Geomorphology
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Lecture-55
Glacier Geomorphology III

So friends welcome to this lecture series of geomorphology and today we will continue with this glacier geomorphology. So if we remember in the last class we are talking something about the glacier formation and the contribution of glacier to or fresh water budget, as well as this water cycle of this globe. And we found definitely there are 2 types of glaciers we can classify based on either it is a valley glacier it is composed of that is ice mass which is confined within the valley.

And another is a ice sheet, which is about 2.5 kilometer average thickness. And they it is middle part it is more thick, and it is the accumulation zone, and it is spreading outward from the center. And that is why this aerial view of this glacier moment is a radial as compared to this valley Glacier. And similarly, this valley glacier, during movement, it mixed with the other glaciers, and it is due to it is easily deformable part, easily deformable deformable rhealogy.

So this valley glaciers and this main trunk glacier, they mix or this coalescence at the same level, but it is identity of this valley, the identity of this tributary glacier they remain identical or distinguished for long distance and later they mixed up. Similarly, there are 2 zones of movements during movement. There are 2 zones of this valley glacier one is the zone of compression and other is zone of extension and zone of compression it movement is less and mostly it is abrasion and it is characteristic erosional process.

And then once we are coming to the extensional flow, it is extended and there are crevases were developed and finally, the glacier moves with different velocity at different points. And today we will talk about the glaciology. Glaciology means it is the scientific study of all ice not just valley glacier, not just the ice sheet, it is all ice all form of the ice crystals. That is high cloud, hail, snow, frozen lake, River, ocean water and glacier ice.

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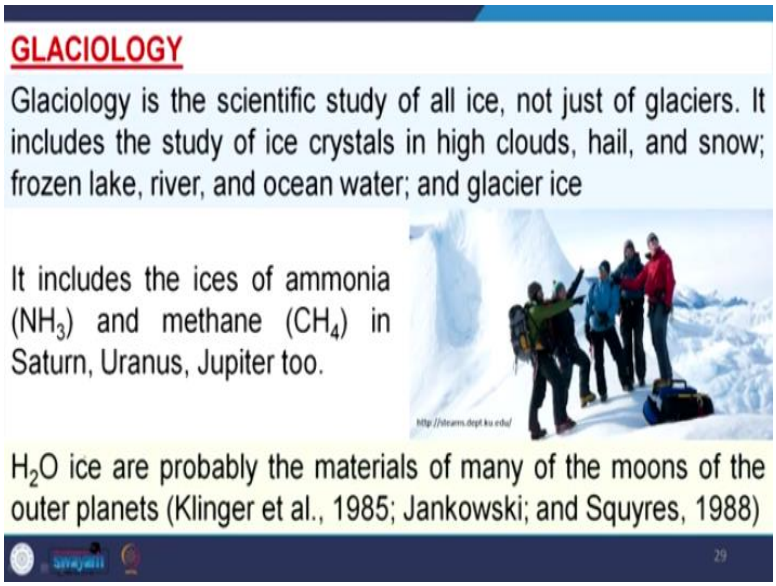

And this also includes this frozen ammonia as well as Methane more mainly it is found in certain Uranus and Jupiter. So, that means glaciology is a broad term that means irrespective of it is glacial form, irrespective of it is composition, it covers all parts of this glacier system. And this H_2O ice probably these materials are for many of these moons of these outer planets. So, that means, once we say glaciers or glaciology that means we include all those things.

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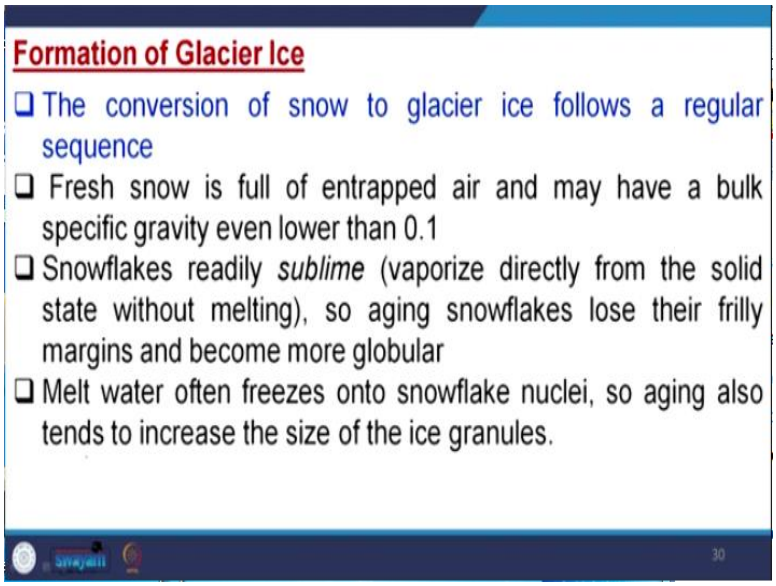

