Geomorphology
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Lecture - 29
Wind Erosional Landforms - II

So friends welcome to this lecture series of geomorphology and in this class we are going to discuss about the wind system dynamics, the wind velocity dynamics. The availability of sand how this wind dynamics and the availability of the sand, availability of the loose material it is creating some of this peculiar landscapes. So suppose we have a length of sand sheet and we allow this wind to blow on it.

With time, the thickness increases or decreases this material at what speed the material start saltating and if the saltating grain is impacting on this another saltating grain, impacted grain how it will behave and finally with more and more saltation this wind becomes saturated with the sediments and finally the system will move, the layer will move and creating a ripple and with more and more addition of the sand this whole system will move forward.

And new landforms will be formed. Strong winds creates surface velocities over hard surface that can transport sand grains downwind over sand however this wind energy near the surface is absorbed by saltating sand and the new sand derived from the upwind is deposited in increasing amount until an equilibrium is reached with the amount leaving from this batch. So that means suppose we are allowing this wind speed to be more. So material removed from here at the same time material is added here. So it will continue up to this equilibrium is reached of the removal material and the addition of material.

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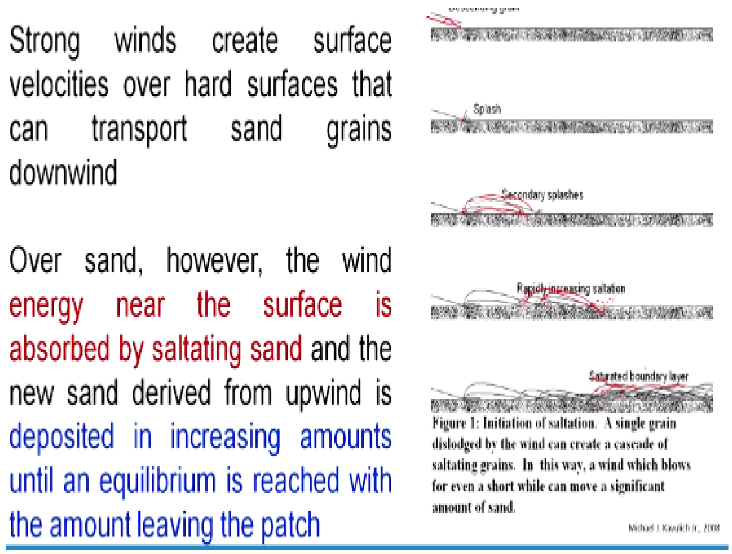

So here it is a figure showing the descending grain suppose a grain in saltating here and descending down here it hits the surface. So once it hits it creates it hits out 2, 3, 4, 5 grains or number of grains and those grain they started saltating here and once this 3,4 grains again add here that will create again saltating more number of grains. Again the same material it is coming again it will be salted more number of grains.

So that means in the downwind directions if the wind velocity or the wind speed continues like this or increases like this in the downwind direction more and more sand will be added to this wind. So that the wind will be saturated with the sediment content. So if you see here rapidly increasing saltation, saturated boundary layer. So that means here this is a saturated system. Here wind is more and more sand grains is added to the wind system.

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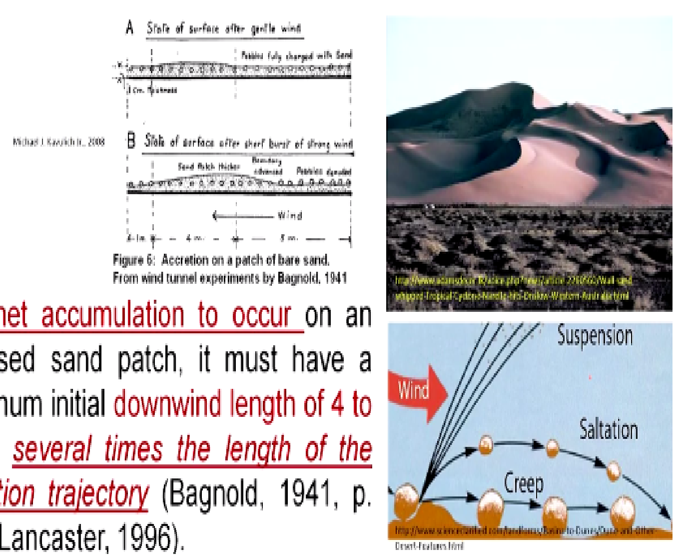

For net accumulation to occur on an exposed sand patch it must have a minimum initial downwind length of about 4 to 6 meter. Several times the length of the saltation trajectory. So now you see suppose this is a sand surface and we are allowing these rock or allowing the wind to move. So it will pick up a sand grain here and it will put it here. So this is the length of saltation or saltating wave.

