Plate Tectonics
Prof. Pitambar Pati
Department of Earth Sciences
Indian Institute of Technology, Roorkee

Week - 10
Lecture - 50
Volcano and its Products- I

Ok Friends, welcome to this class of plate tectonics. And, we are talking the volcano and its product. In the last class we were talking about the different type of volcanoes and their geometry is mainly based on this magmatic composition and this erupting material whether it is lava only, lava or pyroclastic material and the geometry is totally and totally it is the compositional plane. And, today we will talk about this material which is produced by a volcano during its eruption and its property and how this property is governed by this material composition and some other factors are there. So, during an explosion a series of material that means, series in terms of size, a series of size material is coming out and collectively this is called tephra except lava. So, if you see this is the lava which is flowing from this lava flow and you see this eruption so, a huge amount of gaseous material and mostly it is carbon dioxide, water vapour and sulphur dioxide H2S so like that.

So, now see along with lava some material you see these fragments they are coming out and the fragments may be the broken fragments from the surrounding rock and this fragment may be this material which is ejecting from this volcano that is the lava while they are forming and with they are coming back through the atmospheric connection they are solidifying and they are forming some rock fragments. And addition to that we have a huge amount of gaseous material that is coming out. So, except this lava all this material in collective manner that is called tephra that is the broken fragments. So, in an explosive volcano we have magma, we have rock, we have ash burst so that is moving upward in an enormous explosion creating the volcanic ash that is called tephra.

So, under microscopic composition this ash is nothing these are the glass fragments. Glass! You know when we are talking about that particularly in mineralogy we talk about mineral or the crystal and gas. This glass is nothing this is the un-crystallized form it is totally uncrystallized under microscope it will look black dark colour. So, these are nothing so this gas if you see under microscope you will find mostly they are the glass and there no crystallization. So, no crystal structure developed they are just haphazardly oriented this material.

So, they are very sharp in nature. So, that is why it is very dangerous to inhale. So, that means if you are taking it for respiratory system it will damage respiratory system. So, that is why it is very dangerous to inhale it. So, that is why we should avoid those places where the volcanic eruption is going on.

Then this scorching hot tephra, ash and gas may speed down the volcanic slope around 700 kilometer/h and that is called this pyroclastic flow. Pyroclastic, pyro that means it is this fire and this clast they are developed from this fire of this volcano and it is flowing down that is called it is pyroclastic flow. So, now if you see this videograph here. So, you can just imagine when we see in our TV or in YouTube or some other channels. So, this avalanches this ice avalanches in this mountainous region.

So, it is looking similar however that is in the cold environment and this is in hot environment. you see how this ash or this volcanic product it is coming down at the slope of this volcano around 700 kilometer per hour and sometimes this pyroclastic material it is so hot that is internal temperature may around 1000 degree Celsius. So, imagine if something is trapped inside there is no chance of existence. Then the main component of this volcanic gas is the water vapor which is going down from the atmosphere by this water in the pore spaces of sediment and this greenschist facies of rocks which are going down and this clay minerals they are taking this water inside and followed by carbon dioxide, then sulphur dioxide and hydrogen sulphide. Now you remember when we were talking about plate tectonics mineralization.

So, for the mineralization we are needing these materials and these materials are nothing we are putting down some of this material we are putting down through this subducting system and somehow when there is differentiation system this material was lying inside. So, that means all these volcanic product that means when this volcanic system is eruption is going on. So, those material are coming near to the surface and we have groundwater or surface water which is percolating down. So, in between there is an interaction between these materials and this groundwater. So, there is a change of Eh-pH there is change in chemical composition.

So, mineralization is taking place. So, now you see the volcanic eruption though it is also hazardous, but it also you can say a gain for us in terms of mineralization. So, volcanoes release gas mostly sulphurs and eruption through opening that is called fumaroles. So, if you remember when the last class we were talking about the dormant volcanoes the active volcanoes the extinct volcanoes when we were talking about this dormant volcano we say that the lava or the magmatic eruption is not taking place for thousands of years. However, the volcanic activity inside we cannot rule out and the evidence is the hotspring the fumaroles.