How this glacier ice is formed. Generally, there are few sequence of events that this is regular sequences there. This follows the first is the fresh snow is full of entrapped air and may have bulk specific gravity about lower than 0.1. So, it is so light that it can be blown for a few

distance, it is a certain distance by air since snowflakes it is readily sublime, sublime means it is vaporize from this solid state without melting. So, aging snowflakes lose their firny or lose their frilly margins and becomes more globular, melt water often freezes onto snowflakes, nuclei. So, again also tends to increase the size of this ice granule.

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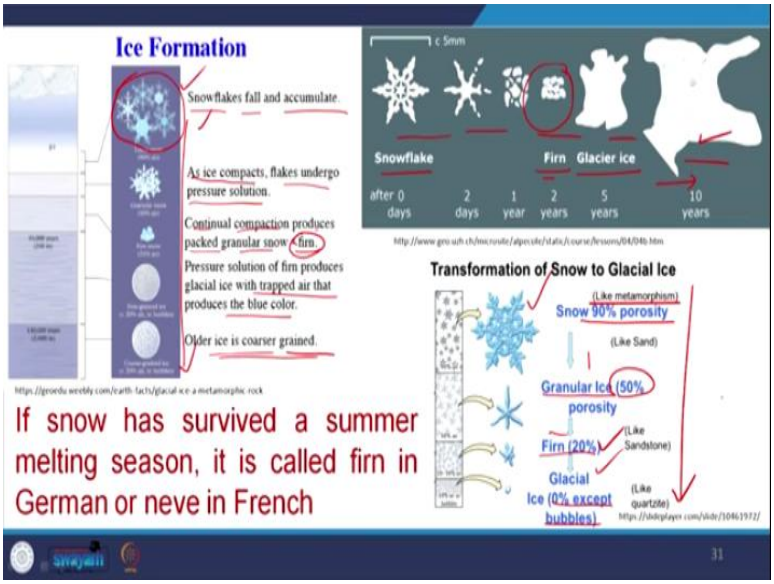

So, that means if you analyze this figures, you can easily understand how these processes are involved. What are their changes occurs starting from the snowflakes to glacier ice. So, in the other way it can be said it is a the type of metamorphism that occurs, which transforms these snowflakes to glacier ice. So, if you see this left hand side figure here, you see these are this ice crystal, the shape of this crystal that means crystal structure of these snowflakes, you see it is looking like a very nice flower. So, snowflakes all fall and accumulate.

So, the next step is once we are accumulating snowflakes one after another. So, you see so as delicate structure crystal structure as they are very nicely developed crystal structure, but for once we are keeping them together. So, this crystal structure deforms. So, that means, as ice compacts flakes undergo pressure solution. Then, continual compaction produces packed granular snow that is called firn. So, now, you see, once we are going more or accumulating more.

And more snow there, gradually we are creating some pressure solution through which the crystal structure we are deforming and more and more we are producing more or more granular we are making it And finally, we are converting it to firn, pressure solution of a firn produces glacial ice with entrapped air that produces blue color that is very important here glacier ice you might have seen from discovery or any photographs from glaciologist and in the internet it is blue color, why this blue color appearance?

This is due to the trapped air. So, more air is entrapped more blue appearance of this ice is and they older ice is coarser grained that means, starting from individual snowflakes, you are coming to coarse grained ice which is granular So, this transformation this deformation of snowflakes crystals, snow crystal, if you see here, the snowflake crystals gradually deform and deforming and finally, after 10 years it average it is creating glacier ice.

So, here snowflake, then deformation, granular appearance, it is called firn, then it is creating glacier ice and this movement of glacier ice is there. So, that means here at this initial time when there is snowflakes, there is 90% porosity and that means the pore space it is occupied by air. So, with granular ice, it is porosity decreased to 50%. Then, once it is firned it is 20%. So, like glacier ice it is 0% except some water bubbles are there. So, that means, gradually this transformation, it is called the metamorphism of snowflakes to ice sheet. If snowflakes or the snow it is survived a summer melting season, it is called Firn it is German.

