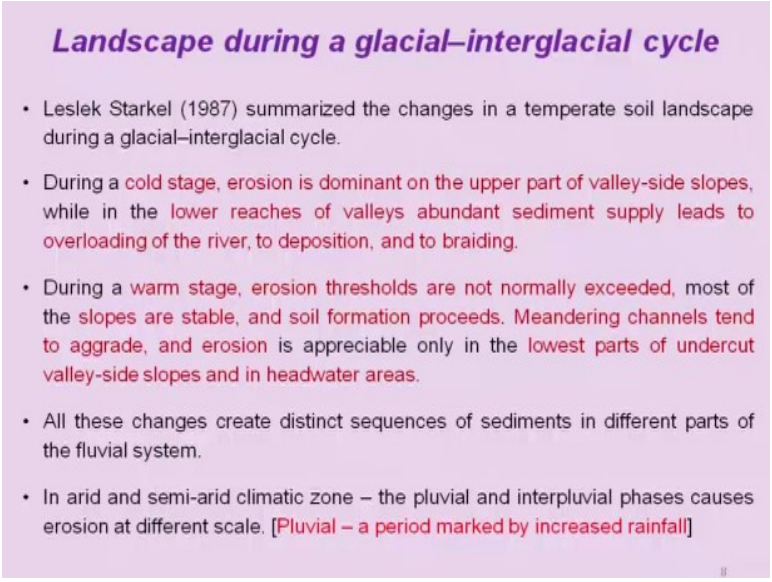

Now landscape during a glacial-interglacial cycle, now Starkel in 1987 summarized the changes in a temperate soil landscape during a glacial-interglacial cycle. So what was been suggested that during a cold stage erosion is dominant on the upper part of valley-side slopes. So this suggests that in the upper reaches or in the headword region there will be more erosion and that will be during the cold stage.

While in the lower reaches of valleys abundant sediment supply leads to overloading of rivers to deposit and to braid. So here again comes the importance of drainage system. So if you increase the load of the sediments because of the erosion in the upper reaches, the channel pattern will also get affected and more amount of sediments will be carried or will be available to the rivers to carry and grade in the downstream.

So if you look at again that during a cold stage erosion is dominant in the upper part of the valley slope while in the lower reaches, abundance sediment supply will result into over loading of rivers will lead to the position and braiding of channels. Now during warm stage, erosion threshold are not normally exceeded most of the slope are stable. Now during this stable stage it will result into the soil formation.

And what we see is meandering channels tend to aggrade and erosion is appreciably only in the lower part of the undercut valley sides. So in the lower part of the basin you will see the erosion or undercuts and in the headwater radius, but the erosion will be appreciably seen only in the lower part of the valley side slopes. All these changes creates distinct sequence of sediments in different part of fluvial system.

For example, in arid and semi-arid climate zone the pluvial and interpluvial phases causes erosion as different scale. So pluvial actually is a period marked by increased rainfall and this is mostly common in such regions where you will have and phase or a period with increased rainfall in arid and semi-arid climate. So this is another important part or the portion which talks about that you are having cold climate then what type of landscape you will envisage.

And whether it will result into the erosion in the upper reaches or the lower reaches and what will happen during the warm stages.

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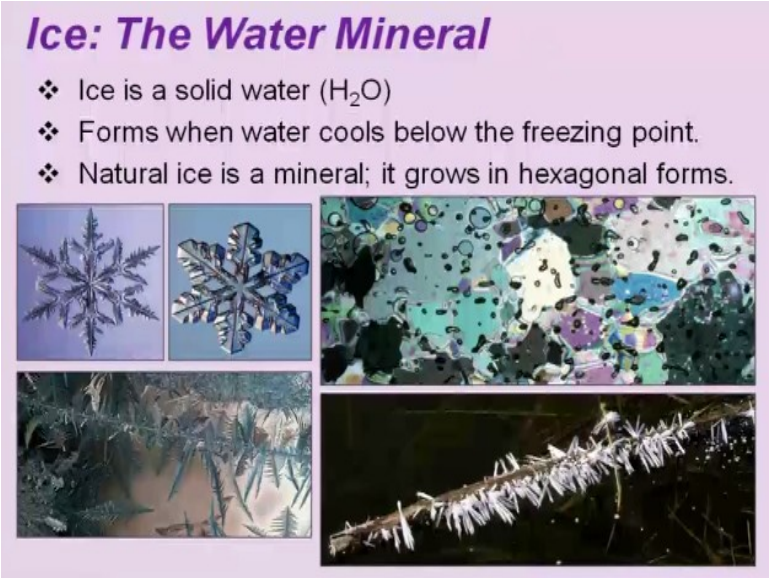

