Geomorphology
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Lecture - 28
Wind Erosional Landforms I

So friends good morning and welcome to this lecture series of Geomorphology. Today, we are going to discuss about the wind erosional landforms. So if you remember our last class we are talking about this wind erosion. The mechanisms of erosion has been divided into 3 part. One is deflation then abrasion then attrition and to summarize it we can say by this wind deflation we are able to create a desert pavement.

By wind abrasion we are creating ventifacts and these are the faceted pebbles which if it is up larger size that can be used to distinguish to determine the wind velocity, wind direction and by this change of this wind direction we can say the change of this landform process or formation of the landform and its position. So now we are going to discuss about this product of this wind abrasion.

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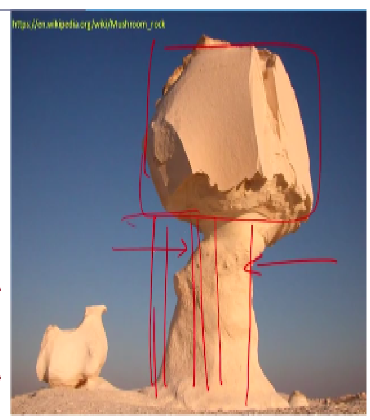
Undercut, mushroom-shaped pedestal rocks in desert areas are commonly attributed to wind abrasion.

However, experiments prove that the median height of windblown sand transport is only about 1 cm over a layer of similar-size grains and little more than 10 cm over hard-rock surfaces.



The first and foremost product of this wind abrasion is due to this action of wind as well as its particle together and this forms the most peculiar mushroom shaped pedestal rocks. The mushroom shaped pedestal rock if you see here the basement or the base of this rock it is more removal that is more erosion occur at the basal part however as compared to the top part this material is less removed.

This experiment proves that the median height of windblown sand transport is only about 1 centimeter over sand layer and about 10 centimeter over rock surface. So if this is so now the question arises how a system or erosional surface is produced which is highly eroded up to this much height.

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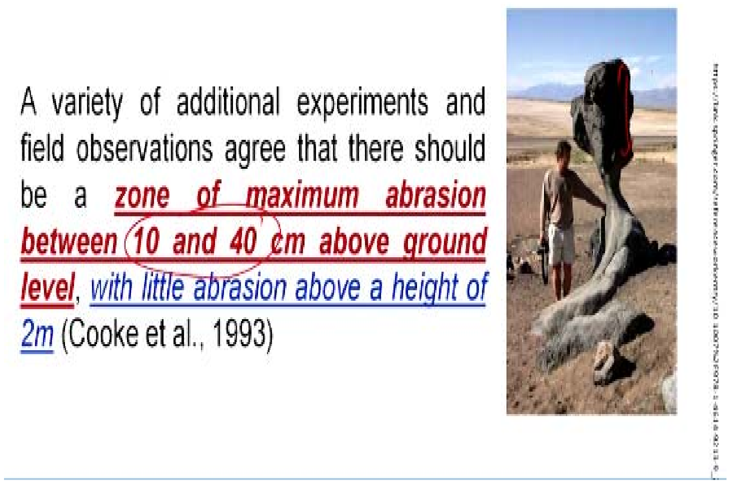

So further experiments says additional experiment and field observation agree that there should be a zone of maximum abrasion between 10 to 40 centimeter above ground level with little abrasion occurs above the height of 2 meter. So that is why all this abraded landforms in this arid region you will see maximum abrasion occurs here up to 10 to 40 centimeter from the surface.

And gradually the degree of erosion, degree of abrasion decreases that is why we are creating a rock body which is lower part of the basal part is highly eroded as compared to the top part. So this type of mushroom shaped rock bodies are called pedestal rocks.

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Then if we continuous with this erosion. Suppose we have unconsolidated or semi consolidated material and gullies are formed here. Now we allow this sand laden wind to interact with this gully surface. So what will happen here you see this gullies earlier it was of fluvial origin and this erosion is added by this wind action. So that means both side of this gully, the removal of material will be more as compared to the middle part.