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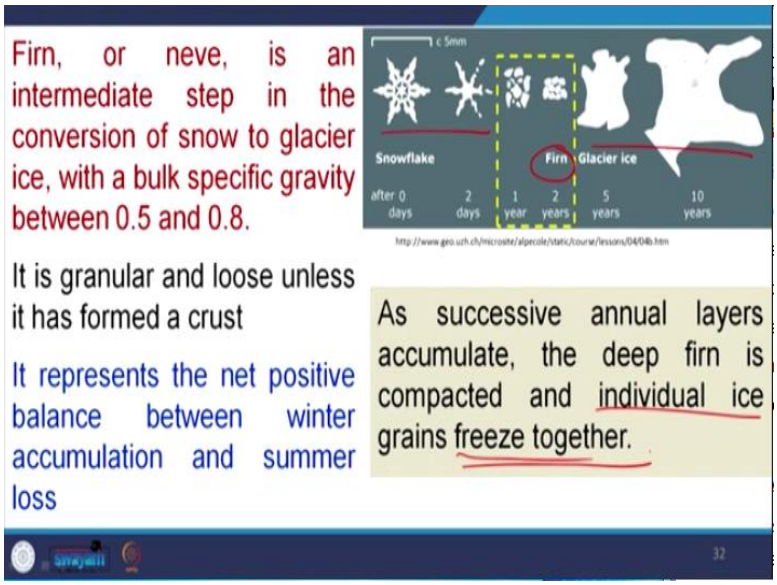

Or in french It is called neve. Firn or neve is an intermediate step in the conversion of snow glacier ice with a bulk specific gravity between 0.5 to 0.8. So, that means, we have snowflakes here, we have glacier ice here in between this firn it is the transition. So, it is a granular and loose only it is formed it crust, so that it will remain here granular and loose like loose sand. So, it will convert until unless it is forming a crust. So, it remains granular. It represents the net positive balance between winter accumulation and summer loss.

So as successive annual layers accumulate the deep firn is compacted an individual ice grains freeze together. So we are creating a glacier ice sheet there. So this transformation process from snowflakes to glacier ice, it takes about 10 years or so. So that means it is the initial stage 10 year, but if you are talking about this Antarctic ice sheets, you are talking this permanent ice caps. So that means it is taken a few see here, it is about if you are getting 250 meter of ice sheet, it is taking 10,000 years.

If we are getting here 2000 meter ice sheet that it is getting about 130,000 years. So that means if we date those ice sheets at the scour of this ice sheet. This we can see how much time it is taken to form this much thick caps thickness of the ice sheets. So the Antarctic ice the Greenland the Iceland ice sheets, they are very old as compared to this ice sheets or this ice of this big glacier of this valley glacier this permanent ice caps.

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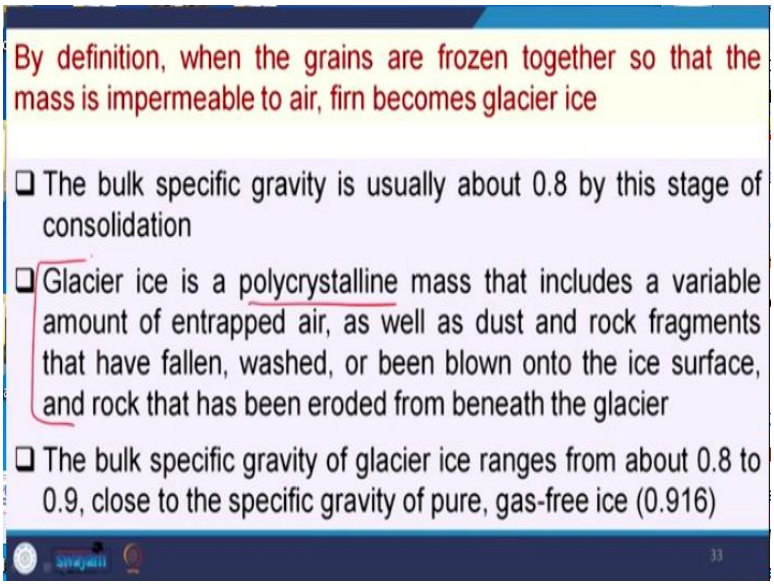

So by definition, when the grains are frozen together, so that the mass is impermeable to air firn becomes glacier ice, the bulk specific gravity is usually 0.8 by this stage of consolidation glacier ice is a polycrystalline mass that includes a variable amount of entrapped air, as well as dust and rock fragments that have fallen washed or has been blown onto the ice surface and the rock that has been eroded from beneath these glaciers.

So, that means here we have a material which is mixed with what mixed with glacier mixed with dust rock fragments, that rock fragment below from this glaciers or the ice sheet or it is fallen side from this and enclosed mountain system enclosed valley. So, altogether if you say that means glacier glacier is a mixture of all those things that mean the whole system that moves from one place to another. The bulk specific gravity of glacier ice ranges from 0.8 to 0.9.

