**Geomorphology**
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**Lecture-56**
**Glacial Geomorphology – IV Geomorphic Changes by Glacier**

So friends, welcome to this lecture series of geomorphology. And today we will continue with this glacial geomorphology mainly the geomorphic changes by glacier. So, what does it mean? This how this glacier changes the topography as we know it erodes the material, it transports and it deposits. So that means we will find both erosional topography as well as depositional topography. And during transportation also in the way it creates some topographic changes some depositional structures and erosional features are created. So that will be discussed in this class. So starting with the streams of the drainage pattern changes in a glaciated area.

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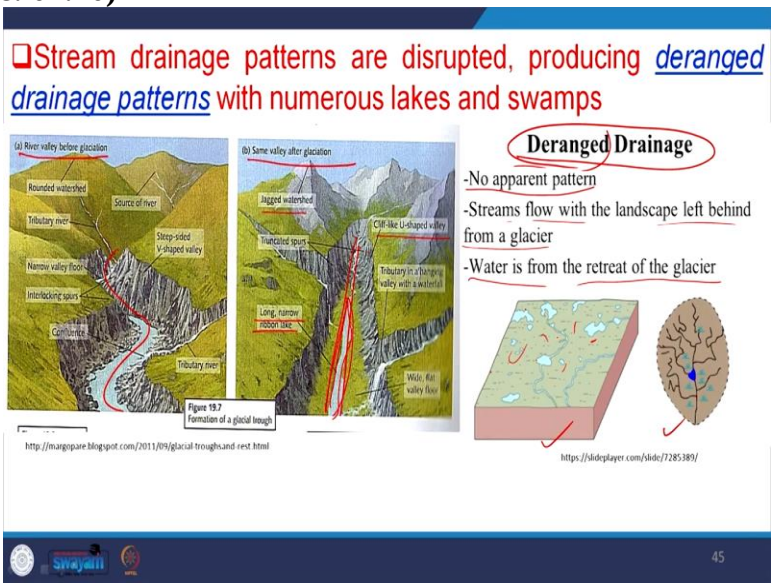


For example, if you remember when we are talking about this U shaped valley & V shaped valley, in this a river system is generally created the V shaped valley but in glaciated sequence it is created U shaped valley, if you see these 2 figures, yes river valley before glaciations and after glaciations, that means the river valley was a sinuous form. But if you see after glaciations, it is become straight.

And here due to deep erosion, deep erosion there are lakes are formed that is long, narrow, ribbon lake then truncated spurs, then jagged watershed in Cliff like you U shaped valley, then wide and flat valley floor. So, all these changes that occurs in higher reaches and due to glacial erosion of this and mostly this, drainage pattern is changed to deranged drainage pattern, deranged drainage pattern.

If you see here that means the characteristic feature is no apparent pattern, haphazard if you see this model or this figure, you see, there is no particular drainage pattern particular type of drainage pattern no particular fashion of arrangement. So, haphazard arrangement is there streams flow with landscape left behind from a glacier that means the glacier erodes very deeply. So it is very difficult to this river system or the channels to accommodate itself with a change system.

That means it has to accommodate itself within this change system by the glacier, because it takes more time to modify this change system by a river system. So, that means the rivers are the channels initially, they accommodate them self within that changed topography by the glacier water is from this retreat of glacier. So, here the retreat of glacier the water is supplied. And there are haphazard orientations there are sag ponds, then the channels there is no fashion of arrangement. So, that is called deranged drainage pattern.

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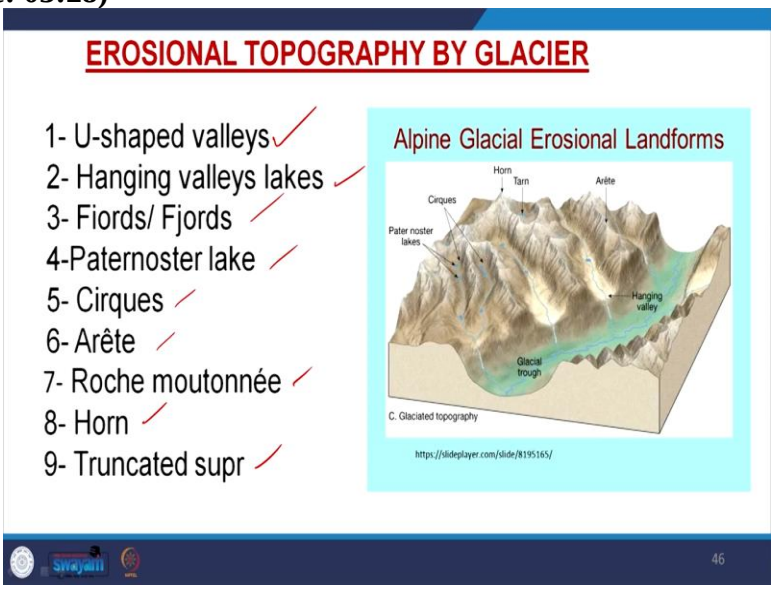

And erosional topography by this glacier it is U shaped valley the post prominent 1, then hanging valley lakes then fiords, paternoster lake ,cirques, arête, roaches moutonnee, then horn then truncated spurs these are these glacial erosional features. And if you see this models given the right hand side, there are a number of erosional features have been discussed here. The cirques this paternoster lake, the horn then arête then glacial troughs, hanging valleys, these are given here we will discuss one by one.

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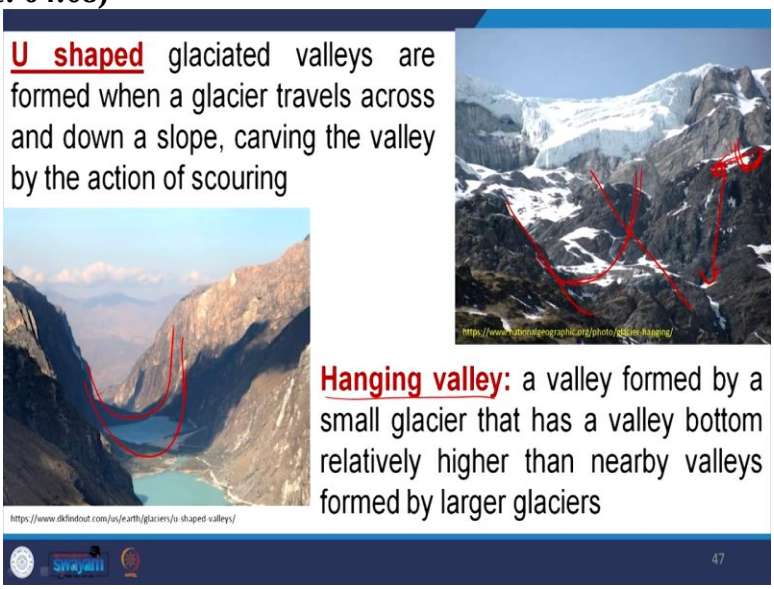


So U shaped valley that is glaciated Valley are formed when a glacier travels across this down slope, curving the valley by this action of scouring. So, here we are getting U shaped valley this is U shaped valley there and the V shaped valley is by the river. So, another there is this hanging valley hanging valley means a valley formed by a small glacier that is a valley bottom relatively higher than this nearby valleys formed by these main glacier or a strong glacier.

If you see here, this glacier it is a trunk it is a tributary glacier. And this is the main glacier valley, and this is the tributary glacier valley, this is main glacier valley, and you see tributary glacier valley is this much height elevation up at this as compared to these main of the trunk glacier valley. So, this is called hanging valley. So, that means is hanging above these main glacier valley it appearance like is that.

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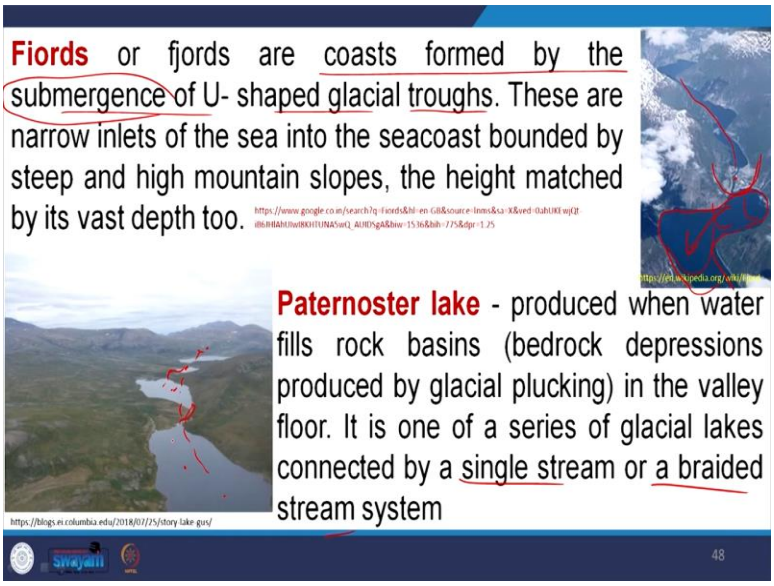


Then fiords or fjords are nothing it is the glaciated valley now occupied by ocean or this marine water. So, fiords are coast formed by this submergence of U shaped glacial troughs. These are, this is the submergence of the U shaped glacial troughs these are narrow inlet of the sea into this seacoast bounded by steep and high mountain slopes, the height matched by its vast depth too. Now see this is glacier valley was there.