That means around the volcanoes we have hot springs number of hot springs they are coming out number of fumaroles. Fumaroles are nothing they are opening through which gas is releasing. If you see this yellow colour it is nothing the sulphur, so sulphurous gas. So, that means gas is emitting or gas is coming from the subsurface to the surface. Hot springs they are coming out from subsurface to surface.

These are this indicator that yes the volcanic activities though it is not expressed in the surface, but still at the subsurface there is some disturbance is going on. So, these are the fumaroles where the gaseous material is coming out through fractures through vents and they also release gas into the soil groundwater. So, this gas it is inserted within the soil within this groundwater. So, there is a chemical reaction inside sometimes this is responsible for mineral deposits. Then another product is lava.

So, it is the ease with which lava flows is taking place at these structures are formed. If it is easily flowing the structures will be low height, less slope like magma flow like this Deccan basalt. But if it is much silica content is there, gas content is there, magma is viscous or the lava is viscous, so it is piling up and forming a cone shaped volcano. So, the more silica the more polymerization and more polymerization that means long chain silicate structures are formed and that is stiffening of this lava occurs. So, this is the key portion of mineralogy.

So, when we were talking about different silicate structures, so starting from the tectosilicate and coming to this nesosilicate, so this chain gradually decreases and that decrease in chain that means viscosity gradually decreases. So, that is why this mafic minerals mostly the olivines, pyroxenes they are forming from the basaltic lava they are of less viscous because less polymerization small chain silicate structures are developed. However, if you moving towards tectosilicate this quartz group, the feldspar groups we are going towards the end, so that means this more polymerization occurs, long chain silicate structures are formed. So finally, we are getting the stiffness of the magma increasing. So the stiffness of lava is described in terms of viscosity.

So more stiffness that is more viscosity. So here this magma flows easily at low viscosity and the lava that is sticky and stiff that is of high viscosity. So that is why basaltic lava is low viscosity, felsic lava is high viscosity and in general high silica content lava contains more gas and that is more viscous. When the gas forms into the bubbles viscosity increases further that means here you see not only the gas, when the gas there is coalescence each other and forming the bubbles and once the bubble is forming that means the viscosity is increasing many pores and the thickness and shape of this lava flow depends upon the viscosity. Low viscosity that means high flow.

So topographically at lesser level that means thin lava flow that will be large distances can travel. The greater the viscosity the thicker the flow and the shorter the distance of travel and it solidifies. If you see here high viscosity lava that is not able to travel for long distance so it is just piling up near the volcano and forming a cone-shaped material just near to this volcanic system and it is forming it is a lava dome. And the lava domes they evolve that evolution is unpredictable because it is non-linear growth is there. So it is non-linear dynamics caused by crystallization and caused by outgassing of highly viscous lava through this conduit of these domes.

And domes undergo various processes such as growth, collapse, solidification and erosion. So that means we have a dome and that dome it is undergoing different processes that is crystallization going on, it is growth is going on, then collapse is going on, then solidification, then erosion by external processes. So the resultant is what is it is looking to us on the surface. And Less viscous rhyolite lava can travel large distance as a thick flow. If you can see here it is flowing as a thick flow to a large distance.

However basaltic lava it is low viscosity flow as streams. So like this water it is flowing through the streams till large distances can travel. And low viscosity basaltic lava flows may travel extreme distances and it is more through conduit called lava tubes. So it is when there is eruption, this lava is flowing, the external surface it is coming to the contact with the atmosphere and it is getting cooled down. So that means it is getting a thin layer which is cooled and which is solidified.

But still inside the lava is liquid form. So that means it is just moving down. So that means what is happening? The thin shield which is formed at the surface, it is providing insulation to this underlying lava so that direct cut off from the atmospheric system. So that means the upper side it is creating a layer of cool layer, however the inside it is allowing the lava to flow. So that means lava is flowing to large distance around 10 kilometer or 50 kilometers in terms.

So that 50 kilometer that means it is providing the insulation as a thick layer on the surface. So if you take a cross-section, so you will find a tube-like system, a tunnel-like system. For example if you see here it is very diagrammatically presented very nicely.

So we have a lava flow with a channel. So gradually it is solidified and with the atmospheric system and finally inside it is providing a tunnel and with time this is also solidified.