But here accumulation when we talk about deposition we are talking about the accumulation. So this removal of this material to deposit we need a critical size of a sand body and that critical size is 4 to 6 meter. So that means if we have a sand sheet running about 4 to 6 meter length. So material can be removed here and due to saltation it will be hit here and again it will create some material again it will finally the wind will be saturated.

And deposition starts at the end. So if it is less than the critical size then simply it will be removed and it will move the sand from one place to another place. So that means deposition within the sand body it occurs only and only if it is of more than of a critical size and for here the critical size is about 4 to 6 meter.

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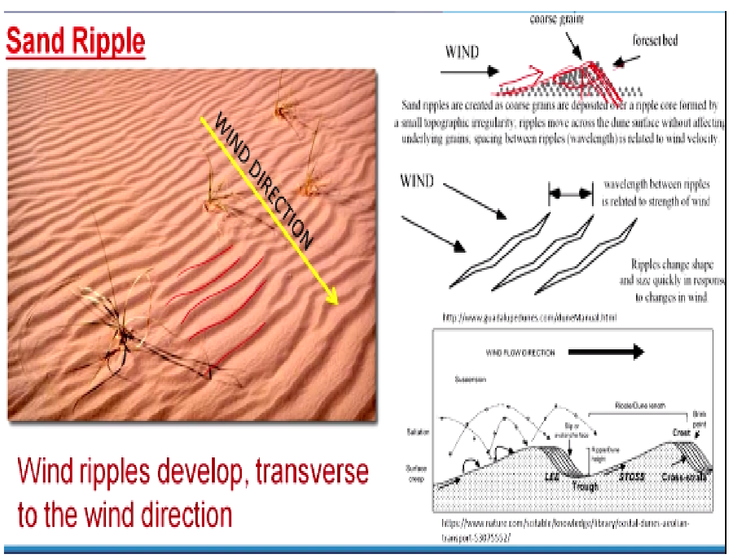

Then the simplest depositional form or the smallest and simplest depositional form of a wind is called sand ripple. Like water ripples, wave ripples similarly we have sand ripples also. Wind ripples develop transverse to the wind directions. Here if it is wind is blowing from here to here this is yellow arrow is shown and these are this wind ripples, these are the sand ripples and the sand ripples if you see by cross section it is asymmetrical shape.

Here this is the wind direction and sand is being transported and here if you see if I am moving from bottom to top the coarseness of the grain increasing. So that means here this is called brink point and this brink point this free rolling is there, free rolling of this because this grain is placed here more than the angle of repose so that is why there will be free fall and will be deposited here.

So that is why the foresets are formed in this position. So now this upper part of this ripple is occupied by coarser material as compared to the lower part, this is due to deflation effect. By deflation, the smaller particles will be removed and this larger particles or the coarser particles will remain at the top. So this is due to deflation effect the surface of a ripple or a top part of a ripple is occupied by the coarser material and gradually the size decreases.

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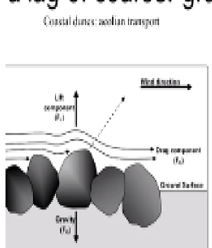
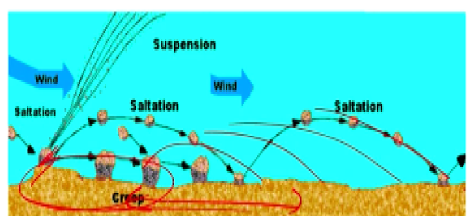
A smooth sheet of sand is inherently unstable under gentle wind

The saltation method of sand movement results in most grains of a given size following trajectories of similar length

At the upwind edge of a sand patch, where transport first begins, a lag of coarser grains is left behind





A smooth sheet of sand is inherently unstable under gentle wind. The saltation method of sand movement results in most grains of this given size following trajectory of similar length. At the upwind edge of a sand patch where transport first begins a lag of coarser grains is left behind. So that means we have a sand sheet it starts from here and the deposition will occur if it is of more than of the critical size of 4 to 6 meter.

So from here once this saltation suspension, creep it occurs so in this area will be enriched with coarser material and the finer material will be removed from this position and will be deposited here. So by this way we can distinguish the sorting. Two different sorting characteristics of material produced here.