And this is the tongue of marine water, which is occupied that means it is submerging by this marine water. So this U shaped valley, which was earlier, this was this U shaped valley the glacier was moving through this path and now it is occupied by marine water. So, this is called fiords. Then paternoster lake it is produced when water fills rock basins or bedrock depression produced by glacial plucking in the valley floor.

It is one of the series of glacial lakes connected by a single stream or braided stream systems. And you see here, this is the path of the glacier, which has moving and after the glasses retreat, there are a number of depressions and the depression is occupied and it is depression is creating some lakes. And now, you see, this lake isolated lake that is connected through a channel.

Similarly, this is connected through a channel. So, these are these paternoster lake. So, paternoster lake it is a typical pattern of glacier erosion remove or the change of this modification of this a parent drainage system by this glacial action and this this is a part of the

deranged drainage pattern. These lakes are interconnected through single channel or braided channel system.

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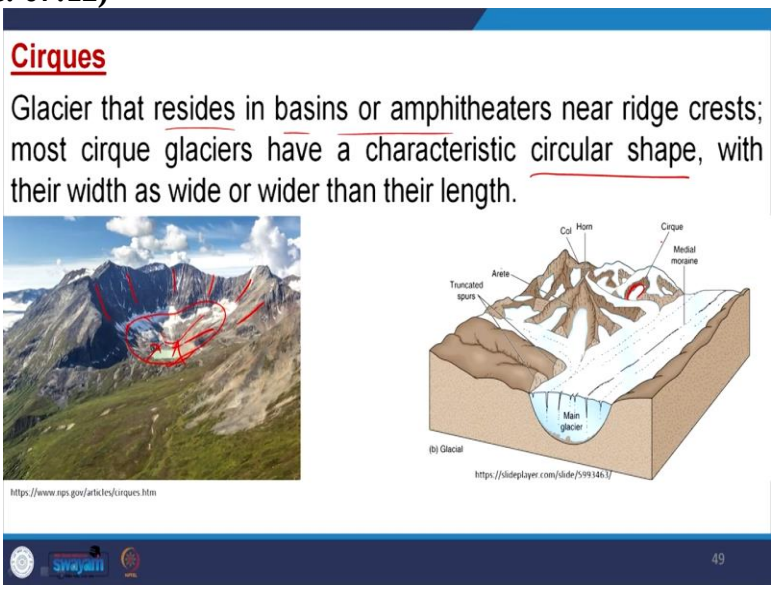


Then cirques that we have already discussed in earlier time also cirques they are isolated patches or isolated valleys that is occupied by glacier. And it is mostly it is circular shape. So glacier that resides in the basins or amphitheater near ridge crests. You have see it is bounded by the ridge crests and the most cirques glacier have characteristic circular shape with their width as wide as or wider than this length. So these are these cirques, so this cirques are there.

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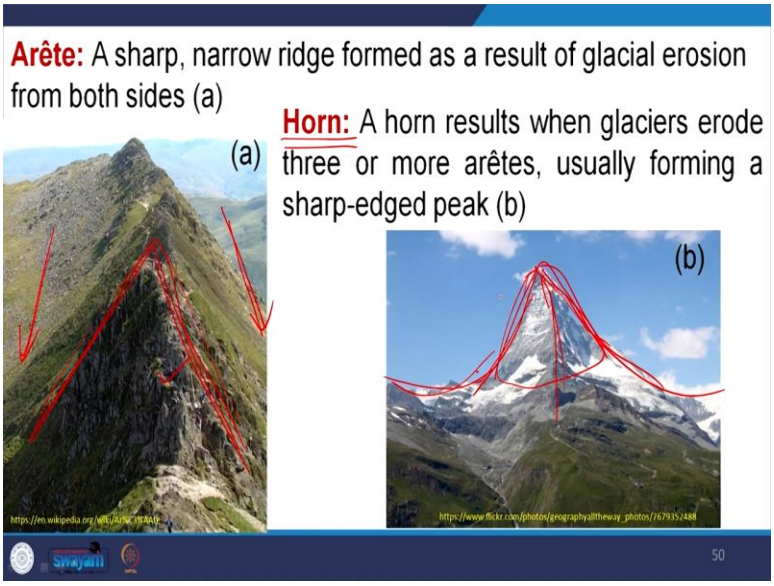

Then arete, if you see these 2 sides, it is bounded by glacier valley and in cross section you are looking is cross section is like this. So here is the glacier valley here is a glacier valley that means this side, glacier erosion will be there, this side glacier erosion will be there. So the remnant part of this hill rock hill that looking like a ridge separated by 2 glacier valleys that is called arête.

And horn means it is a glacier valley permanent mountain, all sides. It is bounded by glacier valley that means junction of a 3 or more aretes is called horn for example, if this photograph you have seen, this is 1 arete, this is another arêtet, this is 3rd arete, and probably that said there will be another arete. So at least 3 arete if mixed together. They are interlink together, it is forming a particular type of erosion on topography that is called horn.

If you remember when we are talking about this erosional system of or sorry this aeolian system we were talking something out to star dunes that means it is junction of number of dunes together languagetional dunes together and all sides it is that means wind velocity. So, that means, it is shape wise if you look from this aerial view shape wise, this is similar to that star dunes, but here. This is due to glacier that means here 1 U shaped valley another U shaped valley here and 3rd will be here. So, 3 different aretes they are linking together at a point and this part, this remnant hill it is called the horn.

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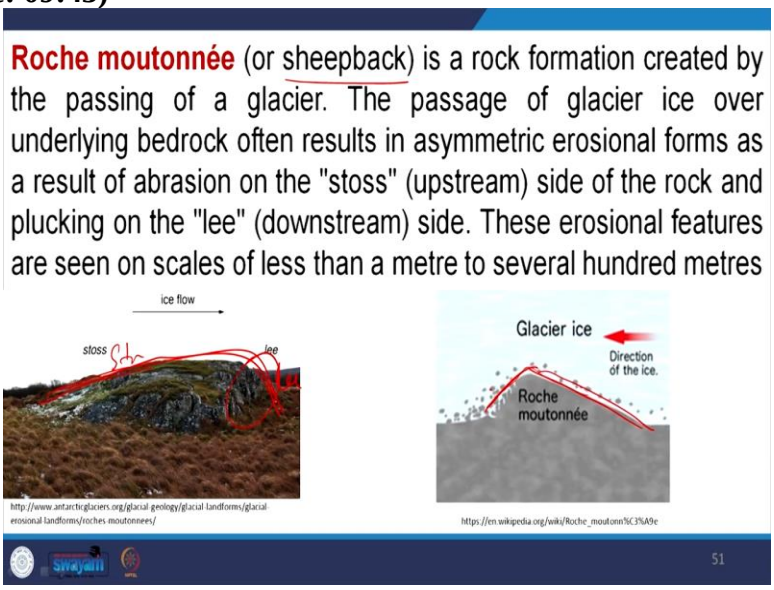

Then Roche moutonnee, it is the otherwise it is called sheep back is looking like the back of a sheep is the rock formation created by the passing of glacier. The passage of glacier ice over underlying bedrock often results in asymmetric erosional forms as a result of abrasion on the stoss stoss side of this rock and plucking on this lee side, these erosional features are seen on scales of less than a meter to several 100 meters if you see here, this is the glacial movement direction.

So, here we have stoss side and this is lee side. So, here is the due to this plucking and this is due to abrasion. So, here otherwise you can see this figure, this is stoss side this is lee side and these type of erosional topography, they are called roche moutonnee.