Close to the specific gravity of pure gas free ice is about to 0.916 so that means this 0.916 is the pure the specific gravity of this pure gas free ice but still it is lighter than water, so that it is floating on what you might have seen in this discoveries and the TVs are in real life, there are masses of ice that are floating on water, this is due to this low specific gravity than water. So, now whatever this ice that means maybe it is valley glacier, it may be the glacier which is the sheet form then we have to classify it this classification is based on certain schemes.

The first classification is a descriptive based classification, what is this descriptive based classification, one is called cirque glacier, cirque glacier if you see it is confined in cirque above the valley, if you see here, these are these cirque that means it is confined within that valley.

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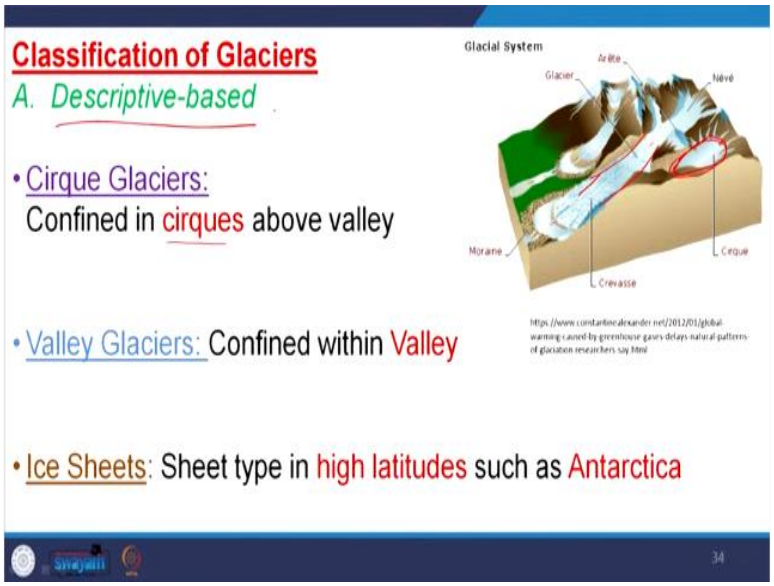

It is isolated, it is cirque glacier. Then Valley glacier that means here. This is the valley glacier this is confined within the valley here cirque glacier. It is isolated, but it is valley glacier, it is moving within very confined by this valley walls to sites. Then ice sheet that we know in high latitudes in like Antartica Greenland, we have ice sheets average of 2 kilometer of 2.5 kilometers take. So, this classification is descriptive based.

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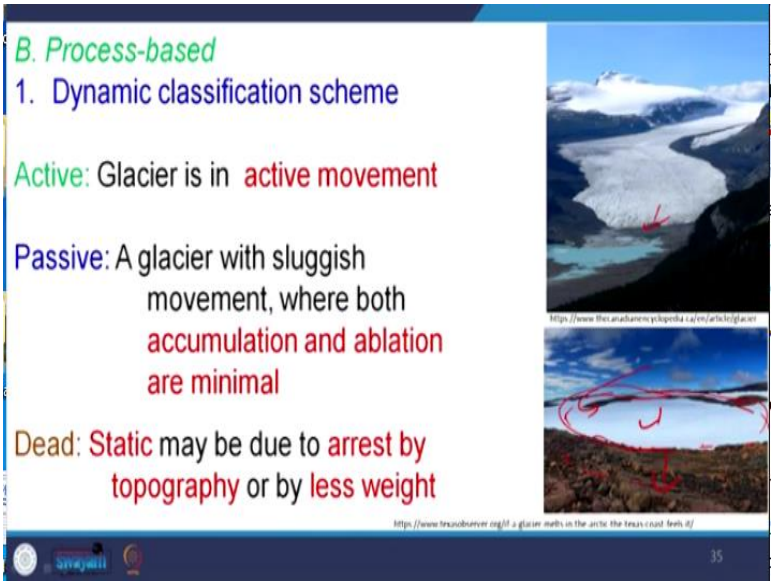

Then second classification is based on the process or it is called process based classification, what is the different process involved? One is called active glacier, active glacier means the glacier is moving on movement active movement suppose for example, here it is glacier is moving active glacier, then passive a glacier with sluggish movement where both accumulation and ablation are minimal sluggish, very slow movement that is or in that means it is it is not detectable for a small time period.

So, that is called passive glacier then dead glacier static maybe due to arrest by topography or by less weight or so, if you see here, this is a dead glacier that means, if you see here this is a depressed part and it is the elevated part. So, that means, it is bounded by this topography. So, that means, it is dead glacier until unless more accumulation takes place here or until and unless it is supplied more ice or more glacier ice supplied.

Here it cannot move in this direction that is topographically arrested. So, that is called dead glacier. So, based on this process, either it is moving or it is moving very slow very slow process or slow movement is there or it is not at all moving. So, based on that this classification is there.