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The saltating grains moving downwind from that lag area impact at the mean distance of saltation and produce another lag area

By this process, wind ripples develop, transverse to the wind direction

Their typical wavelength is 1 m or less, very similar to the characteristic flight length of saltating grains, *but probably more influenced by statistical fluctuations in the scatter of the impacted grains* (Lancaster, 1994, pp. 475ff)

This saltating grains moving downwind form from that lag area is area impacted the mean distance of saltation and produce another lag area. So once the saltating suppose for example saltating starts here and its comes here and from here it is coming here again coming here. So by this way progressively lag area is being created. So that is why this area will be occupied by more coarser particles, finer particles gradually increases to this area.

Okay so by this process wind ripples develop transverse to the wind directions if you see this is the ripple axis. So this is the wind direction so it is transverse to that. So there typical wavelength is about 1 meter or less very similar to this characteristics flight length of the saltating grain, but probably more influenced by statistical fluctuations in this scatter of impacted grains.

Here impacted grains plays major role. For example, suppose one grain is picked up from here and saltating is here, but once it impact here 3 to 4, 5 grains they are again saltated. So again that 3, 4, 5 grains again salted number of grains. So that means this typical wavelength of saltation equal to one meter or less very similar to the characteristics of length of the saltating grains.

But probably more influenced by this statistical fluctuation in this scatter of this impacted grains. So this wavelength of this is called this ripples, the wavelength of this ripples is about to 1 meter so this is near about equivalent or similar to that saltating effect that means a grain which is salted from here will move here or saltated from here will move here near about here. So a grain which is saltating from here it will move here. So this is all about your saltation and ripple development.

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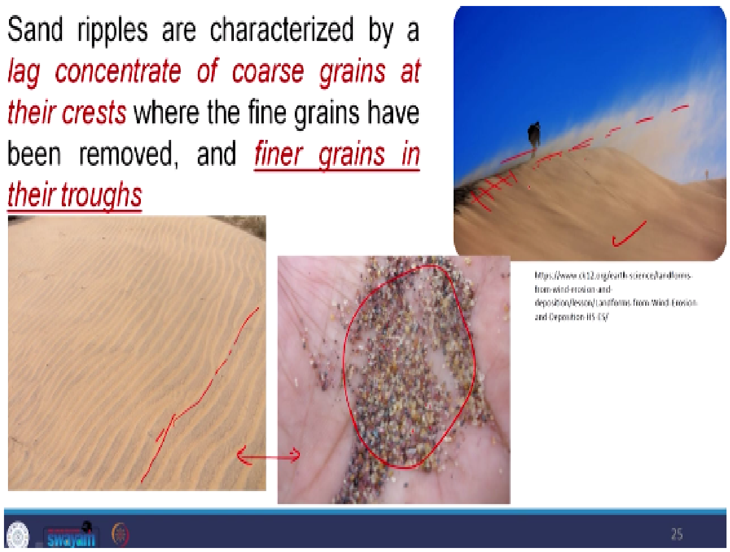

Sand ripples are characterized by a lag concentrate of coarse grains at their crests where the finer material have been removed and finer grains in their troughs. So here if you see this 2 photograph is taken from this Vishakhapatnam East Coast of India and you see this crest this is the wind crest or the ripple crest this is looking relatively black in color as compared to the troughs.

So not only the coarser particle will occupy the crest the heavier particle also occupy the crest and here from the crustal part I have taken some of this sand particles and you see not only the coarser remnants are there, but these dark color minerals are there, they are the heavier particles the garnet, the sillimanite those are the heavier particles are there. So that means this wind ripples at this crest it is occupied by coarser particles and heavier particles.

And at the trough it is occupied by smaller particles or the finer particles or the lighter particles. So if you see here in this photographs this wind is removing the material from this dune crest and finally the dune crest or this ripple crest if you individually ripple crest you imagine the individual ripple crest will occupy by the coarser particles, the finer particles they are removed here.

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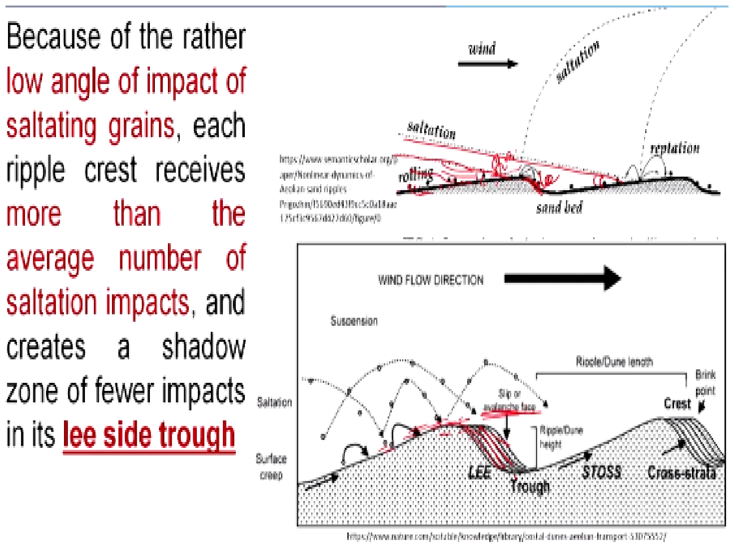