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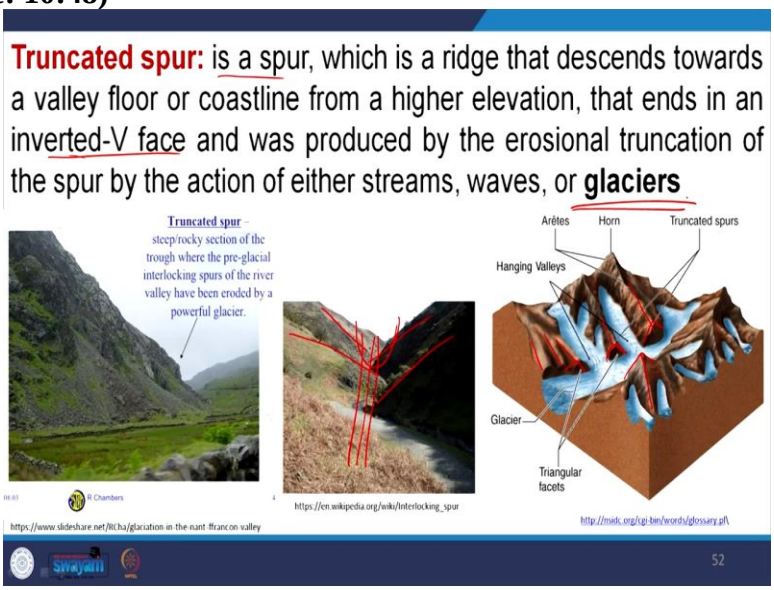


Then truncated spur, truncated spur means if you see this a spur when we if you remember our classes when we are talking about this fluvial geomorphology erosion of river. So, we have interlocking spurs are there if you see here, this is 1 spur this is another this is a 3rd this is 4th. So, the interlocking spurs are there. So, now, if we allow the glacier to move within that, so it becomes straight.

So, once it becomes straight if you see here, this is a spur, which is truncated here, this is spur which is truncated here. So, these are similarly this is a spur which is truncated here. So, these are these truncated spurs here, this is a truncated spur, these are the truncated spurs. So, that

means, once glacier is moving it is removing this rock materials by valley side erosion, as that is why these truncated spurs are developed.

So, it is a spur which is a ridge that descends towards the valley floor or coastline from a higher elevation that ends at an inverted V face and was produced by erosional truncations of this spur by this action of either streams, waves or glaciers. But here glacier at the glacier valley at the U shape valley at this side of the U shape valley these type of truncated spur are common, the higher reaches.

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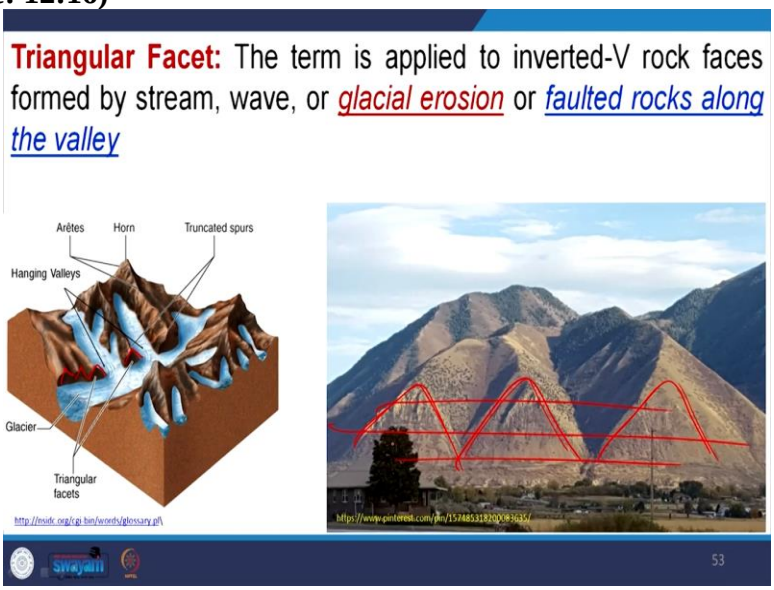


Then triangular facets this is the part of this truncated spur where this spur truncates this cross section if you see, it is looking at triangle. So, these are called triangulated facets, so, triangulated facets not only they are the product of the glacial, erosion there are number of ways through which this a of triangulated facets can be developed. For example, suppose there is a fault here, I am putting a fault here and this is the fault plane.

This is the fault plane through which this spurs can be truncated and these type of triangular facets can be developed there are a number of ways through which this facets, triangular facets and truncated spurs are developed, but if they are confined or their location is that they U shape valley, which is not affected by fault. So, that means, we can say in safely that these truncated spurs and these a triangulated facets, they are the product of glacial erosion.

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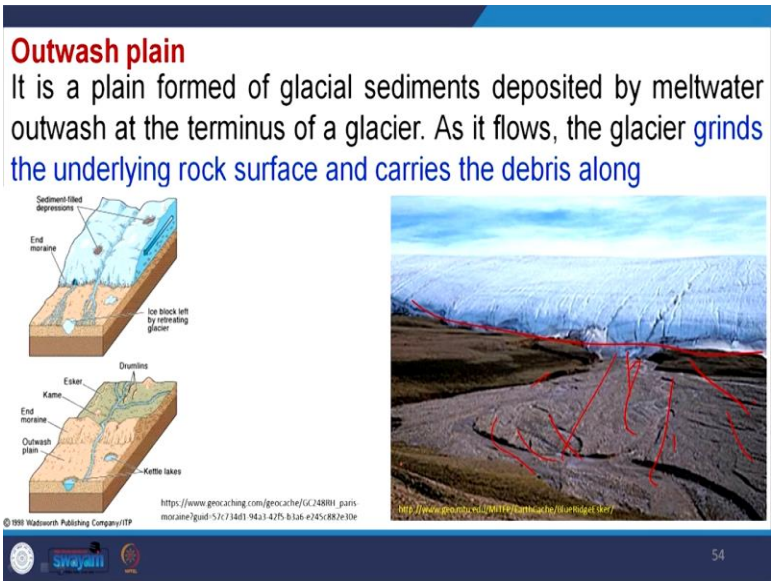


Then outwash plain, outwash plain that means, where the glacier retreats, where this fluvial system develops, so, that means it is more or less is a glacio-fluvial environment. That means the of retreat glacier here. And there see these are this fluvial system they are the channels that are developing from the glacier. They are eroding here, depositing the sediment there. So, mostly it is glacial, glacio-fluvial environment.

This is outwash plain and many times this area is also that means restructured it is rearranged and reworked by wind action also so this outwash plain it is the first plain which is in front of the glacier. And is defines this retreat of this glacier. As a result this streams which are generating from this glacier, they rework the sediments, they transport the sediment they rearrange the sediment along with some aeolian action.

So, this is total called outwash plain. It is a plain formed of glacial sediments deposited by melt water outwash at this terminus of a glacier. As it flows the glacier grinds the underlying rock surface and carries the debris along. So, these glacial debris, they are redistributed by the fluvial action. This is outwash plain.

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Then all those things that we are talking something about the glacier system. Now we will talk about these glacial deposition system that means by erosional the system we have created some of this topographic and this time it is to discuss about the glacial deposits. So, that means, those materials which are removed by this glacier due to the retreat of this glacier in the ablation zone. So, this material has to be deposited.

And this forms some of these say landforms that is depositional landforms it is here the first one is the till or otherwise the deposit is called tillits. So, it is unsorted that is important unlayered that is another important that means, no stratification is there, no layer wise arrangement is there, no sorting is there. So, that means as it is dumped like bulldozing action, so, this bulldozing action all this material irrespective of its sorting irrespective of its origin.

So, there will be no layer sequence so this material is dumped as it is, that is called till. So, till is unsorted unlayered material deposited directly by a glacier landforms composed of till includes Moraines, Drumlins and glacial erratic and glacial erratic that we have already discussed earlier. And moraines and drumlins these are the unsorted unstratified form of the glacial deposit, they are directly deposited by the glacier not it the outwash plain.

Outwash plain means that it glacio-fluvial deposits, but here it is the glacial deposit. Now, if you see this photographs, they are the material there is no sorting they starting from the boulder

through clay size particular there is no sorting. No prefer orientation, no preferred layering, so this material is called till.