For example, if you see here if we allow the wind to interact here more erosion will occur along this gullies. However, in between this material, this segment will remain less eroded as compared to this gully erosion and this gully erosion. So that minor eolian abrasion landforms includes chutes and flumes that notch low escarpments around playas and other desert plains.

So these are the chutes and flumes. Minor erosion is there they are aligned with locally effective winds and are probably scoured by windborne sand being swept through small gullies. So as we are talking about these chutes and this flumes they are formed by this wind abrasion around this small gullies and that is why if you take a profile from here to here it will look like this. So these areas they are more eroded by wind and this area is relatively low these are called chute and flume structure of wind erosion.

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A **yardang** is a streamlined protuberance carved from bedrock or any consolidated or semiconsolidated material by the dual action of wind abrasion by dust and sand, and deflation which is the removal of loose material by wind turbulence (wikipedia)

The shape of yardangs probably originates from gullies and their interfluves at a scarp edge of a deflation basin, and evolve toward relatively stable streamlined bodies with a width-length ratio of 1/4

So if we allow the wind to interact further the removal of material by abrasion a landform peculiar to this hull of a boat is formed that is called yardang. So yardang is another product of wind abrasion which says it is a streamlined protuberance carved out from bedrock or any consolidated or semiconsolidated material by dual action of wind abrasion by dust and sand and deflation by which the material which is abraded is removed by this wind, this loose material is removed.

So that only the rock surface is there. So this is by this way a yardang is produced. The shape of this yardang probably originates from this gullies and their interfluves at a scrap edge of the deflation basin and evolve towards relatively stable streamlined bodies with width length ratio equal to 1:4. So that means if we consider its width as compared to its length this ratio will be 1:4.

And this part will be these are the gullies and this side is the gully and this represents the interfluves and due to this wind action material is removed from here, material is removed from here by abrasion and this abraded material which will lie here that will be removed further by the deflation action. So that is why this topography if you see here this is looking asymmetrical like this. So this is the upwind direction and this is the downwind direction.

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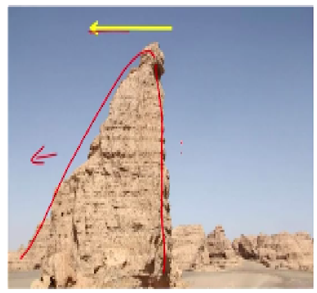
The tapered downwind end, considered to be the shape of least resistance of a solid body immersed in a moving fluid (Ward and Greeley, 1984). It looks like the hull of a boat.

http://www.hemeshoff.org/news/



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So by appearance if you see this tapered downwind end considered to be the shape of least resistance of a solid body immersed in a moving liquid it looks like the hull of a boat. So this is indicating the wind direction here asymmetrical shape if you see this side is downwind direction, this is the upwind direction so this is yardang.

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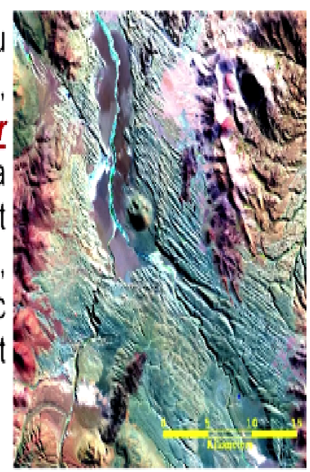
On the high, cold, dry Altiplano Plateau of the central Andes in Argentina, Chile, and Bolivia, wind-eroded, ***linear gullies in ignimbrite*** show a consistent northwest-southeast orientation from about 18S to 28S, independent of local slope, tectonic trends, and ignimbrite emplacement direction [http://www.geo.cornell.edu/geology/eos/atmos2/eolian.html]



http://www.geo.cornell.edu/geology/eos/atmos2/eolian.html

So another type of wind abrasion feature it is mostly found in Argentina, Andes, Central Andes Chile and Bolivia. These are the linear groups, linear gullies that is found in ignimbrite. Why these linear gullies are said to be this wind product or wind abrasion products. You see the tectonics, the ignimbrite emplacement directions and other factors they do not satisfy the direction of this alignment.