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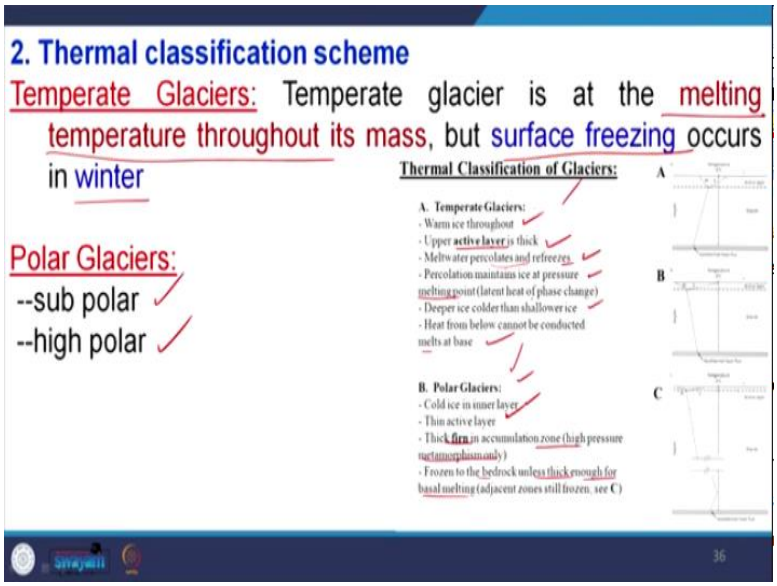

Then another scheme of classification is called thermal classification scheme thermal classification that means based on the temperature, so though you know the glacier system, it is a low temperature phenomena is minus it is temperature region minus degrees Celsius, but still

based on the temperature we classify the glaciers into temperate glacier temperate glacier means, temperate glacier is at this melting temperature throughout this mass, but surface freezing occurs in winter. So, that means it is always melting it is always providing water perennial rivers are there.

So, though this temperature is of melting is throughout the year, but surface freezing occurs in winter. So, that means except winter, all through this year, this glacier is in the melting form. So, that is called temperate glacier. Then, polar glacier, if you see, polar glacier is again divided into sub polar and high polar that means high polar means this exactly the pole or near to the pole and sub polar means somehow away from this pole.

Now, if you see here thermal classification glacier is called temperate glacier warm ice throw out, upper active layer is thick melt water percolates and freezes percolations maintains ice at pressure melting point, deeper ice colder than shallower ice heat from below cannot be conducted melt at the base then polar glacier cold ice in inner layer thin active layer thick firn accumulation zone high pressure metamorphism only frozen to bed rock unless thick enough for basal melting. So, these are the difference between these temperate glacier and polar glacier.

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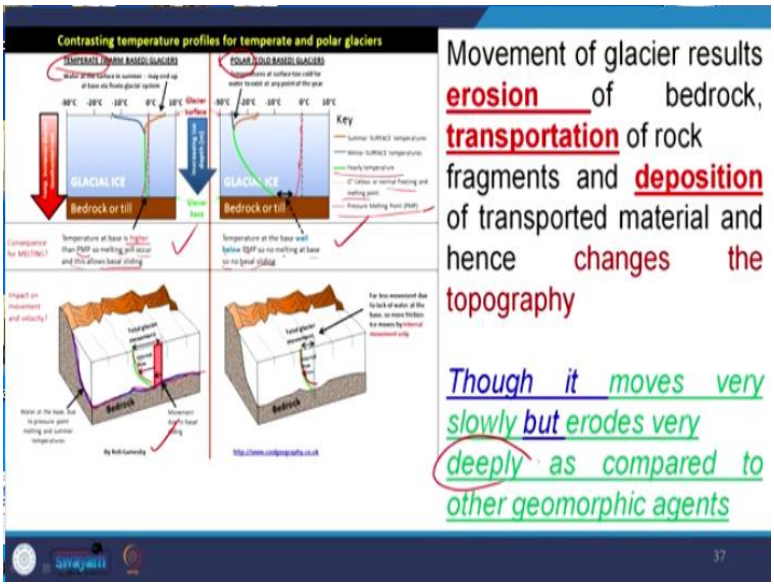

know, here, there is differences between these polar glacier and this temperate glacier. It is also given if you see here, this figures this line orange color it is the summer surface temperature.

Now, if you see here, this is temperature temperate glacier and it is polar glacier, this line that is this summer surface temperature if you see this summer surface temperature is starting from near about it is 8 degree or 7 degree and it is gradually decreasing.