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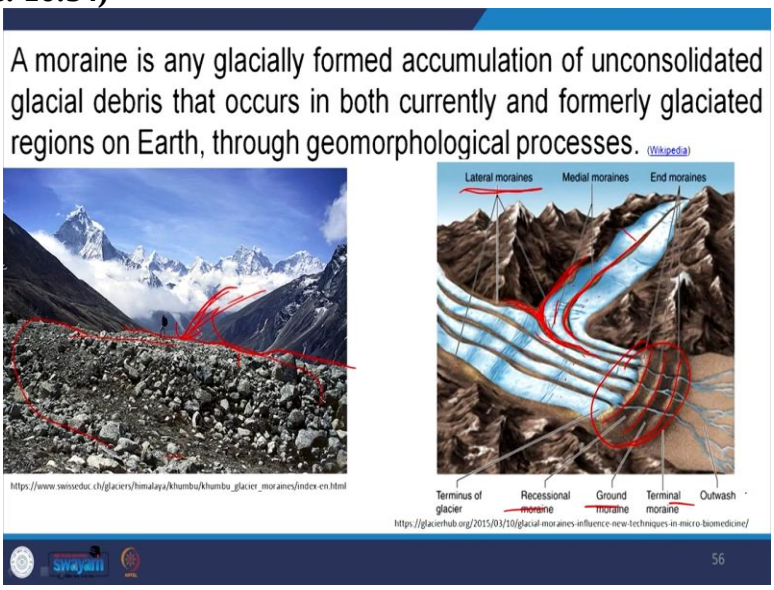


Now we will discuss about moraine the first that moraine is a any glacially formed accumulation of unconsolidated, glacial debris that occurs in both currently and formerly glaciated region on earth through geomorphological processes. So that means these are these moraine that means if it is a glaciated valley and these are this region where glacier is glacier is moving and here if you see this end of this glacier we are getting some material.

And that if this is the glacial valley is continuing at the side of the glacier we are getting some material and here is a model very nicely elaborating the system. Here, this is the glacier and these are the material there is moraines and here the material is here the material that means each and every glacier by this side at this end at this middle where this 2 glaciers meet. Moving side by side, and this middle part, we have; that deposits.

Here at the side of this glacier here we are having deposit and here 2 glaciers meet. And here, 2 different ridges, they are also merging. So, depending upon these type of relationships, either they occur at the end of this glacier, they occur at this side of glacier. They occurred at this junction of this glacier, the moraines are named so, first this is called lateral moraine lateral moraine means these moraines or this deposits, they occur at the side of this glacier, it is called lateral moraine.

Similarly, medial moraine medial moraine means here you see, these 2 moraine 2 lateral moraine here this is lateral moraine. They are linking here and forming a single moraine that is called medial moraine the medial moraine means here 2 glacial meet as 2 glaciers meet 2 different moraine, they are meeting this point and continue. This is called medial moraine and these are called end moraines.

End moraine means, who are the glacial retreats that means the glacier is retreating down. So this end moraine occur at the end of this glacier these moraine are deposited this is called recessional moraine, ground moraine terminal moraine. So that means depending upon its position with respect to a moving glacier or a dead glacier, these moraine are named this is called moraine.

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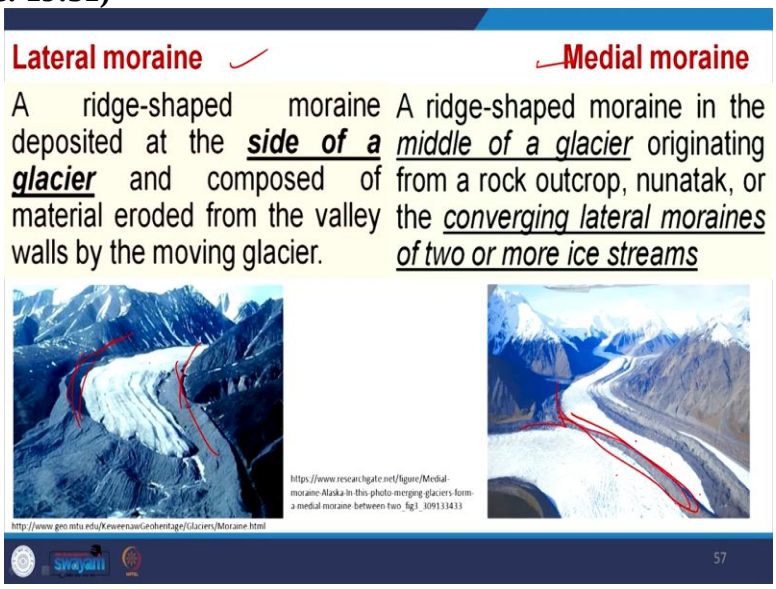


And we have discussed these things. Lateral moraine, medial moraine, lateral moraine, these are this lateral moraine their laterally at this glacier and this is medial moraine because 2 glaciers that meet and here 2 lateral moraine they are mixed and this part is called middle moraine.

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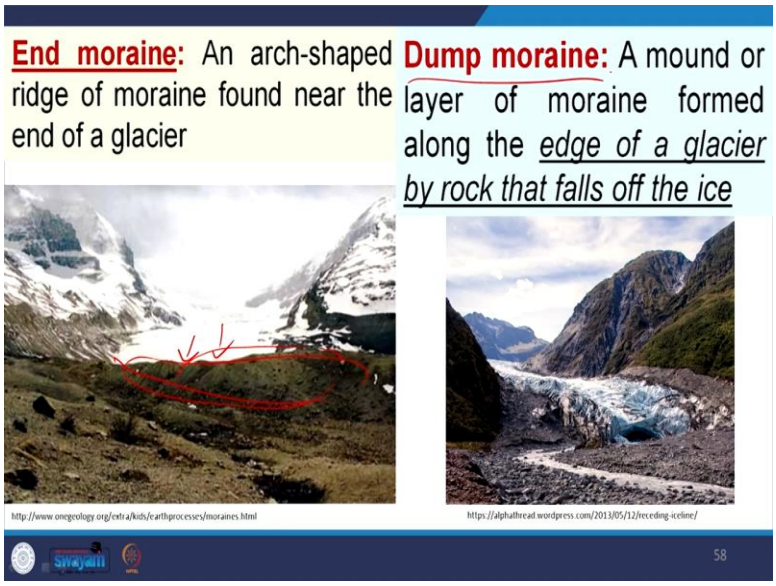


End moraine here the glacier here melts the ends its position and this is called the end moraine. And another type of moraine which is called dump moraine dump means it is dumped. So a dump or dump moraine is a mound or layer of moraine formed along the edge of this glacier by rock that falls off the ice. So now here that means rock fall from the ice, so that means ice it ice valley glacier is moving on with this valley, it is the bedrocks.

They are eroding blocks they are also falling within that ice. If these blocks due to movement of this glacier these blocks are moved apart or they fall off the glacier to the side and forming this moraine that is called dump moraine. So it is a special kind of lateral moraine.

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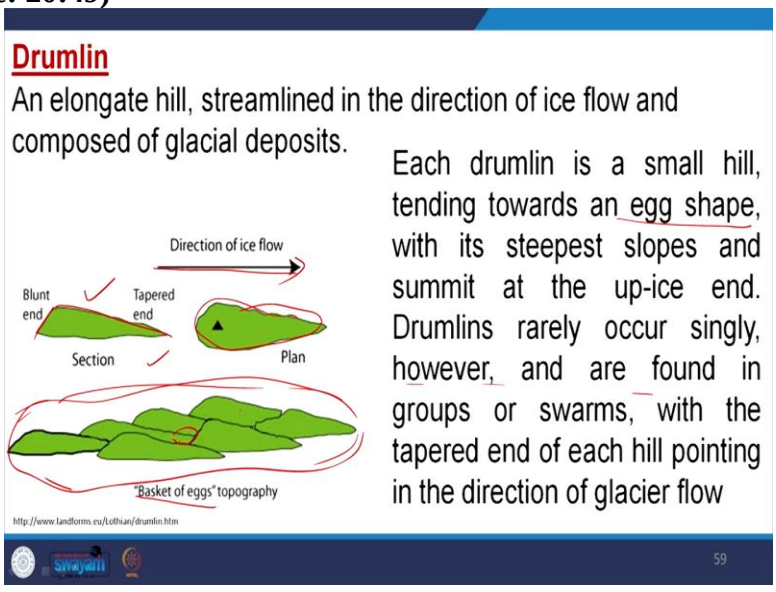

Then other type of deposit is called drumlin. It is elongated hill streamlined in the direction of ice flow and composed of glacial deposits each drumlin is a small hill. So now you see here, this is small hill type. And if number of moraine, they are forming here, this is called drumlin field. So, tending towards the egg shape, if you see this plan view, it is looking like a eggs shape with a steepest slope and submit at this up ice end drumlin rarely occur single.

And however, these are found in the groups of swarms with the tapered end of each hill pointing in the direction of glacial flow. So, here the direction of glacial flow, this side is the blunt end, and this is the tapered end and this is called drumlin field. And if you look from this plan view, this drumlin field is looking like a basket of egg so that that means you can place egg here place. That is why this is called a geomorphological term this is called basket of eggs, it is drumlin field.