Because of the rather low angle of impact of saltating grains each ripple crest receives more than the average number of saltating impact and creates a shallow zone of fewer impacts and its lee side of this troughs. Now you see here this is the figure and this is the figure you see this is the low angle of impact this is the low angle of impact. So maximum impacts occur this side and as it is coming relatively in wind shadow here are less number of impact will be there.

So that is why we are getting here less number if you have only the free flow of the material from the crest to trough free fall of material, but mostly impacts they are on the stoss and this is called lee side and this is called stoss side. So stoss side it impacts maximum number of impact as compared to lee side. Here at the lee surface avalanches occur that means here impact is more and here impact is less.

So due to this more impact this grains will transfer from here to here and finally once its crest as removed finer material is removed from here the remaining coarse material that avalanche here and this is called the avalanche surface or the brink points. So brink point where the avalanche occur.

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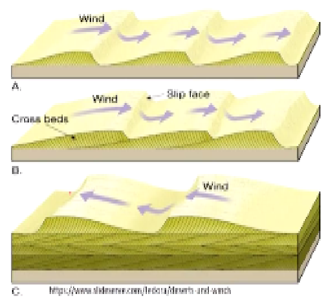
Under stronger winds, the surface of a sand patch loses its rippled form because less size sorting takes place

Then the entire surface layer is sheared forward by saltation and surface creep

However, under such conditions, new sand is also trapped from upwind sources, and the sand sheet is not eliminated but increases in area and thickness as long as an upwind sand supply is available and forms "**sand dune**"

Formation of sand dunes



Under stronger winds, the surface of a sand patch or loess is rippled form because less size sorting takes place. Then the entire surface is sheared forward by saltation and surface creep. Now see suppose we have a sand sheet we allow the wind to transport. So that wind after a wind speed the grain picks up and saltation starts. Under stronger winds, the surface of sand patch losses its rippled form.

Because less size sorting takes place because when you are talking about the ripples we are talking about the size larger grains at the top and smaller grains at the bottom. So it is particular wind speed is confined, but if you we are increasing the wind speed this type of arrangement will not there this is totally mixed up. So then the entire surface layer is sheared forward and by saltation and surface creep occurs.

So that means we are pushing this upper surface by this because we are not able to distinguish them the whole system irrespective of its size, the whole system were stretching it so this is the affect of shear. So what happens however under such condition new sand is also trapped from upwind source and sand sheet is not eliminated, but increases in area and thickness.

As long as upwind sand supply it is available it form sand dunes. So that means more and more the wind speed, more and more sand we are adding so that is why here we are not going for selective pickup that we are creating some troughs, we are creating some ripples, some trough of the ripple or this crest of the ripple so that the whole system without distinguish in the grain size the whole system shears up.

So once this whole system shear more and more sand is added the thickness of the sand is increasing and the size is increasing and the whole system once it is moving shearing it form sand dunes. So sand dune it is the larger form than the ripples. So in this dune surface we can create ripples, we can see ripples. So we are discussing about the sand ripples, the ripples as we know that these are formed in the gentle wind conditions.

Here at the top surface it is occupied by the larger grains and the heavier grains and this bottom or the trough it is occupied by smaller grains and the lighter grains. So once this wind speed is increased so erase this grain size distinction is vanished. So that means the whole total system irrespective of its size, shape irrespective of its lights and heavy the whole system moves as a shear movement. At the surface due to the shearing effect the whole system moves forward and creates the sand dunes.

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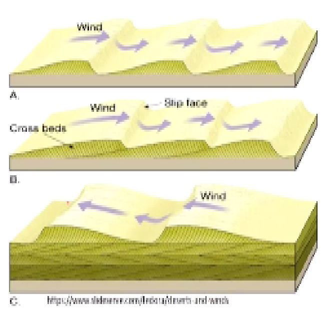

So large accumulation landform, windblown sands are called sand dunes, large accumulation landform here accumulation takes place, larger in size, thickness is more, length is more so this is called sand dunes, but once this wind speed decreases so this movement or the migration of the dune ends there. So in that case on these dune surface ripples again dominant, ripples again form and ripples start migrating.