So that means it is believed that these are the gullies earlier it was created by the fluvial action later due to this wind abrasion this gullies widens and this free space was filled with the sandy material. So here on the high cold arid dry altiplano plateau of the Central Andes of Argentina, Chile and Bolivia wind eroded linear gullies in ignimbrite. So a consistent NW-SE orientation for about 18 degree South to 28 degree South independent of local slope.

Tectonic trends an ignimbrite emplacement directions. So that is why it is believed these are the groups or the gullies which are formed by this fluvial action first and later it was modified by the wind action.

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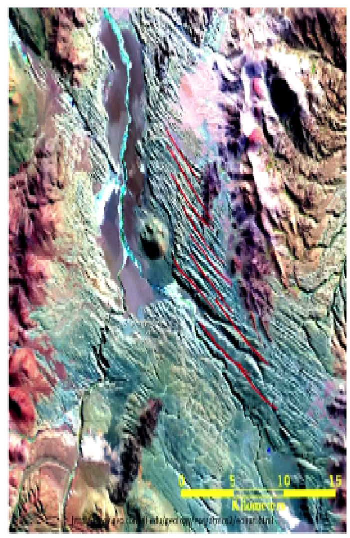
They are probably eroded in part by fluvial action along cooling joints in the ignimbrite plateaus, with wind abrasion preferentially elongating and extending those open joints that are aligned with the wind, and perhaps with drifting sand filling those joints that trend obliquely to the wind



Plateaus with abrasion preferably elongated and extending those open joints that are aligned with the wind and perhaps with drifting sand filing those joints that trend obliquely wind directions. So these are the trends, these are the groups which are formed in the ignimbrite and these grooves are filled with sandy material or the abraded material from this wind directions.

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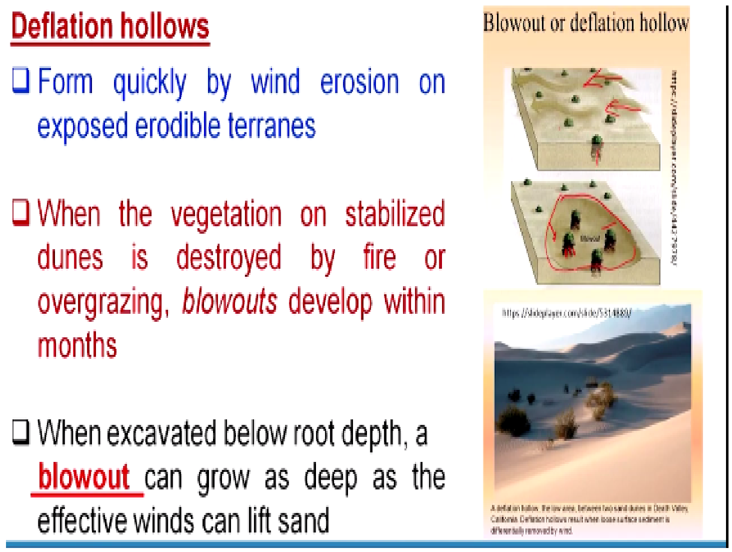

Then another type of erosional feature which is called deflation hollows. We know deflation it is the selective removal of finer materials. So once the finer material is removed that means it creates desert pavement, but sometimes what happens this removal of material maybe extend to certain depth so that it reaches about this root level of the associated vegetation. So form quickly by wind erosion on exposed erodible terranes.

When this vegetation on stabilized dunes is destroyed by fire or overgrazing, blowouts develop within months. When excavated below root depth a blowout can grow as deep as effective wind and can lift the sand. So now in this figure it can be explained here we have a block consisting of sand and some vegetation this is the root level we allow the wind to pass on it blow on it.