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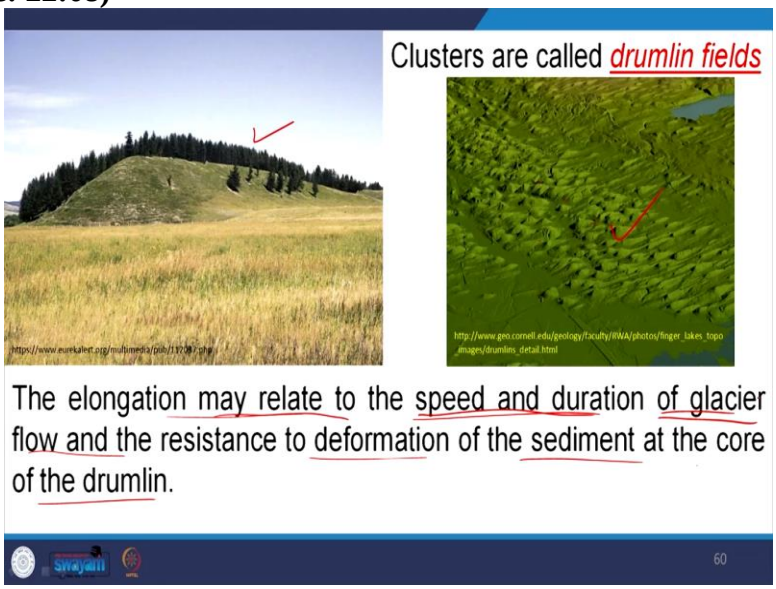


The clusters if you see this aerial photograph, this is the drumlin field, and a number of drumlin is there, and it is a single drumlin this elongation may related to the speed and duration of this glacier flow and the resistance to deformation of the sediment at the core of this drumlin. Now, you see here, it is mostly it found in the sedimentary rock. So, here this is the basket of eggs are there and it is elongated, maybe related to speed and duration of this glacier.

How speedily this glacier was moving, and how much time the glacial is taken to move and this duration of glaciation and duration of the glacial moment and the speed of the glacial moment that depends how this length will be a length of this drumlin will be.

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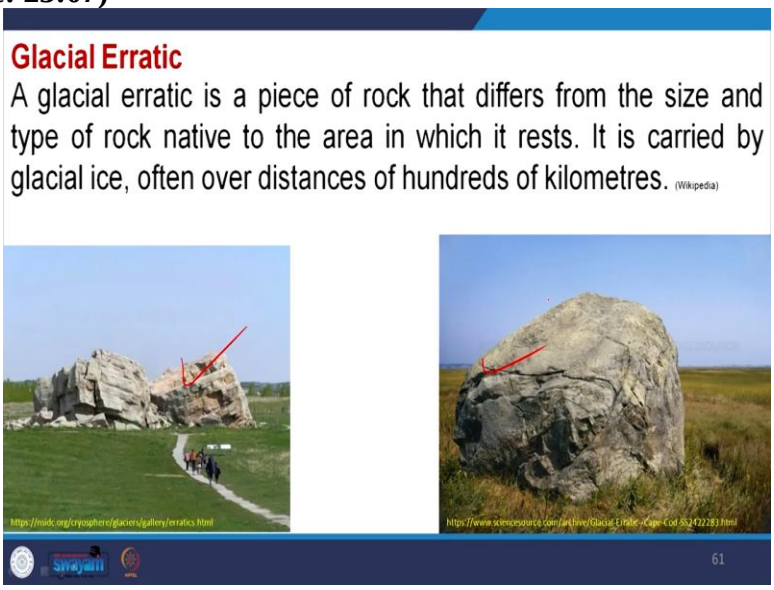


This glacial erratic that we have already discussed about it, it is the foreign rock which is transported for 100's of kilometers from this original position and due to glaciation and it is falling an area which is no relation with the surrounding rock that is called glacial erratic. Then all these things we are discussing about either this moraine drumlin, this glacial erratic that we are talking about these unstratified deposit. There is no stratification. However, here we will talk about this a stratified deposit, stratified deposit there is proper arrangement, proper layering will be there but there is no layering, there is erosional topographies.

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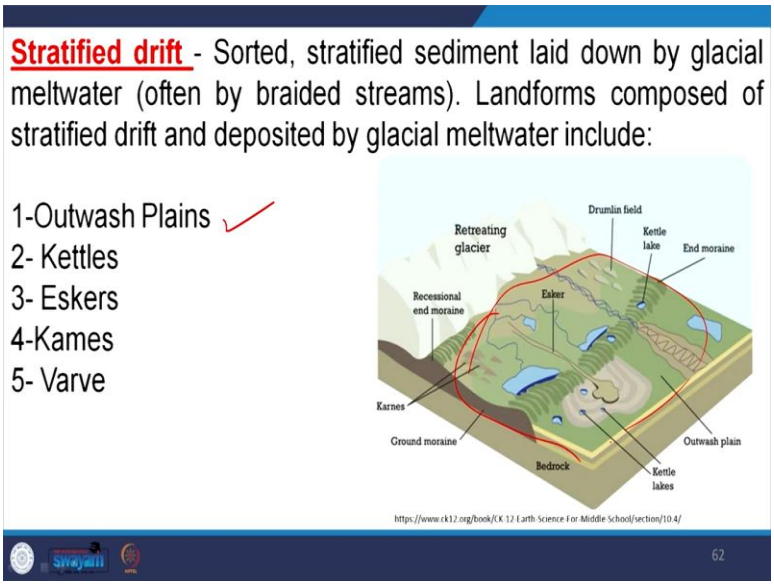


So stratified drift or this sorted, stratified sediment laid down by glacial melt water, often by braided streams landforms composed of stratified drift and deposited by the glacier melt water include outwash plains that we have discussed about these are these outwash plains. That means by melting up the glacier, they rivers their deposit there, they rivers their transport and rework this glacial sediments. And different forms of depositional topography erosional topography are formed that is called outwash plains. Then kettles, Eskers, Kames and varve.

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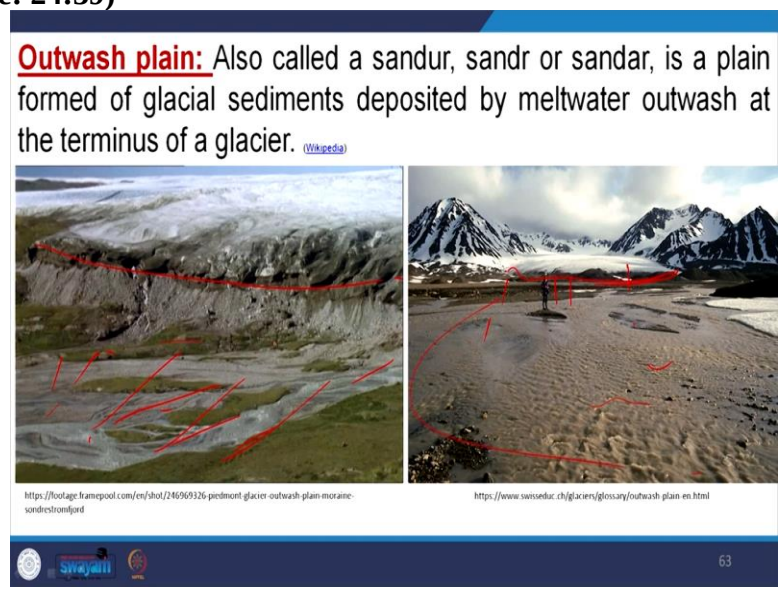


So, here outwash plain is also called sandr. It is a plain formed by glacial sediment deposited by melt water out wash the terminus of this glacier. So, here this is the terminus of this glacier, this is the terminators glacier and now sees the rivers are coming. This channel are coming up, there

will be braided streams are there. So these streams, they are depositing their sediments, these sediments were reworked and this is called the out wash plain.