Now looking to some of the important aspect what usually we talk about the snow or ice. So ice is basically, the water mineral. Now any substance, which holds the crystal form we categorize that as mineral. So ice, the water mineral why it has been said like that. So ice is the solid water H2O basically, forms when water cools below the freezing point. Natural ice is a mineral it grows in hexagonal form.

So this is the shape or the form which you see, this side is shown as thin section of this and the crystal formation which has been shown here. So it grows in an hexagonal form hence a solid water you can term that as the mineral, so ice, the solid or the ice the water mineral.

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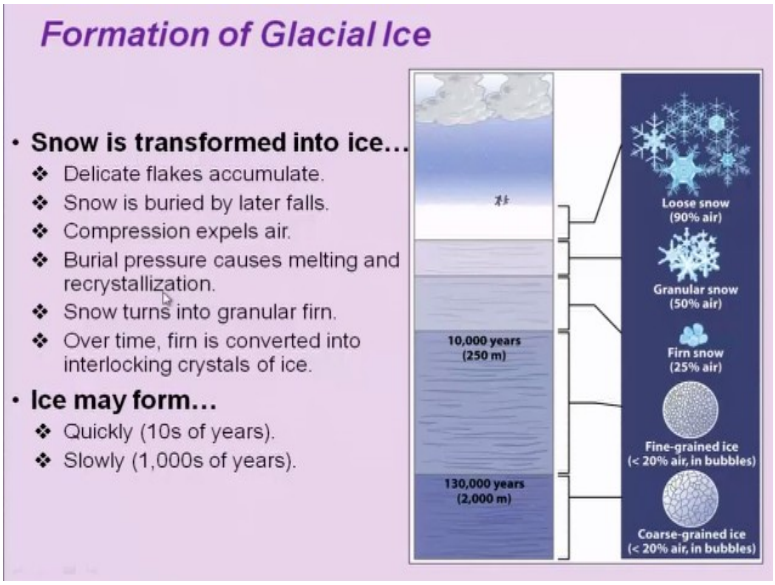

Formation of glacial ice, it takes place in stages and as you move down subsurface and a profile what you find is the grain size varies as well as the age. So snow is transformed into ice from delicate flakes accumulated over here like these are the flakes and as you move further down then you have the grain size, which varies from fine grain ice to coarse grain ice crystals.

So snow is buried by lateral falls compressed and you will have the removal of air from this as you move further down. So this will have some sort of pores which will be occupied by air but as you move down it will be more compacted and compressed and will have more compact structure. So burial pressure causes melting and recrystallization, snow turns into granular firn.

Over time firn is converted into interlocking crystals of ice as it has been shown here. Ice may form quickly, slowly. So quickly 10s of years it will take or slowly it will take 1000s of years. So if you study the snow than the older snow will be coarser and we can say that it is more crystallized in form.

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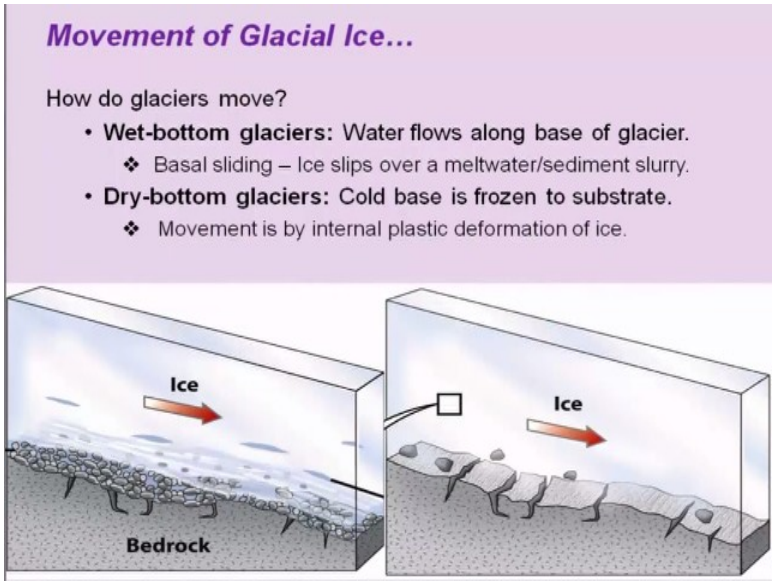