So after months if you see due to removal of this material we are creating a depression and depth of depression reaches up to the root level. So this is called deflation hollows and those materials which are removed from here that will be deposited somewhere here. When we will talk about the classification of dunes we will talk about this parabolic dune mostly those parabolic dunes they are formed around this type of deflation hollows.

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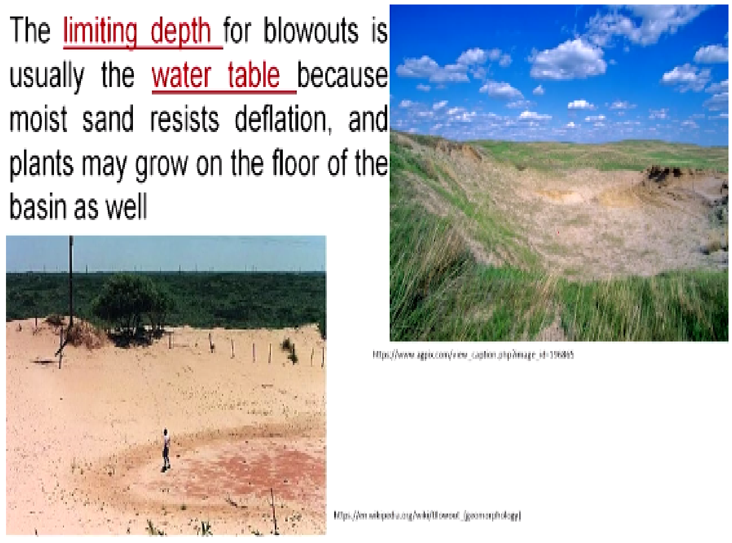

So the limiting depth of blowout is usually the water table because once the water table is there or above the water table there will be capillary action some vadose zone will be there. So in that due to this adhesive force of this water with the sand, the sand will remain intact. So either it will reach up to this water table or it will reach close to the water table that depends upon this conditions of the material.

So the limiting depth of blowout is usually the water table because most sand resist deflation and plants may grow on the floor of this basin as well once we have water table it will promote vegetation to grow and water table this adhesive force between water and sand will increase. So it will resist further deflation. So this blowout depth maximum depth is up to this water table depth. Sometime the water table is exposed and is forming isolated pond that is called Oasis.

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Larger closed basins in arid regions, some of them *many kilometers in diameter and more than 100 m in depth*, have variously been attributed to solution, differential compaction, faulting, and deflation

Some times, the deflation hallow is deeper enough and it reaches up to the ground water table and forms oasis

Larger closed basins in arid region some of them many kilometers in diameter and more than 100s of meters in depth have variously been attributed to solution, differential compaction, faulting and deflation. So as a geologist we must be cautious about what type of depression we are dealing with. So in arid regions these are the other possibilities that the deflation hollow can be formed or depression can be formed by solution also.

Because it is mostly the calcium carbonate sand particles are there if it is dominant then solution is a major factor. Then differential compaction we know we have this sorting differences there will be somewhere little bit sand nearby there will be silt. So those area are more porous that will settle down first and that is why differential compaction occurs. Faulting in arid region if there will be faulting.

Through the fault scarp, through the fault plane or the fault zone there will be depressions and deflation itself also. So that means by looking a depression in arid regions it should not always come to this mind that it is formed by deflation only. There may be the possibility that other process may work or this different process may work together to form a hollow. So irrespective of its only if this size and depth is more and it reach up to the water table.

Then water comes to the surface and it forms oasis, but deflation follows we only and only we use the terminology if the removal of material or a depression is formed by deflation only.