But here in the polar glacier the surface temperature lies around minus 15 degree Celsius for similarly, winter surface temperature, winter surface temperature for this polar glacier is about minus 25 degree, but here it is about to minus 15 degree. Similarly, yearly temperature here if you see yearly temperature polar glacier, it is varies from minus 25 to here minus 10. But here this temperature this remain constant that means near about minus 2 degrees or so, similarly, pressure melting point pressure melting point it starting from 0 about minus 2 degrees here it is starting from 0 to minus 2 degree or so.

So, this pressure melting point remains same throughout. And here, if you see 0 degrees Celsius or normal freezing and melting point, these are these lines this is dotted line is 0 degree. Now, if you compare this to the temperature at the base is higher, I am talking about this temperature there is temperate glacier, the temperature at the base is higher than pressure melting point. So, melting will occur and this allows the basal sliding.

So, here the temperature at the base is well below the pressure melting points. So, melting as the basis no basal sliding, so, that means it is less basal sliding here, more basal sliding is here. Similarly, if you see here as it is basal sliding that means it melts. So, there is a water layer at the base. So, once it remains the water layer at the base, so, basal sliding becomes easier. So, that this movement of the rate of movement will be more here if you see here the rate of movement it is more as compared to these polar glaciers.

So, polar glacier it moves at a slower rate as compared to temperate glacier movement of glacier results erosion of bed rock transportation of rocks and fragments and deposition of these transported materials, which changes the topography. So, there will be both erosional topographical change as well as depositional topographical change. So, erosion, transportation and deposition that occurs in by this glacier like other geomorphic agents like water, like this wind they also erode and transport.

And deposit material. Similarly, this glacier also erodes transports and deposits material, but the difference is that here glacier erosion is more deeper as compared to water or wind erosion that means glacier can erode up to the deeper level as compared to other geomorphic agents. Though it moves very slowly, but erodes very deeply as compared to other geomorphic agents. So, this is the difference between these other geomorphic agents and glacier.

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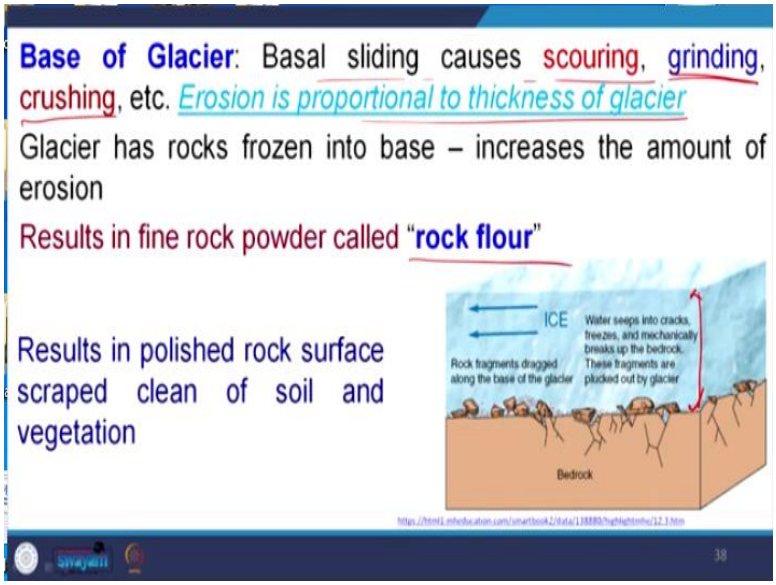

So, results in polished rock surface. Now, I see it at the base of this glacier basal sliding, causes scouring. That means, scource this rock at the best and grinding that means a huge mass which is transporting at huge mass and below the bed rock and huge mass of ice in between if rock fragments are there. There are crushed, so that means it is grinding is there crushing is there erosion is proportional to the thickness of the glacier.

That means, if the glacier is more thick, it will erode more because more pressure is there at the base. So more deeper level of erosion will you be there. So, that means it is glacial erosion, it is proportional to its thickness glacial has the rock frozen into the base, increase the amount of erosion results is fine rock powder that is called a rock flour. Now if you see here, this is the glacier, the thickness of this glacier ice glacier ice. These fine grains they are the rock flours because they are crushing grinding or their rock flours are generated. And result in polished rock surface scraped clean of soil and vegetation.

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So if you see here, these are these rocks dragged over the bed rock can produce glacial striations glacier striations means if you see here these are the linear structures lineations these are the glacier striations that means, it indicates the glacier movement on bed rock. Now, which direction the glacier ice has moved either for example, if you see, we can say either in this way or in this way. So, if by looking this type of steps, this type of structures, we can say which direction the glacier ice has moved.