So dunes are distinctly larger and stable of growing landforms even larger scale complex and compound dunes are called draas. Complex and compound that means here interaction of more than 2 dunes may occur. So this system is called draas.

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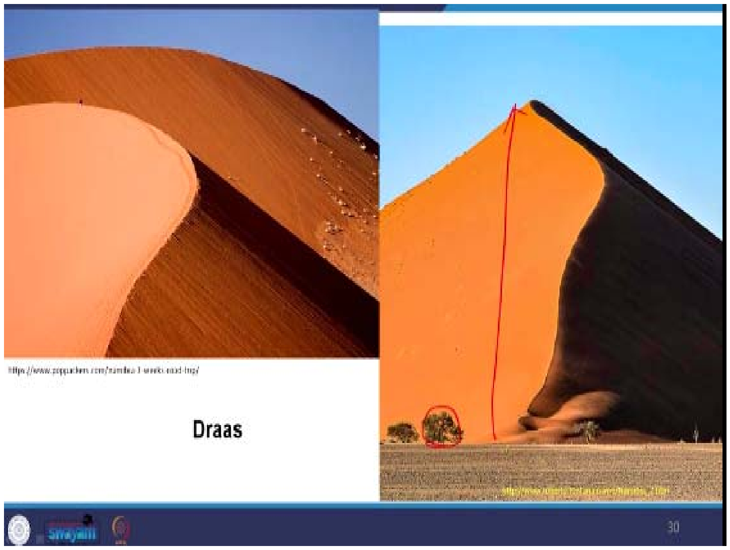

Here this photograph of the draas system is huge dunes. If you see this scale if you take this tree and scale relative to that how big is that, how height wise big is that, this is called larger dunes or huge dunes is called draas.

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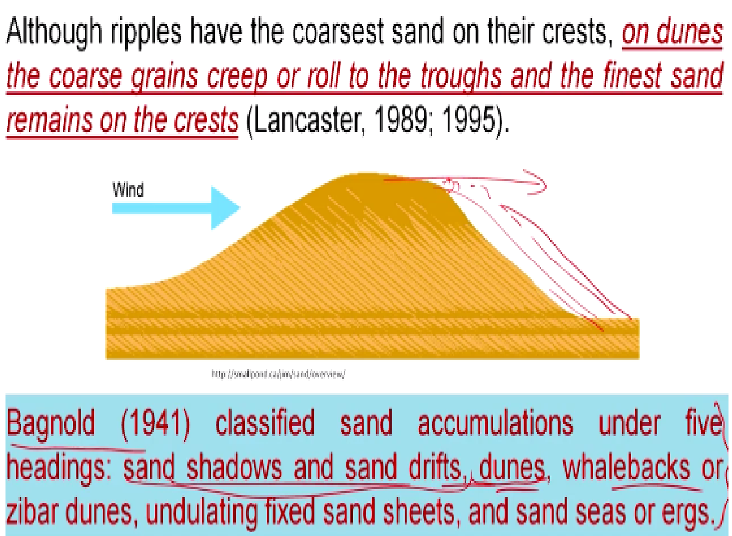

Now you see although ripples have the coarsest sand on their crest, on dunes the coarse grain creep or roll to this trough and the finest sand remains at the crest. Ripples and dunes this is the difference at the ripples the coarses grain or coarser particle remains at the crest and the finer at the trough, but in the dune is concerned here this coarser particles they will finally roll down to this troughs and this is why the cross bedding comes and dune migrate from one place to another place.

This gentlemen which is a pioneer worker in this wind geomorphology or the aeolian system it was Bagnold in 1941 it classified sand accumulation under five headings. What are those five headings? One is sand shadow and sand drift. Sand shadow and sand drift then second is dune, third is whaleback or zibar dune. Fourth undulating fixed sand sheets and fifth sand sea or erg. So all those landforms they are associated with sand not gravel lags. So depending upon their size, depending upon the shape, depending they are a distribution that means dimensions these terminologies has been used to classify the deposited materials.