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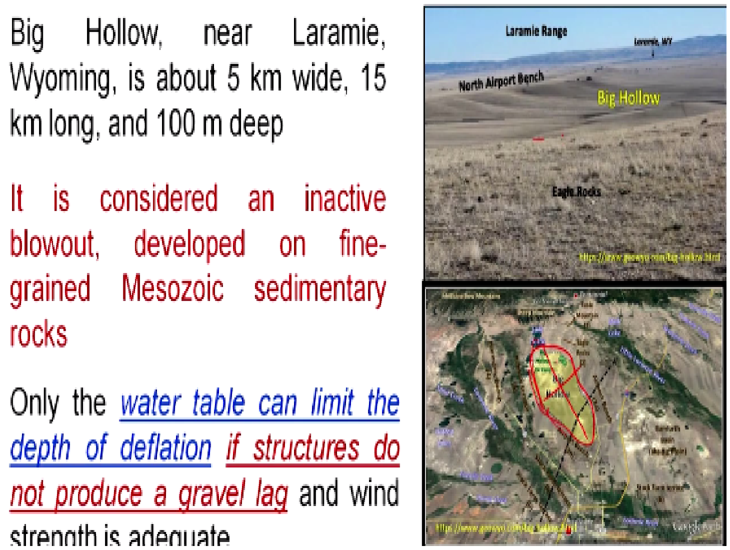

Big hollows near Laramie Wyoming is about 5 kilometer wide, 15 kilometer long and 100 meter deep here this is the Google Earth image of this hollows and this is a photograph taken above from it. So it is considered an inactive blowout developed on fine grained Mesozoic sedimentary rocks. Only the water table can limit the depth of deflation if structures do not produce a gravel and wind strength is adequate.

So that means you see deflation will continue up to that either it is the influence of water table is there otherwise it will cover by a gravel lag and gravel lag if it is covering that means we are creating a desert pavement there. So if gravel lag is there then further wind action reduces. So that is why a depressed part here this is Wyoming we are getting a 5-kilometer-wide and 15 kilometer length and 100 meter deep hollow is there this is due to deflation.

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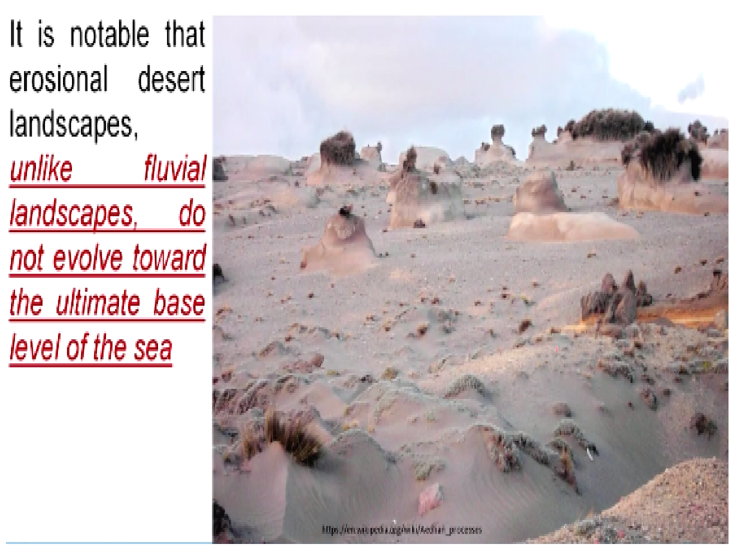

It is notable that erosional desert landforms or landscapes unlike fluvial landscapes do not evolved towards the ultimate base level of the sea this is very important because whenever talking about this fluvial environment the erosional level, the maximum level or the maximum depth a river can erode it is the base level, but here there is no question of base level it is a dynamic process.

A sand can be removed from here and sand can again deposited here. So there is no leveling that up to that depth it can erode, but here we take about this water table depth, this erosion can occur or the depth where there is a depth at a certain arbitrary depth where there will be a gravel lag then erosion will stop or relatively reduce there. So there is no relation with the base level of erosion.