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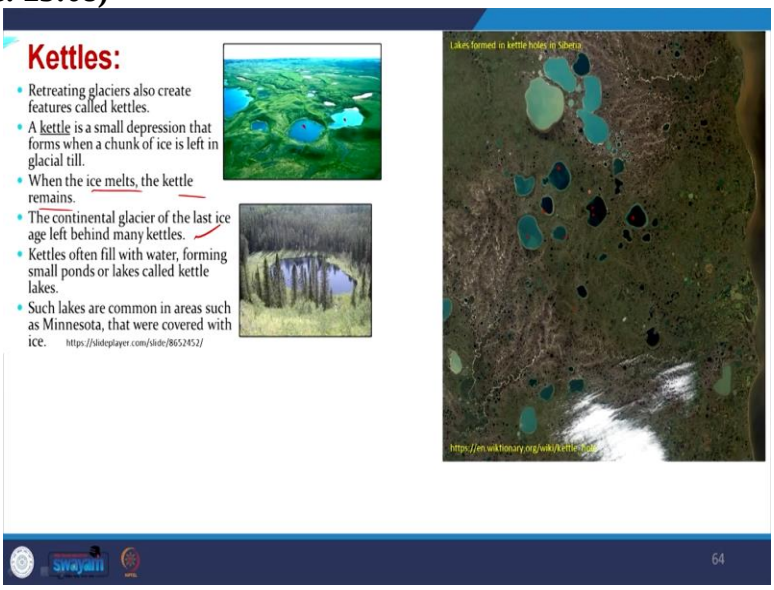


Then kettles if you see this is retreating glacier also create features this is called kettles, a kettles a small depression that is formed when chunk of ice left in the glacial till. So, now you see the mechanism of.

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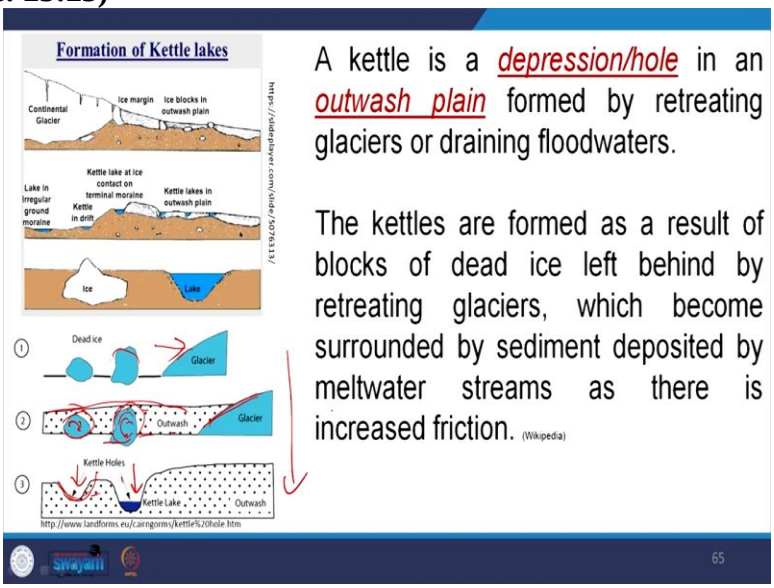


kettles formation if you see here, these the ice sheet or the valley glacier who is moving and at this ablation zone, you see this chunk of ice broken apart from the system is it dead ice, now it is no relation with the parent ice sheet ice body. Now if it is deposited wise it is covered by

sediment after few times, if by the melting of this ice here, this depressions remain the sediment collapse the overlying sediment the collapse and finally forming a hole that is called kettle.

So, if you see this aerial photograph of the satellite imagery of this region, so these are these kettle lakes. Similarly, these are the kettle lakes. So, when the ice melts the kettle remains. This continental glacier of last ice age left behind many kettles, kettles often filled with water forming small ponds or lakes that is called kettle lake. Such lakes are common in areas such as Minnesota where they are covered with ice.

So these are this places where buried ice pieces are there. So once the and date is covered by sediment, once the ice melts the overlying sediment that collapse down and forming this whole type or this pond like environment pond like topography, and this is kettles lakes. So a kettle is the depression or hole in an outwash plain formed by retreating glacier or draining floodwaters. The kettles are formed as a result of blocks or dead ice left behind by retreating glacier. Which become surrounded by sediment deposited by melt water streams as there is increased friction. So these are the mechanisms how this kettles lakes are formed.

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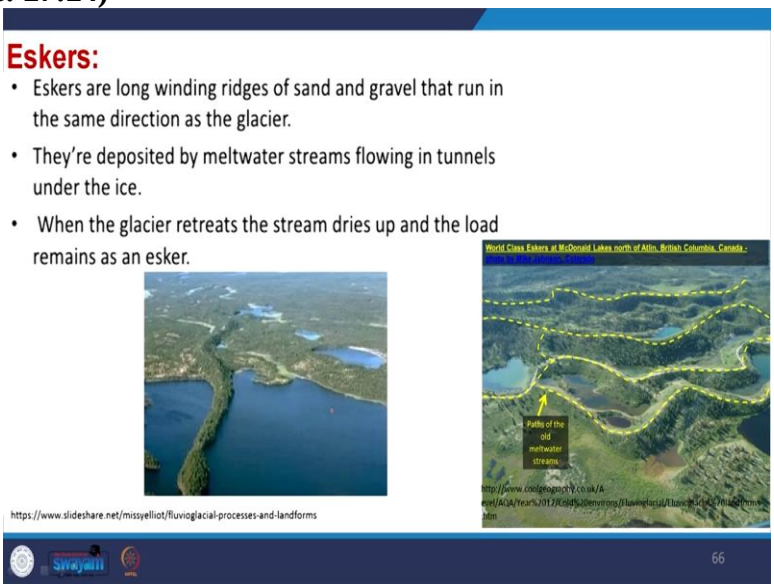


Then another type of deposit glacial deposit is called eskers. They are the long winding ridges of sand and gravel. They are drawn in the same direction as glacier. They are deposited by melt water streams following the tunnels under the ice. When this glacier retreats, the streams dried up, and this load remains as an eskers that elevated topography. So now we see.

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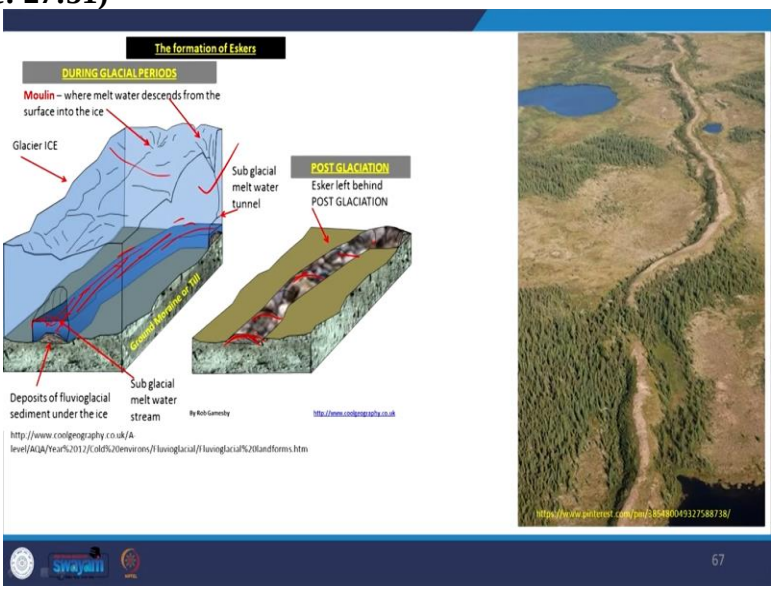


We have glaciers and from this glacier, due to tunneling effect, some streams are coming up and once the streams coming up here. So, they are transporting sand and gravel with that. So, now once the glacier retreats, these sand and gravel which are transported by the stream that remains as it is. So, that means it is creating a locally positive topography and you find these are these eskers. So, here we see number of eskers are there that means, this number of interconnected channels they were coming up from this glaciated region.

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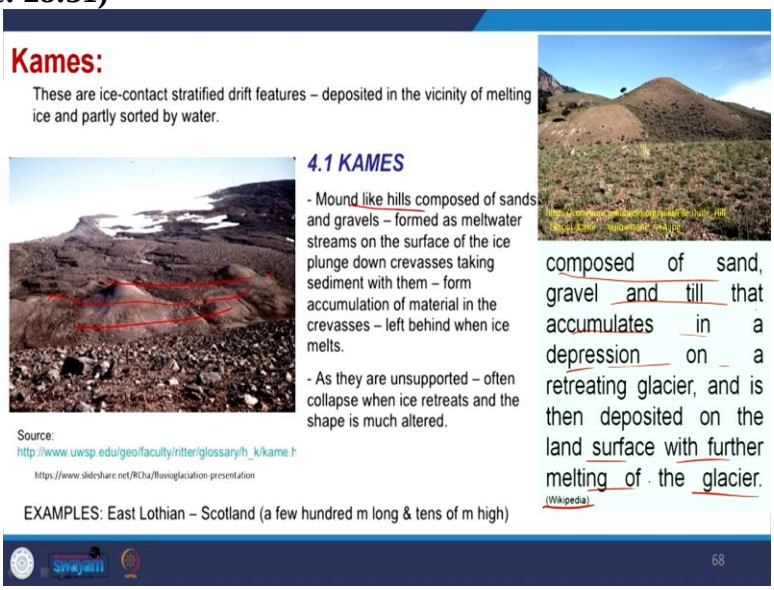


Then kames these are this ice contact stratified drift features deposited in the vicinity of melting ice and partly sorted by water so, that it is mostly it is partly glacial at partly fluvial. Kames are this mound like hills composed, of sand and gravels formed as melt water streams on the surface

of this ice plunge down crevasses taking sediments with them. Form accumulation of materials in the crevasses left behind when ice melts.