So finally we are getting a lava tunnel. So here you can say this lava tunnel very well exposed. So in Hawaiian volcanoes this lava tunnel around 50 kilometers long. So you can say a 50 kilometer tunnel which was earlier flowing with lava and this upper surface it is providing insulation from this atmospheric system. And if the lava tunnel is broken sometimes, at some part it is broken.

So that means you can see the tunnel from the surface and that is called skylight. So that is nothing, this is just you break this top of this tube. So you will allow atmospheric system that means you can see this tube from the surface. So that is called the skylight. So here you can see this lava tunnel is inside, lava is inside but the top surface it is broken here that is forming the skylight here.

And here this is the lava tunnel and this diameter of tunnel may be more than a height of a human being. A human being can travel, a small vehicle can travel inside without any hindrance. So this is the height of a lava tunnel. So here there are two terminologies that you have to understand and remember.

One is called Pahoehoe lava. Pahoehoe lava it is not the English term, it is coming from this Greek or Latin term. So it is not of English. So this Pahoehoe you see this is the pronunciation Pahoehoe. So it is otherwise called Ropy lava. This Ropy lava because you see this appearance is like ropes, there is a bunch of rope is lying here and its appearance here you can say this is.

So this is the basaltic lava which is flowing on the surface but the upper surface is solidified but still it can that means it can bend, it is flexible though it is solidified like our skin. So we have a thin skin on the surface but still it is flexible. Similarly this top surface though it is solidified and cooled but still it is flexible. So that the low lying lava which is flowing just below you can see here just below we have you can say just a polythene and the polythene we are filling with water. So this polythene the upper surface it is behaving like a polythene and inside we have water and we are allowing it to flow.

So during this flow it is also deforming this polythene on the surface. So that means the deformation is in such a way that it is not allowing to puncture the system sometimes it gets punctured here and the flow may occur from here to there. So that means this top surface though it is smooth and it is wrinkled like a skin and inside we have full of lava. So that is called ropy lava it is rope-like appearance is there. So the ropy lava the outermost layer is cool and develop a skin but the skin is still hot and thin enough to be flexible that we have discussed here you see the lava flow is there and the outer skin it is solidified and still it is flexible.

Now you see how the system is just wrinkled due to its flexibility and this effect of this lava flow inside. So the skin is stiffer than the lava beneath it and is dragged by flowing lava and it is folded up to wrinkles. So this is called the ropy lava. And if it is vesicles inside for example here these are the ropy lava different skins that in different wrinkles and we have a vesicles inside. So if vesicles formed when the lava is solidified around the gas bubbles so that means here we are creating some vesicles.

So if the vesicles are there so this wrinkle that means you can say the size of a wrinkle that depends upon these vesicles if inside. And these are some of these field photographs of this ropy lava you see the surface is very much smooth. However another type of lava that is called a'a lava so that means you are putting your hand on the plant of a cactus so knowingly or unknowingly once you touch this cactus plant just suddenly your feelings it is coming or your sound is coming a'a so like that. So that means you see the surface it is too rough and it is too sharp so once you touch the surface it is feeling or in a sound automatically is coming from your mind it is a'a. So that means you see how difference is that one side we have very smooth surface.

So if the outer layer of this lava flow will break into fragments and the lava moves beneath it. So now you see this is lava is moving and these outer fragments are just lying here and there and it is very sharp and it is very rough surface. If the lava flow develops a thick or more brittle outer layer it moves faster and results a sharp and splintery rubbles like lava flow it is called a'a lava. So you see here this lava flow the lava is flowing slowly and the outer surface is so sharp it is very difficult to touch it. So this is also called blocky lava we have different blocks so starting from size of various dimensions.

So higher viscosity and andesitic lava that is flow develop a fragmented surface that is called blocky lava. So blocks you can say here different size of blocks it is just you can say it is a boulder's effect like this when this glacier is moving and this is taking too much boulders on its surface. So you can compare to similarly so it is in hot environment of the lava which is flowing on the surface and it is solidified blocks and that blocks are transported by this bouldering effect of this magma or the lava on the surface. And the difference between a'a and this andestic blocky lava is that the blocky lava has fragments with smoother surface than the few vesicles. So this is the difference one is the a'a lava another is the blocky lava which is the smoother surface and few vesicles are there and a'a lava that is related with the blocks are not of smooth surface that is sharp surface and sharp surface, thorn like surface you are putting your hand just your that means voice automatically coming inside a'a.