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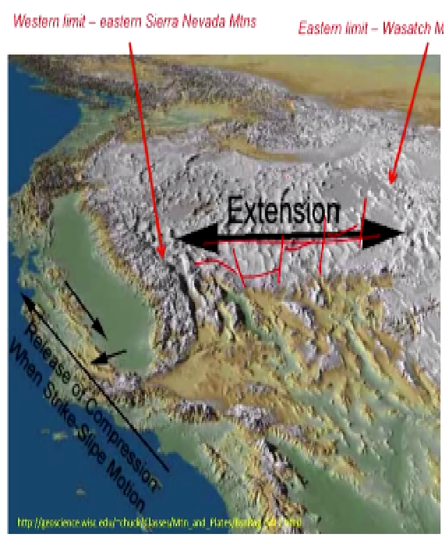
Although ***tectonic desert basins*** seem to be sediment traps it is possible that some basins could deepen almost *without limit by deflation alone*



Although, tectonic desert basins seems to be sediment traps it is possible that some basins could deepen almost without limit by deflation alone. Here if you see this extensional basin of this basin and range province this is an arid region wind is actively acting at the same time it is tectonically very active and is forming horst and graben structures and this here tectonics playing major role in modifying the landscape along with this wind action.

But here if you see the tectonic desert basins like this type of basin and range province where these are the sediments traps because whatever due to tectonic action whatever due to this breakage of the rock, whatever the sediment is produced it is deposited within this gravels. It is possible that some basins could deepen almost without limit by deflation alone. So deflation may or may not work it is not depended on deflation because tectonic is active here.

So extension is going on here new and new faults are added here. So that is why there will be depressions, there will be subsidence. So here as it is a tectonically active basin we should not say it is those depression it is only occurred by the deflation, but deflation may work there, but this majority of this activity or this basin configuration, basin modification is carried out or it is governed by the tectonic process. So now let us go to this consolidated sediments the sediment is horizontally deposited or horizontal deposited sediment.

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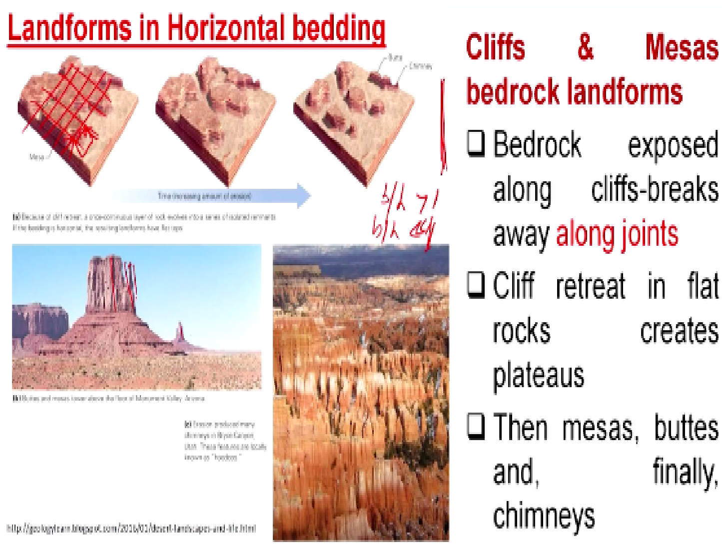

Here landforms in horizontal bedding. Cliff and Mesas bedrock landfalls. Cliff will be there vertically facing slope face if you remember when we are talking about the slope evolution mass wasting Cliff are those which are vertically or near vertical surface of the slope and which is characterized by freefall of this material only air resistance will be there and mesas and buttes these are two different terminology here.

Bedrock exposed along cliff breaks away along joints. We have different joint surfaces suppose we are joint like this one set of joint is like this another set of joint is like this. So through the joints wind action will be there, abrasion will be there. So gradually it removes this material, abraded material by deflation and these joints gradually widens with time. So this side joint is migrating inward, this side joint is migrating inward.