Now, if you see these steps, they are opening in these directions and here for example, here you can see it is a speed break of it is there. Similarly, here is a speed break that means, if you take this cross section of this part, it will look like this. So, that means, this way the glacier has moved this way the glacier has moved in this particular photographs. So, by looking these type of structures on the rock surface of the bed rock you could say which direction the glacier is moved that also.

It is important to reconstruct the paleogeographical history or paleoclimate history by looking this type of structure and establishing the glacier movement. Now, the particular type of glacial erosion that is called plucking or quarrying.

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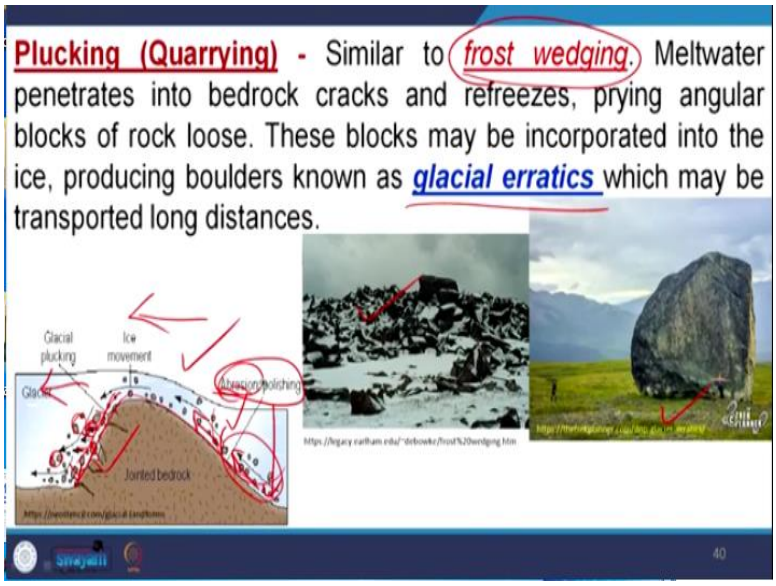

So what is plucking? It is similar to frost wedging, you might be remembering about this frost wedging when we are talking about weathering and erosion, specially the physical weathering by frost wedging, if there are fractures, water is freezed there and once the water freezes, its specific volume increases, so that it produces cracks, and these cracks with time becomes wider and wider. And finally, rocks are eroded apart or break broken apart. So this is called frost wedging.

So frost wedging the melt water penetrates into the bed rock cracks and freezes prying angular blocks to rock up loose rocks. These blocks may be incorporated into this ice producing boulders known as glacial erratics, which may be transported long distances glacier erratic is very peculiar type of rock which is not related to any rock in the surroundings. So, these are the foreign rock particles so it can transported to up to 100s of kilometers, there are a number of glacial environment evidences in this Gondwana time.

if you go to any Gondwana environment, in peninsular of India, so you will find there are a number of boulders lying here and there which is not related to any types of rock in the surrounding. So this is called glacial erratics. That means they were transported by glacier from 100s of kilometers away and due to this melting of the glacier here, they are remaining there. This is called glacial erratics. So, plucking if you see here; that too, if you remember our last class we are talking about this compressional flow.

And extensional flow here, this is the glacier movement directions and we have laches of bed rock exposure and here there will be compression and due to compression, there will be erosion there will be a abrasion so, abrasion or polishing and mostly the glacial striations, they are very well developed the spot and once the glacier crosses this barrier, here, this side is representing the compressional flow and due to this compressional flow, you will find this pluckings that means pieces of rock they are plucked away from this bed rock and it is remain the base of this glacier.

So, this type of removal of this rock from this rock mass or this parent rock or the bed rock that is called glacial plucking. So, this is a photograph of frost wedging, then it is glacial plucking, and this is erratics. So, these boulders suppose for example, these boulders if they are transported by this glacier of long distance and here deposited in some part which is not anywhere related to this surrounding rock that is called glacial erratics.

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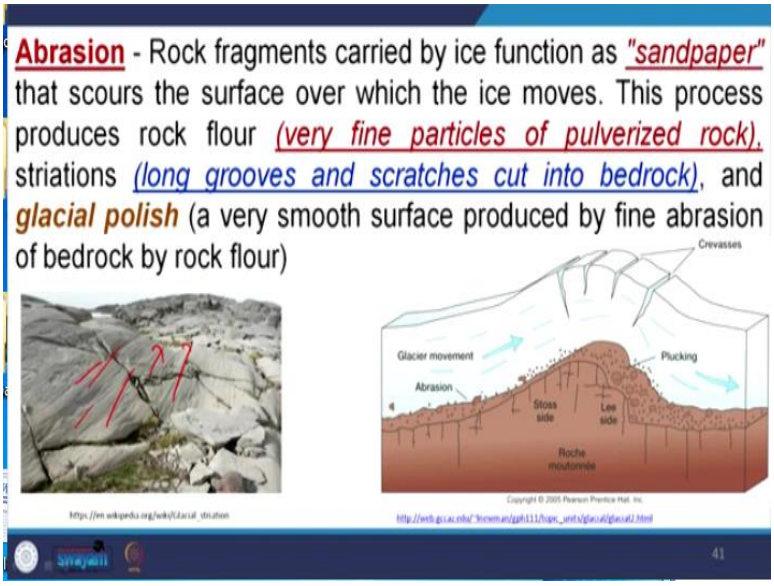