Movement of glacial is again an important aspect to understand the past history. So it is difficult to just look at the surface of the snow and say that this movement has taken place, but when the snow block moves it will result into the development of landscape as well as it will leave some marks on the rock surface which can help us in understanding the movement. So how do glaciers move?

Wet-bottom glaciers, water flow along the base of the glacier. So basal slide will take place, so the basal part will move and it will force the upper portion to slide or move along with that. So basal sliding ice slip over a melt water and sediment slurry because the melt water will create a sort of an slurry along with the sediments which are getting eroded. Now if you are having dry bottom glacier, one is wet bottom glacier and the dry bottom glacier.

Cold base is frozen to substrate up. Movement is by internal plastic deformation of ice. So this is the major difference between the red bottom glaciers and dry bottom glaciers. So wet-bottom glaciers, the basal slide, the basal portion of this, the glacier will slide whereas in terms of the dry bottom glacier it will not allow the basal part to slip, but the movement will take place because of the internal deformation in the ice.

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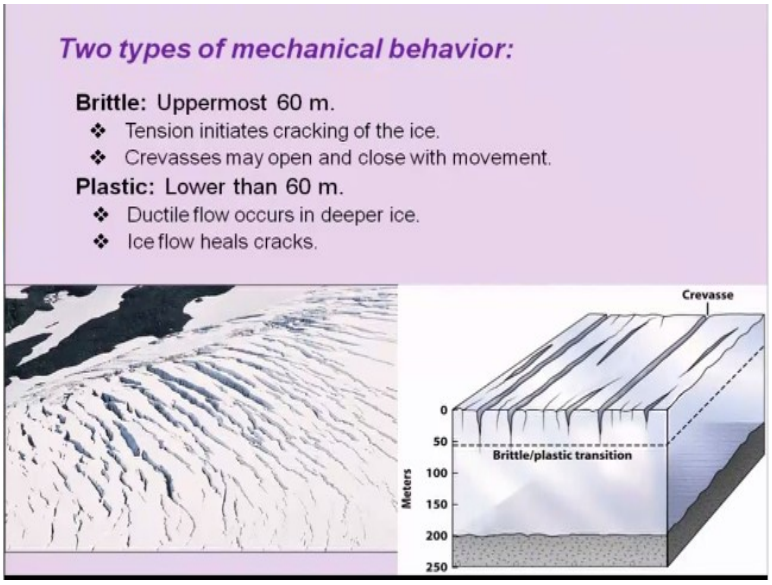

So type of mechanical behaviours of 2 glaciers if you take then you have, you can see that one is the plastic deformation or with the internal deformation, with dry bottom glacier and another is wet part of glacier. So brittle up to 60 meters, tensional cracks will form in the upper part. Crevasses may open and close with movement and another is plastic movement. So one is brittle and other is plastic. So lower than 60 meter.

So in this case the uppermost part will be your with the crevasses or the tensional cracks and below the 60 meter there will be in plastic deformation. So below 60 meters you will not be able to see the crevices where mostly the deformation is ductile flow occurs in the deeper ice, ice flow heal cracks. So this is the most common process which is experienced in glaciers, which we say the type of mechanical behaviour.

One is brittle and another is plastic deformation or the movement, which result into the movement basically.