When the two sets of joints join together a part of this rock is isolated here. So it has certain height, it has certain surface area, it has certain base area. So that means this will be called mesas or buttes depending upon its b/h ratio b is the base and its height ratio. So based on this base length and its height ratio is defined whether we will assigned it the name mesas or buttes.

Cliffs retreat in flat rocks creates plateau here cliff retreating creates plateau these are the plateau surfaces. Then mesas, buttes and finally chimneys. Now you see mesas where b/h ratio > 1, buttes where b/h ratio is < 1 and it is << more and more < 1 then it is called chimney. So chimney it is simply a linear or it is a columnar form of this rock it is chimney. For example, here it is a chimney, but if it is base height ratio is > 1 that is called mesas and < 1 it is called buttes.

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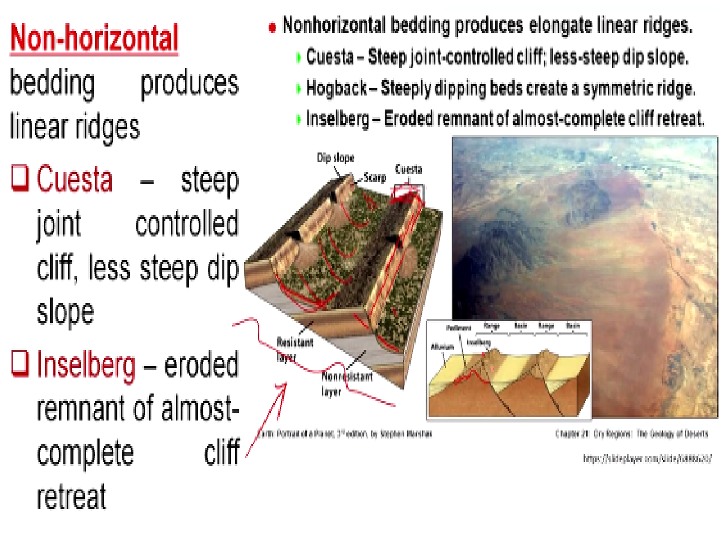

Then the same type of erosion if it occurs in non horizontal beddings. So that means here the bedding surface is dipping. So bedding produces linear ridges. Non horizontal bedding it produces linear ridges. Here you see suppose we have alternate hard and soft rock this part is soft rock, this is hard rock again this is soft rock. We allow wind to blow on it. So due to this soft rock the first it will erode this part.

It is easily eroded and removed and the hard rock remain resistant. So that is why you will get a topography of like this. So this is called Cuesta and this is a scarp, this is resistant layer it is non resistant layer. So this is Cuesta is a dipping surface. Here it is a steep joint controlled cliff less steep dip slope then inselberg. Inselberg is another part here if you see here this is Inselberg is eroded remnant of almost complete cliff retreat.

If it is less eroded, then it is primary bedding structure is there and there is bedding shape is there or bedding form is there so here it is called Cuesta. We allow it to erode abroad so that means gradually its size will be reduced and finally we are getting reduced form and this is called Inselberg. So Inselberg is the eroded remnant of almost complete cliff retreat and hogback is steeply dipping beds create asymmetric ridge and Cuesta stiff joint controlled by cliff less steep dip slope so these are the definitions of this structures.

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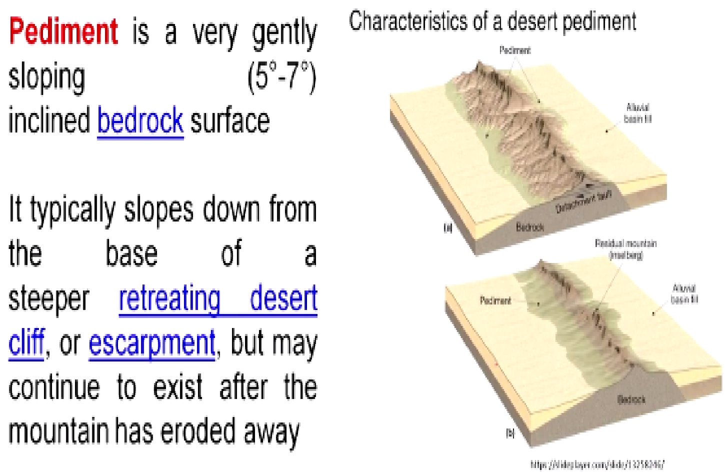