So another is the pillow lava that is very much important if you remember when we were talking about the divergent plate margin system we were talking about the pillow basalt which is layer 2, layer 1 was the sediment and layer 2 was the pillow basalt. So this is the pillow basalt or the pillow lava mostly it is the pillow lava it is very sensitive to aqueous or subaqueous environments. When this lava eruption is at the subaqueous environment either beneath water or beneath ice so this is quenching out or cooling out very suddenly and giving rise this type of appearance these are the pillows and the size varies length it varies differently and these are this pillows you can say this is the boundary of this pillow and you can say this is a polythene we are putting it is water inside and just binding it. So here this outer surface is cooled down very rapidly because direct contact with water. However inside this material they are very hot and they are cooling very time taking so that is why there will be different mineralization here inside this pillows.

However at this boundary and it is quenching or it is cooling down very suddenly mostly crystallization you cannot say any good crystals are forming at the surface because crystallization for a good crystal it takes time. Pillows always form under water finding them in the rock record gives information that the environment was under water so subaqueous environment. So we have different pillows structures if you go to Jabalpur you go to many part of this Deccan you will find the pillow structures. So mostly sometimes there was eruption at the under water environment so that is why these pillows are there. Similarly if you go to Chitradurga Schist belt we have different pillow basalt that is basaltic magma flows are there underwater magma flows we have well developed well-preserved pillow basalt is there one particular place I can say Maradi Halli there is a place in Karnataka.

So here you will find well developed pillow structure that is preserved and it is described or developed as a geological monument by geological survey of India. So here some of these field photographs of this pillow structures so now you see this cartoon says how this magma is coming out and the lava eruption is there and due to sudden cooling this pillows are developed and this is new pillows and these are the older pillows are here and it may happen that this pillow get punctured somewhere. So once it is punctured that means this lava flow is there further and it further punctured further lava flow so that is why the length of this pillow is gradually increasing it is starting from here and magma supply is still continuous so it is just you can say you are putting air in a balloon so its size increases if more air is there so that means sometimes it will burst. So that is why bursting out that means the lava is released and again this released lava it is finding a sub-aqueous environment again it is getting a balloon shape again the lava is released again it is forming a balloon shape. So gradually this size of pillows are increasing and that you can see here how this length of pillows are varying from small size to larger size depending upon this mechanism.

And here you see this is the boundary of a pillow it is mostly it is glass because sudden quenching sudden cooling is there in a sub-aqueous environment so mostly it is glassy. However you will find these crystals inside and basalt we know this is pyroclage, olivine, pyroxene are the minerals so most of these minerals which is in the basalt you will find here and in the surrounding that is in this particular picture it is altered. And this is the video graph how this lava eruption in a sub-aqueous environment it is forming the pillow and it is well video graphed here at the subsurface of the sub-aqueous environment. So, another structure it is called columnar joints. Columnar joints if you see here when there is a lava pool that is erupted lava it is cooling down.

So here this cooling cracks are developed and this is the nucleus and due to cooling contraction occurs. So once contraction occurs you are getting well-developed valves or these fractures. See these well-developed fractures that are forming when this magma was getting cooling. So there may be 5, 6, 7 sided valves your fractures develop and this is if you see in the cross-section you will see this type of pentagon hexagon like that. And in this cross-section you will find this is the columns like this you see these are the columns that is pillars and this is one of these photographs taken by me in 2010 near to Jabalpur and how these columns are lying in the basalt this is related to Deccan volcanism.

And this is also photograph near Mumbai so these pillars are developed that means this columnar basalt or columnar joints are developed there. So thank you very much we will meet in the next class with continuation of this topic this classification of these materials and how these materials which are ejecting to this atmosphere how they are taking shapes and when it is falling down to this surface how their shape changes and so on. So thank you very much we will meet in the next class.