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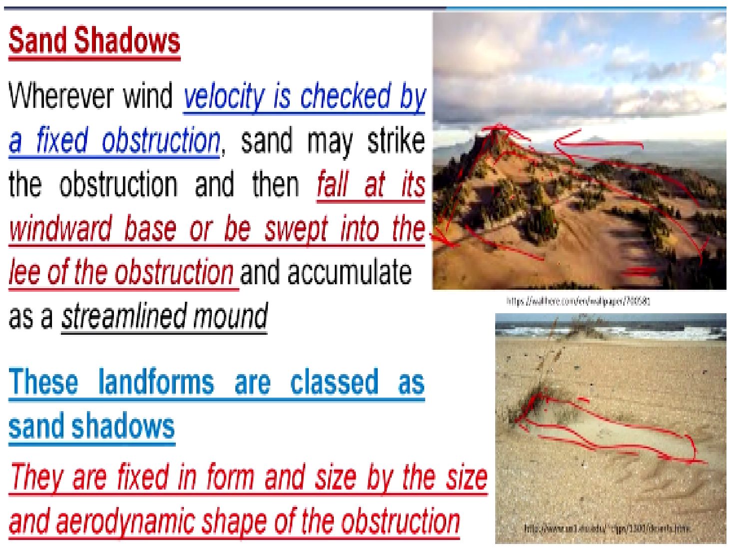

First let us discuss about the sand shadow. What is sand shadow? Shadow means behind something. Whenever wind velocity is checked by a fixed obstruction that means here wind is not blowing freely a fixed obstruction is there, obstruction maybe rock body, maybe a vegetation, maybe a tree. So whenever these velocity is checked by a fixed obstruction sand may strike the obstruction and then fall at this windward base.

Or be swept into the lee side of the obstruction and accumulate as a streamlined mound. So now you see suppose this is the wind direction and this hill is the obstruction. Here these due to these obstruction this sand is accumulating here and this accumulated sand maybe blown at this side to this lee side of this obstruction and these landforms are classed as sand shadows because this sand accumulation occurs due to the obstruction.

Not due to change in velocity itself. So they are fixed in form and size by size and aerodynamic shape of this obstruction. What would be the size, the size of this sand shadow that will depend upon the side of this obstruction. It is a small tree is there this obstruction will be less, if it is a larger mound is there, the obstruction will be more or size will be more. So that depends upon now you see here some bush is here and the bush we are creating a sand shadow here a very small size. But in a large mound is there we are creating a sand shadow here it is larger in size. So that depends upon the size of the obstruction.

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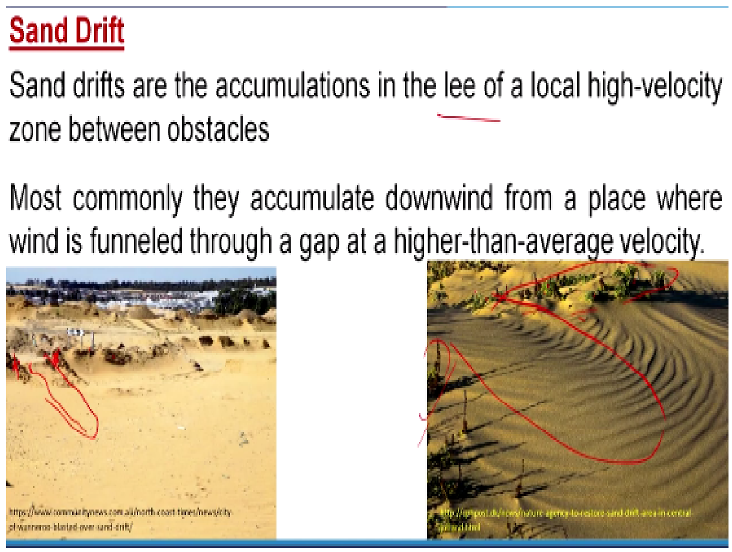

Then sand drift. Drift are the accumulation in the lee of a local high velocity zone between obstacles. Suppose we have one obstacle here another obstacle here. This obstacle means we have checked velocity. Here obstacles means we have checked velocity, but in between these two obstacles here we will be high wind velocity, high wind speed. So here deposition occurs due to high wind speed this is called sand drift.

So that means sand drifts are accumulations in the lee of a local high velocity zone between obstacles. Most commonly they accumulate downwind form from a place where wind is funneled through a gap at a higher than average velocity. Now see these are the gaps. Similarly, if this vegetations are taken as obstructions within that vegetation these are the gaps. This is a zone of vegetation simply this side will be zone of vegetation and this is the gap. So those deposits within that gap the lee side of this gap it is called the sand drifts.

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An important site of the sand drift is at the foot of a downwind cliff or escarpment. For example, if you hear let us see this wind is blowing in this direction and this is the cliff. So what if the material is removed by deflation, this material transported, transported material because here this area this is relatively low velocity it is calm and quite wind is there and wind is blowing there.