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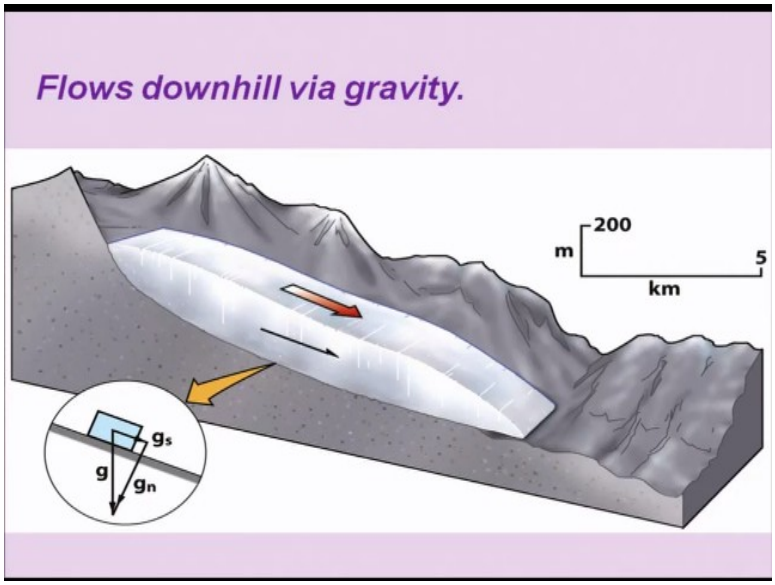

So again all this movements are governed by slope or we can say the valley glaciers or the alpine type glaciers, which of course have the slope that helps in the overall movement. Now here this is just been shown as the gravitational put and g normal and g share. So the shares which tried to pull the mass here and this one is the normal which tries to resist the movement. Flow down via gravity along the slope.

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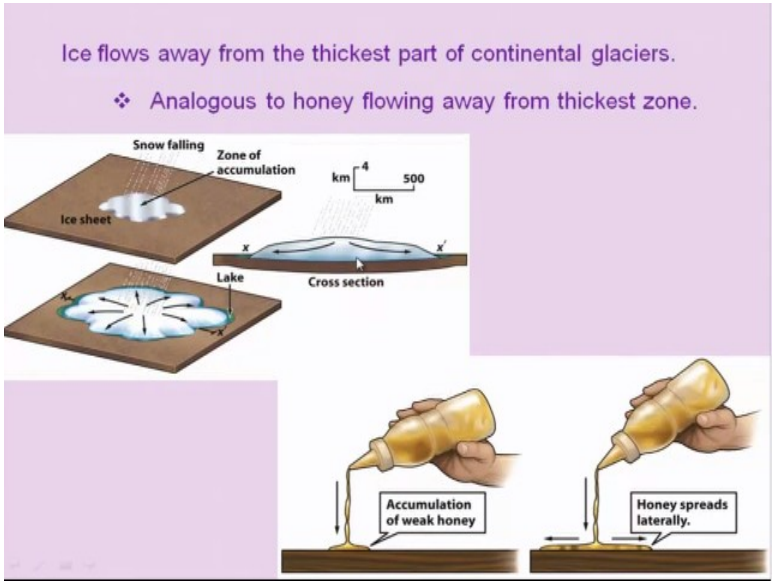

So ice flows away from the thickest part of continental glaciers. So one is along the slope whereas what we call as an Valley slope whereas in case of the glaciers which are lying on the flat surface in terms of the continental glaciers they will accumulate at one place, spread out in all directions and then they move away from the centre. So it shows an analogous to honey flowing. If you drop the honey it will flow away from the thickest zone.

So the thickest zone will be at the centre which has been shown here. So it will keep accumulating slowly and then it will keep moving away from the centre point. So it is very much similar to the honey flowing away from the thicker zone. So one is under gravity and this will be because the slope is available, but this will be because of the accumulation at the centre, the thickest one. So you have it will flow in either direction.