So, these are these areas where crevasses were formed in the ice. So, through this crevasses the streams are moving down and taking the sediments with them. So, once the glacier is melt, so, this crevasses where through the stream was deposited the remains there at the depositional formed, so, composed of sand and gravel and till that accumulates in a depression on a retreating glacier. And it is then deposited on the land surface with further melting of this glacier it is from taken from Wikipedia. So, these are these kames.

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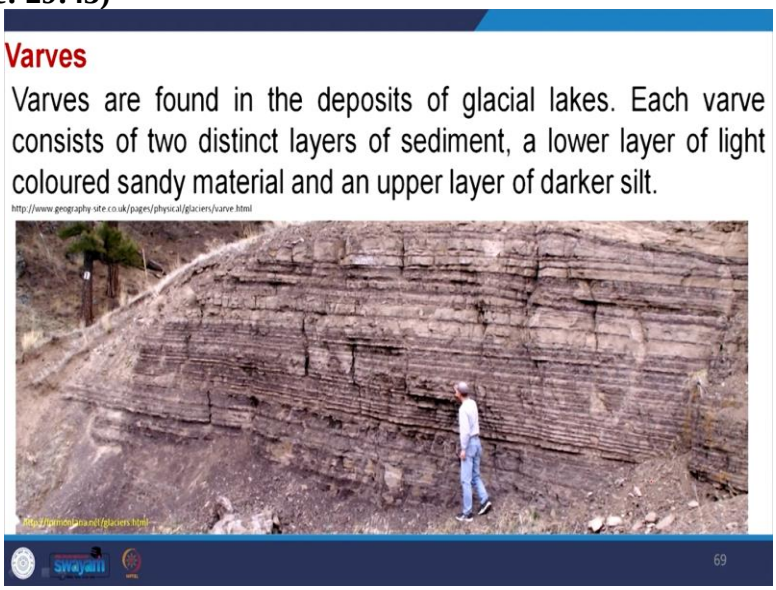


So, then later on the most prominent one is the varves. Varves are found in the deposits of glacial lakes. Each varve consists of 2 distinct layer of sediment, a lower layer of light color sandy material and an upper layer dark silt. So, this light and a dark there indicator of different seasons of an year, the light color is deposited during the summers are this melting of ice day where the water velocity is more mostly sandy pebbly or gravelly. And the other one, the black dark 1, it is the represent winter 1 where there is we there will be the death of organisms due to winter.

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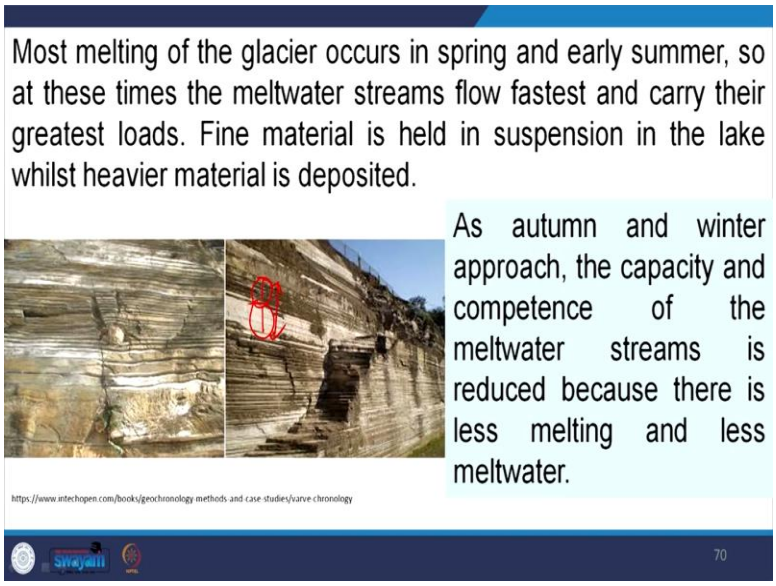


Most melting of this glacier occurs in the spring and early summer, so that these times the melt water streams flow fastest it and carry their greatest loads. Fine material is held in suspension in the lake whilst the heavier material is deposited. As autumns and winter approach. The capacity and the competence of these melt water stream is reduced because there is less melting in the ice. So that means each alternate dark and white layer. This indicates summer, and this indicates the winter 1. So totally, they represent 1 year.

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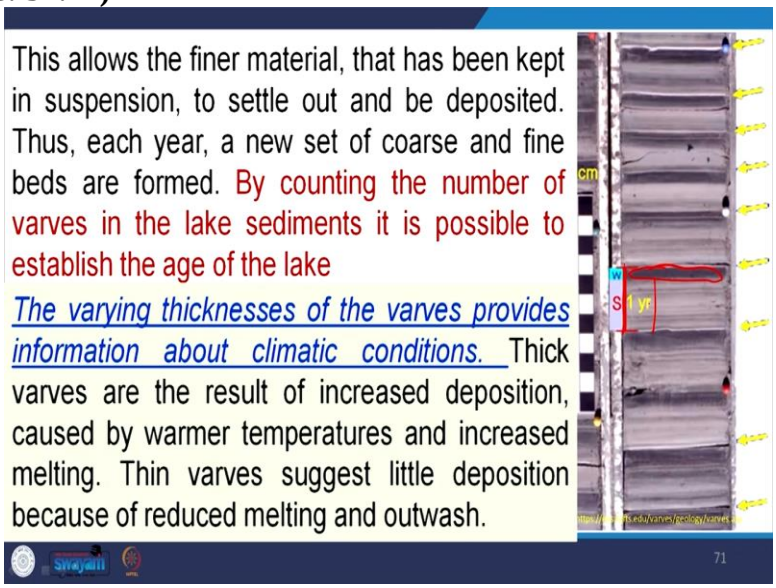


This allows this finer of material that has been kept in suspension and settles out settle down and deposited this each year. A new set of coarse and fine beds are formed by counting this number of the black and white or there is dark and white combination, we can age that how much it age

is the lake that is Glacier Lake. For example, if you have seen this figure it is given it is representing 1 year so this representing this winter and this representing the summer 1.

And generally the summer one is a thicker as compared to the winter one due to this water scarcity in the winter. So the varying thicknesses of these varves provide the information about the climatic condition. Thick varves are the result of increased deposition caused by warmer temperature and increased melting. Thin varves suggest little deposition because of the reduced melting of water.

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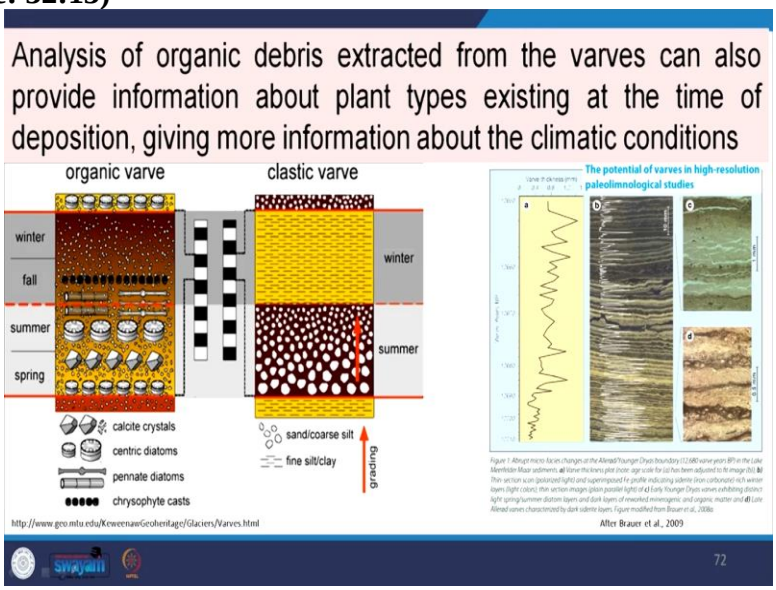


So, analysis of this organic debris extracted from the varves can also provide the information about this plant type existing at the time of deposition and being more information about the climatic conditions. So, these varves, they are a good indicator of climate.