Then pediment again and again we allow it to remove the material finally we are creating pediments. So pediment we have already discussed in last to last classes what is the pediment how they are formed, what is their significance, how they modify. So pediment is a very gently sloping 5 to 7 degree sloping inclined bed rock surface. It is typically slope down from the base of the hill or to the planes of their escarpment may continue to exist after the mountain has eroded away.

So these are the pediment surfaces. So with more and more removal of this material with more and more erosion this type of Cuesta will convert it to Inselberg, Inselberg will convert it to pediments.

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Now depositional landforms of Aeolian sand. So far we are discussing about this erosional landforms that means material was being removed from the system either the system was a loose material itself was removing or the loose material and air jointly they were bombardment on the consolidated rocks and forming or widening the spaces widening the joints.

So those are the erosional processes and from now onwards we will discuss about the depositional landforms. So that means those removed material by the wind it will be transported, it will deposit in a place that is called deposited material or the depositional landforms. So a patch of sand on a desert plain has curiously definitive size limitations. Under gentle winds barely strong enough to stir the sand grains.

The patch is spread downwind and grows thinner and dispersed. So now suppose as we know we have three types of material one is bare rock or Hamada and sandy rock that is ergs and the rocky surface that is called or this pebbly bouldery surface that is called regs. So now we allow the wind to blow. So depending upon the wind speed and depending upon the vegetation, depending upon the availability of the material those material they change their position and their shape depending upon the wind velocity direction.

So these different shapes this give rise sometime it form dunes ripples like that. So that means gentle wind barely strong enough to stir the sand grains. However, if the wind speed increases this sand grains are picked up and it is spread on the surface and finally it disappears from that position and that disappeared sand grains they may be transported to long distance or short distance that depends upon the velocity or depends upon the speed of this wind.

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If no new sand is delivered that place so from upward wind because the available sand, there is sheltered by bedrock or gravel irregularities. Suppose we are not allowing addition of the sand to that position. So that means those sand which is available and we allowed the wind to transport it that will finally spread from their places and it will disappear, but if we allow the wind to add material from the upwind saltated material that is coming up.

So that means this surface continuously removing and continuously adding the material. So that means here this depositional landform will be of different kind. Under strong winds however a preexisting sand patch larger than a critical size of a few meters grows in thickness and in size and its upwind border extends still further upwind. So that means even if strong if the wind is strong then the material can remove from this place and material can add this place.

So that is why we will create a depositional landform either in this downward direction or here so depending upon the sand supply. So when we are talking about this behavior of related to wind-transport dynamics that means here some factors are affecting this wind transport dynamics. One is the wind speed another is the material available and on which surface the wind is being blowing.

So because if this wind is blowing on sand surface its velocity or its speed is absorbed by the sand and that speed that wind speed is transferred to this movement of the sand and saltating effect starts, but if it is wind is blowing on bare rock surface that means the wind speed is increasing. So here if a patch of sand is there and it is being allowed the wind to pass on it so it will redistribute the sand in the downwind direction.

And finally with time this total sand surface will be vanished, but sand is added to it that means a depositional takes place or so. So that means it is completely about this change in behavior related to the wind transport dynamics whether this landform will form or the landform will disappear. So this is all about this wind transport dynamics. I think we will stop here and we will meet in the next class to discuss about how this wind system dynamics changes the landform from one to another.

The shape of this landform, the size of the landform, the position of the landform, how it is changing we will discuss in the next class. Thank you very much. Thank you again.