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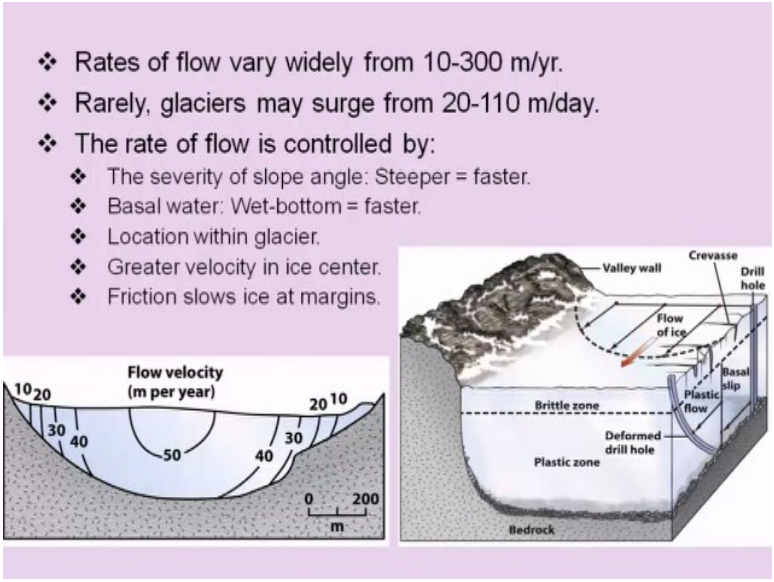

Now rate of flow varies widely from 10 to 300 meter per year, so movement is very slow. Now this shows that the flow or the rate of flow will vary from centre to the ages of the valley. So if you are having glacial valley where the movement is taking place. So in the centre the movement of the ice will be much higher like for example, 50 meter per year. Whereas on the either side of the valley.

Or as you move towards the either side of the valley then it reduces and goes up to like for example, 10 meter per year. So rarely glacial may search from 20 to 110 meter per day. The rate of flow is controlled by one, the severity of the slope because if you are having the greater slope the things will change. So steeper slope you will have faster movement, basal water wet bottom you will have faster movement.

Location within glacier, this is also important where the glacial mass is located within the glacier either in the centre or on the either side of the valley. Greater velocity in ice will be or the glaciers will be in the centre. Friction slows ice in the margin. So less friction, more movement on either side, more friction the movement will be slower and again what we have, we were discussing that on the top upper 60 meters you will have brittle zone.

So along with the movement you see the formation of crevasses or the tensional cracks, but below this you will have the plastic zone by the movement depending on whether the basal portion is wet or dry, the movement will take place. So basal slip under and plastic flow.

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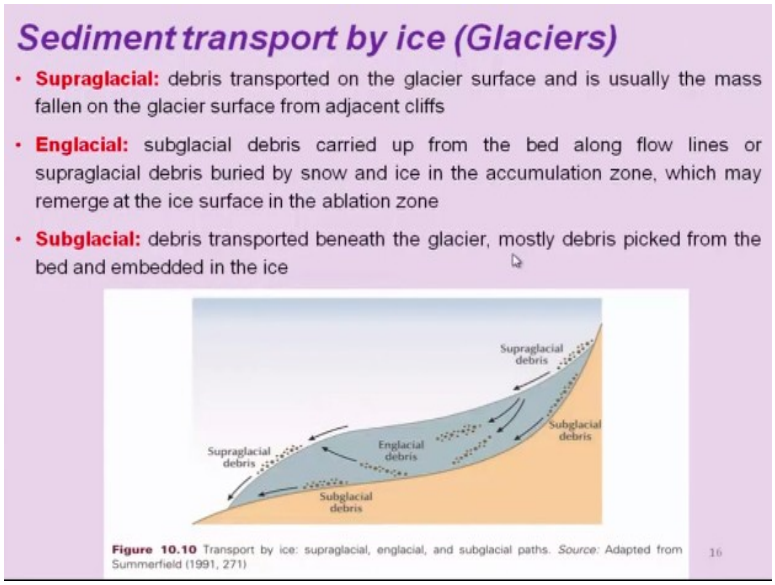

Sediment transport by ice or glaciers. So again this is very commonly observed in any glacial terrain. So you have 3 zones here. One is the supraglacial, englacial and subglacial. So we will see one by one. So sediment transport by ice or glaciers, supraglacial has been shown here, this debris as well as this debris. So debris transport on the glacier surface basically, is your supraglacial debris.