Then, another type of erosion that is called abrasion that we have discussed here, the abrasion this side it is the abrasion or polishing of this rocks. So abrasion is the rock fragments carried by ice function as a sand that means we have such a sandpaper that scours the surface over which the ice moves, this process produces rock flour very fine particles of pulverized rock, it is striation that is long groups and scratches in the bed rock and glacial polish It is very smooth surface produced by fine abrasion of bed rock by rock floor.

So, if you see these are the glacial striations they are very prominent in the bed rock particularly, if it is the sedimentary rock it will be very deeply scoured and it can in Indian context, if you go to any Gondwana terrain, like in Maharashtra, it is Jharkhand and in Bihar or wherever you go to this any Gondwana terrain you will find this type of glacial scours, based on this glacier scour based on the movement, the paleogeography is a restructure or paleogeography called region where this glacier was movement glacier movement was there were glacier was forming. So those glaciers can be identified.

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Although abrasion models depends critically on whether clasts are treated as dependent or independent of subglacial water pressure it appear that abrasion is favoured in situations where effective basal pressure are greater than 1mega Pascal and where there are low sliding velocities. So, if you see, if we have low sliding velocity again low sliding velocity means we have low water pressure inside this interface of this glacier and bed rock.

So, that means, we are talking something about this polar glaciers. So, that means polar glacier they abrade more deeply as compared to valley glaciers. So, now here this glaciers So, that means, this abrasion is more effective, it is pressure which is greater than 1 mega Pascal and these bulldozing action bulldozing action simply if you see here a bulldozer which is removing this debris This is from one direction to one place to another.

Similarly, this glacier it is behave as a bulldozer here and this rock mass if you see here, these are this rock mass it is falling here. So, that means, this removal of this rock mass or transportation of the rock mass from one place to another this mass transport is due to this bulldozing action of this glacier,

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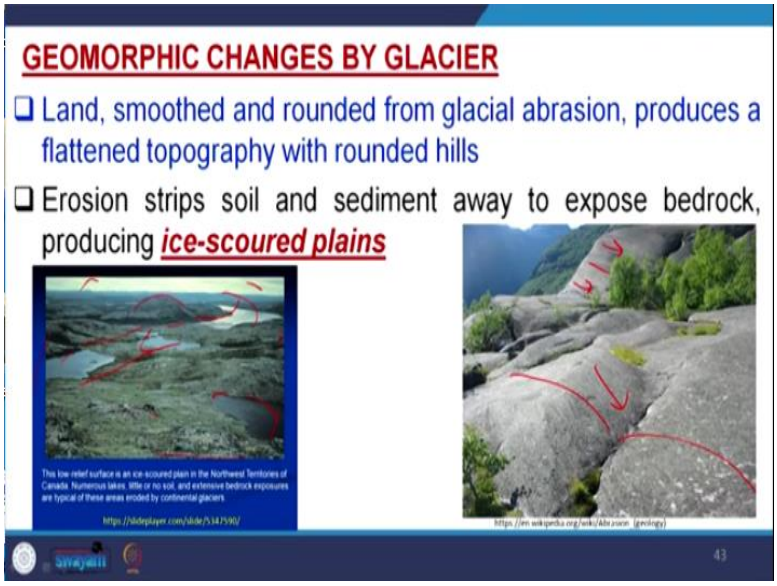

Then geomorphic changes that created by glaciers in the land smooth and rounded from this glacial abrasion produces a flattened topography with rounded hills. here if you see here, we have rounded hills which flattened topography, similarly if you see we have smooth hills and they flattened topography, erosion strips, soil and sediments, away to expose bed rock in producing ice scoured plains there the ice scoured plain there these scouring you can see this direction the linear strips.

So this ice scoured surface and if you see here, they had the valley of the glacier was moving and the whole system was glaciated valley, if you see drainage system is peculiar that is called deranged and we will talk later. So this glacier that strips this bed rock. And finally, it is forming the bed rock topography, which is of a different kind, which is peculiar with the compared to other types of erosional systems. So I think we should stop here, and we will meet in the next class discuss further about this glacier system. Thank you.