So that will deposit here the material deposit here. So this is the best place to form a sand at drift and the foot of a downwind cliff or escarpment sand blown of the plateau surface sinks into the still air in the lee of this cliff. You see this is the still air so due to the still air this blown of material from this plateau surface it will be deposited here. When such sand drift grow large enough they begin to trail off downwind from the base of this cliff.

And on image of this Martian surface and on the photos and electronic image of the terrestrial deserts sand shadows and drifts are collectively called wind streaks. So here the wind dynamics has to be understood this upper part we have larger wind speed and we have removed material from the plateau surface, but in between these valleys at this cliff surface we have relatively less dynamics that means that means stagnant wind will be there.

Relatively less that means this velocity will be less here it will be stagnant wind. So this material which is removed here it will be deposited here. With more and more accumulation we will get elongated sand body here that is wind drift is there. So mostly in the Martian surface we will find these type of sand drifts.

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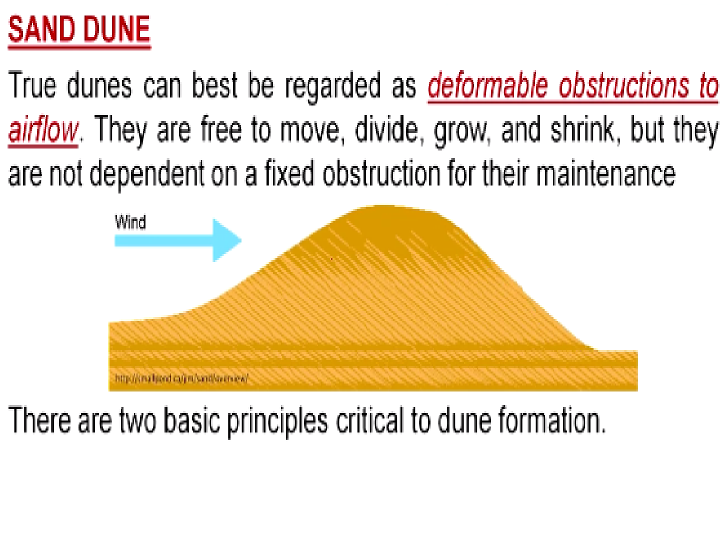

Then sand dune continuous the true dune can be best regarded as the deformable obstruction to airflow. They are free to move, divide, grow and shrink, but they are not dependent on this fixed obstruction for their maintenance. So this sand drifts we are talking about it is depended upon the obstruction, but here the dune itself is own obstruction. Here no external obstruction is required to create a dune. So that is why true dune can be best regarded at deformable obstructions to airflow. So that means here we have it behaves its own obstruction.

And it migrates you see they are free to move divide, grow and shrink, but they are not depended on fixed obstruction at all. So they can divide a dune can divide a dune can grow, a dune can shrink, so dune can spread, so depending upon the wind, depending upon these sand supply, wind dynamics this dune may deform. These are two basic principles critical to dune formation. What are those one is the sand supply and another is the wind velocity or wind speed.

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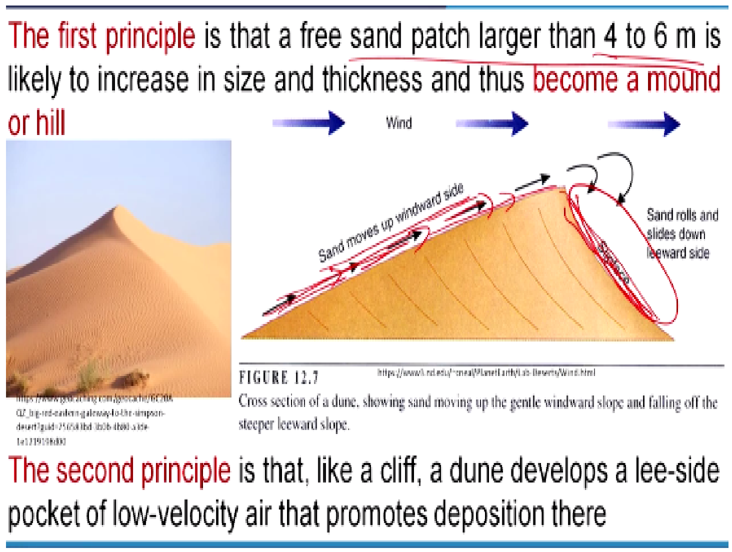

The first principle is that free sand patch larger than 4 to 6 meter likely to increase in size and thickness and thus becomes a mound or hill. Why this 4 to 6 meter because when we are talking few minutes back we are talking about this critical size. The critical size that means after that or beyond that size, deposition takes place. Otherwise only the removal of the material will be there.