And is usually the mass fallen on the glacier surface from adjacent cliffs. So in one way we can say that this supra glacial debris where the material is on the or over the glacial surface. So the material is on the glacier surface and glacial is within. So subglacial debris is carried, so basically, this subglacial debris are carried. Subglacial debris carried up from bed along flow lines or supraglacial debris by snow and ice in the accumulation zone, which may remerge at the ice surface in ablation zone.

So one we have in the next slide we will see what is the ablation zone where the ice or the you can mark the snow line. So now the englacial will carry the sub glacial debris from the bottom and also the supra glacial debris which are carried within the or mixed within the glacial ice and further along the down slope they may emerge at the zone of ablation.

Subglacial debris transported beneath the glacier or at the contact between the glacial and the rocks.

Most debris picked from bed and embedded in the ice. So most of the debris are being picked up from the bedrock level and they are moved along the basal part. So these are the 3 main portions or we can say the pattern of sediment transport supraglacial, englacial and subglacial.

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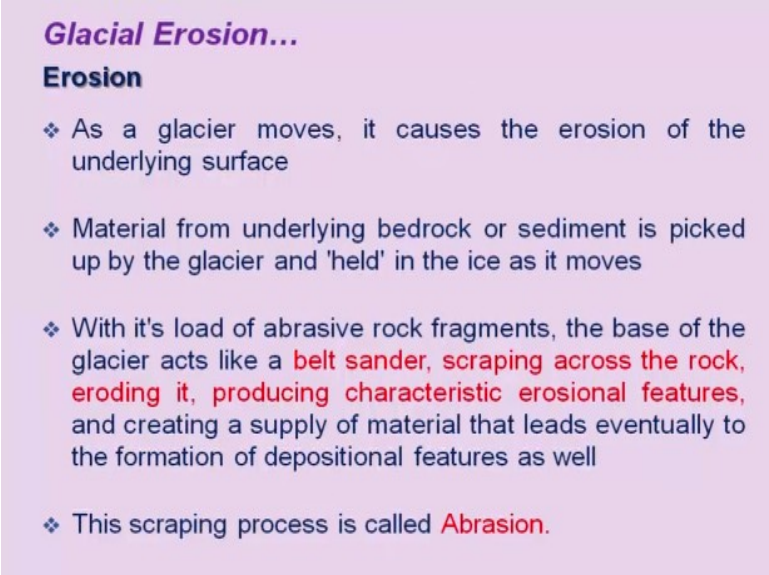

So erosion as a glacier moves it causes the erosion of the underlying surface. Material from underlying bedrock or sediment is picked up by the glacial and held in the ice as it moves as we were looking at the englacial part. So with it is load of abrasive rock fragments, the base of the glacial acts like an sander belt, scraping across the rocks, eroding it, producing characteristic erosional features.

And creating a supply of material that leads eventually to the formation of depositional feature as well as this scraping process is called abrasion.

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Accumulation & Ablation Zones

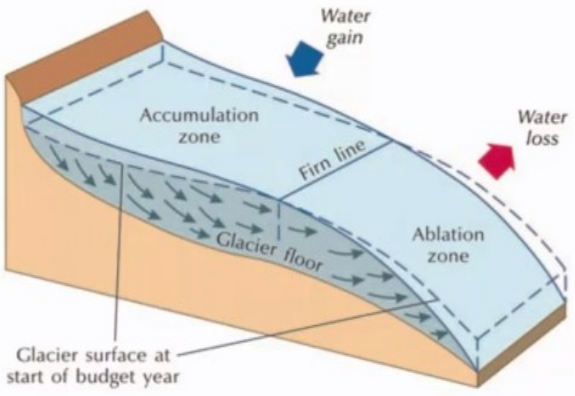

Figure 10.8 Glacier mass balance: schematic changes in the geometry of a glacier during an equilibrium budget year. *Source:* Adapted from Marcus (1969)

So this is what we were talking about the accumulation and ablation zone and in the previous slide we were talking about that if you are having the subglacial, englacial and supraglacial material. So one is the accumulation zone and then you have a firn line and then you have an ablation zone. So below the firn line you will have the ablation where you will loss the water whereas here you will gain the water and these are the profiles which have been shown during different seasons. So this we will discuss in the next lecture. I will stop here. Thank you so much.