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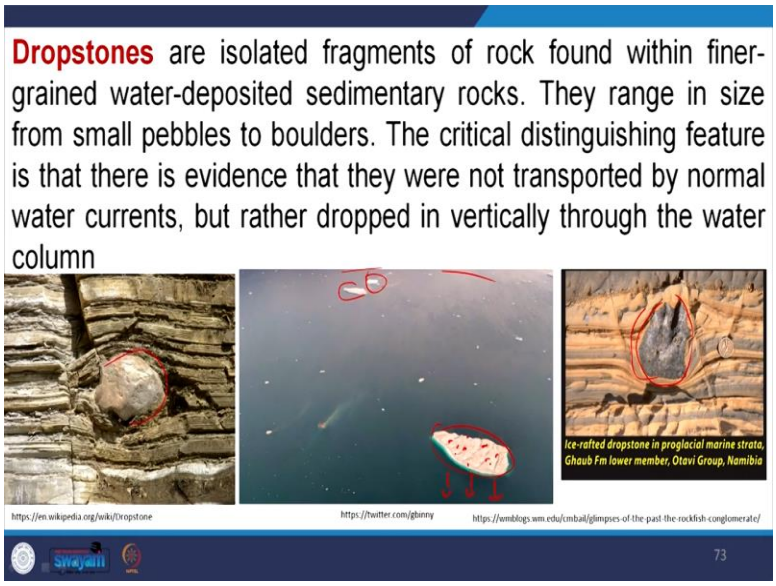


Now another type of deposit which is very peculiar in the glacial landforms which is called dropstone. Dropstone by the name itself says it is dropped, not deposited by this water of the glacier it dropped means suppose we have a lake where this glaciers pieces of glaciers or chunks of glaciers they are floating. If we have boulders embedded within that by melting of the glacier this boulders that drop down and this dropped boulders they are embedded within that glacial varves. So, these are these are called dropstones. So that means the name itself it was dropped from the glaciers.

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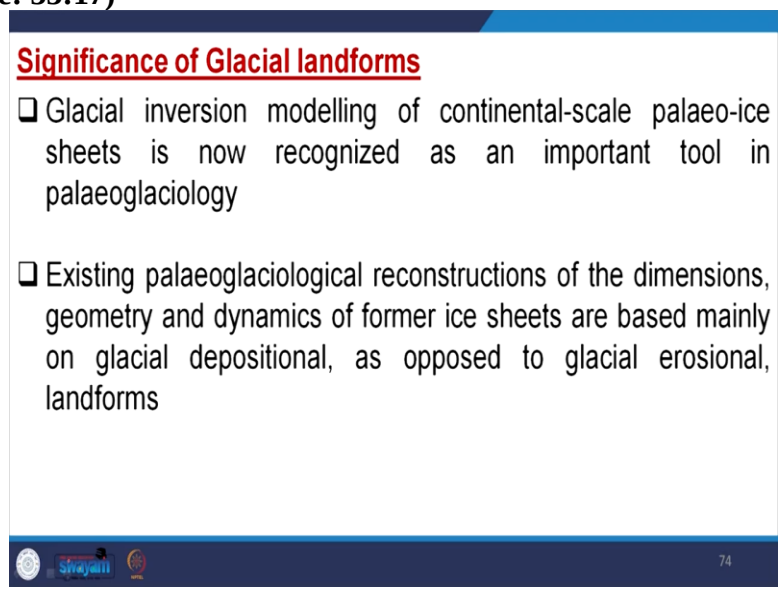


Now what is the significance of the glacial study? Why we need a glacier environment study? first is glacial inversion modeling of continental scale palaeo ice sheet is now recognized as an

important tool for palaeogeographic study or palaeoglaciological study, existing palaeoglaciological reconstruction of this dimension geometry and dynamics of former ice sheets or based mainly on, glacier depositional as proposed to the glacier erosional landforms.

So that will by looking this erosional landform depositional landform types of erosion types of deposition. We can reconstruct, we can restructure how this ice sheet was moving where this accumulation area where the retreating area which path this glacier was moving through like that. Investigation of this relationship.

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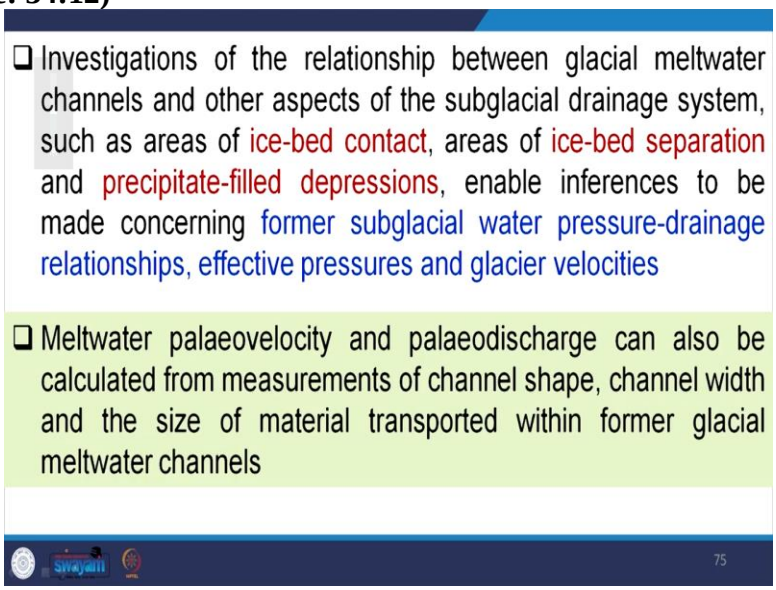


Between glacier melt water channels and other aspects of the sub glacial drainage system such as areas of ice bed contact, areas of ice bed separation and precipitated field depressions enable the reference to be made concerning former sub glacial water pressure drainage relationship effective pressures and the glacier velocities so that means all this deposition or the erosional landforms that can tell about this nature of the glacier.

Where it is moving where this more pressure was there was less pressure with the thickness of the ice sheet there thin ice sheet there small valley glacier is there where the cirques quarries is and all the other lesson battles are glacial related topography are there. So based on that we can reconstruct the palaeogeography we can reconstruct the palaeoclimatic history melt water palaeo velocity and palaeo discharge can also be calculated from these measurement of the channel shape, channel width and size of the material transported with former glacier melt water

channels. So, that means palaeo glacio-fluvial environment can also be reconstructed through these types of studies.

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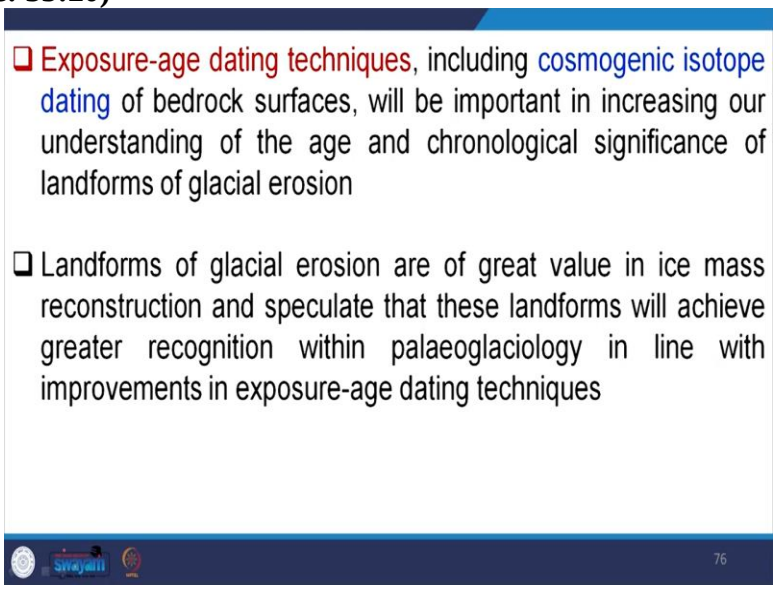


Exposure age dating techniques including cosmogenic isotope dating have the bedrock surface will be important in increasing our understanding of the age and chronological significance of the landforms of the glacial erosion. These varves can be dated these sediments can be deposited, that can be dated, this surface glacial surface can be dated, so, that we can have this chronological constants when the glacial age when the ice age was there. So, that means it the improvement of science improvement of this knowledge regarding palaeo-glaciology paleoclimatology.

Landforms of glacial erosion are of great value in ice mass reconstruct and speculate that these landforms will achieve greater recognition with palaeo-glaciology and line with improvement with exposure age dating techniques. So with the help of age dating techniques, we can constraints, the climatology, we can constant the chronology of the glacial systems. So I think it is the end of this topic. So thank you very much. We will meet in the next class.