So that 4 to 6 meter critical size is required for the depositional features in a sand system or the desert system. So the first principle of formation of the sand dune is that it is the free sand patch larger than 4 to 6 meter is likely to increase in size and thickness and thus becomes a mound or hill and the second principle is that this second like a cliff a dune develops a lee side pocket of low velocity air flow and its promote deposition there. So here this is a lee side and this is stoss side.

Here you see sand moves up windward side that means here erosion here erosion and in the stoss side here relatively calm and quiet air will be there. So that means once the calm and quiet air will be there whatever the material is being transported from this place that will deposited here. It will slide down here and forming deposition. So these are the two principles one is the critical size of the sand should be there and transportation or erosion takes place from this stoss side and deposition at the lee side.

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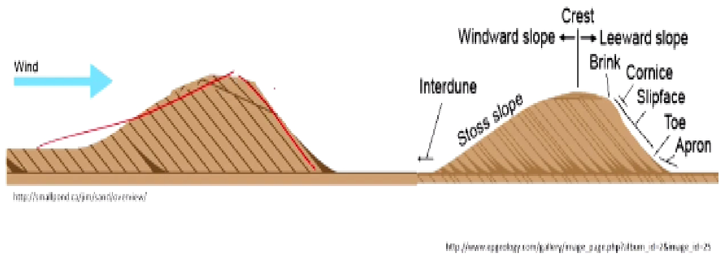
As soon as a mound of sand grows to moderate size, it develops the classic dune asymmetry of a gentle windward slope and a steep, angle-of-repose, *slip face* to leeward

The sand on the windward slope is firm and compact, but as it blows over the crest and cascades down the slip face



As soon as the mound or hill of sand grows to moderate size is develop the classic dune asymmetry of a gentle windward slope and a steep angle to the slip face which is called lee side it is a asymmetric geometry. Here we have gentle sloping, stoss side and steeply sloping lee side is there. The sand on the windward slope is firm and compact, but as it blows over the crest and cascades down or the slip face.

So this side it is dangerous for a geologist because this sand system is loose. So it may happen that this casualties may happen here if you do not properly understand this dune dynamics. Here this side this sand is compact because shear force is there that means hard and compact that is compressing the system, but here it is a freefall means there will be empty space more empty space, more space will be there. So this part it is very dangerous for a geologist which is actively involved to study the dune dynamics.

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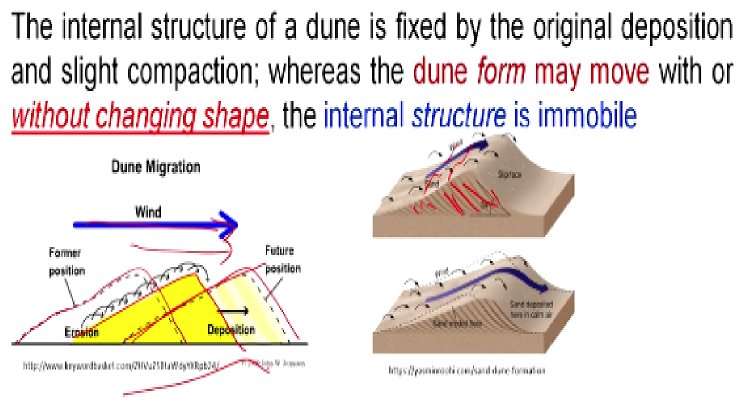

The internal structure of a dune is fixed by original deposition and slight compaction whereas the dune form move with or without changing the shape. The internal structure is immobile. Now you see in this particular figure that is shown here suppose it is the earlier position of this dune. Now dune is migrating from this position to this position. Again it is migrating from this position to this position.

So that means here you see the position is changing, but the internal structure whatever the cross bedding was here, this cross bedding was here, the ripples are in the surface it remains same. So that means it may change with or without changing its shape the shape sometimes may like this or sometimes may like this. So that means during this movement its shape may change, but its internal structure, internal configuration is remains same as it is.

So a dune migrates from here to there so its internal structure will be remained as it is however the shape may change its position may change. So here this internal structure remains constant. This dune may migrate from one place to another place its shape may change, its size may change, but this internal configuration will remain same. So I think we will stop here and we will meet in the next class to talk about the dune classification, what are the different types of dunes, how the wind dynamics, the sand supply, the vegetation that affect this dune shape and size. So I stop here thank you very much, thank you again.