Mineral Resources: Geology, Exploration, Economics and Environment
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Lecture – 25
Hydrothermal Systems (Contd.)

Welcome to today's lecture. We have been discussing about a very particular class of hydrothermal process or hydrothermal deposits; that is, the epithermal system in young volcanic islands. We discussed about these deposits being classified into 2 broad categories as high sulfidation and the low sulfidation one. The high sulfidation deposits, have a very close association with the porphyry deposits occurring in in the as exemplified by the western the Chilean Andes in the western part of the southern American continent, and in some other areas. In some of the islands like the Japanese island we see them occurring in close a proximity to each other. But they do they do display very distinctive characteristics in the mineralization style, the mineralogy, and the alteration characteristics.

Now, we will discuss about the low sulfur we finished our discussion on the high sulfidation ones. Let us now see the characteristics in a more simplistic and broad way the characteristics of the low sulfidation deposits.

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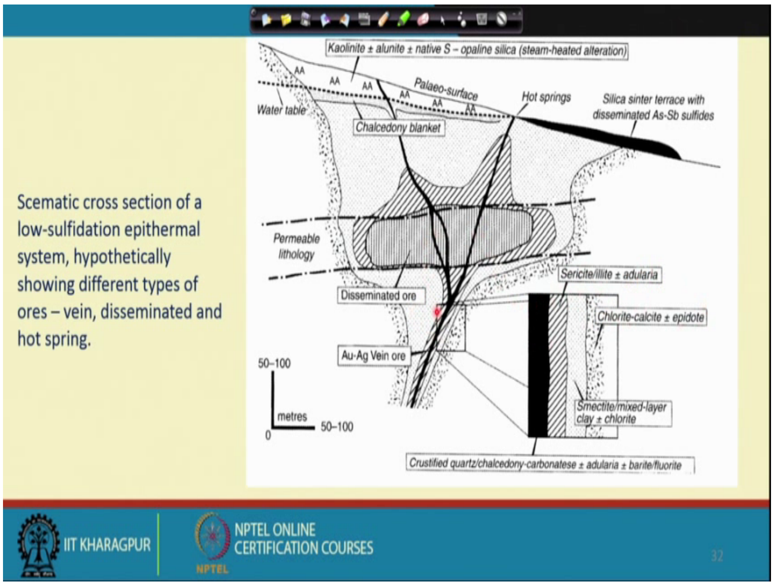

As against the high sulfidation once there here the pH of the fluid is overall is higher than the fluid which is involved in the formation of the high sulfidation deposits. And these are they generally do have different types of ores disseminated, vein type, and as well as the hot spring type are deposits. In fact, these are the deposits which were earlier classed as the as the geothermal type of the hot spring type, because of their close resemblance to the geothermal systems; which we see in many of the areas like which will be discussing in a short while. They are they are associated with the hot spring or the sinter type of are deposits where we get sometimes are good concentrations of arsenic and antimony sulfide in form of real (Refer Time: 02:32) and also mercury deposits, which the resemble very much like the sinters on the hot spring, vent of the hot springs in different parts.

So, subsurface so, one of the major distinction of these deposits is that, they do occur distal to the volcanic center, they can be away from the volcanic center by even 5, 10 kilometers from the active volcanic center. And so, here as you could see, they the disseminated ore this gold silver vein ore, and a magnified view of these veins shows the alteration to chlorite calcite epidote type of alteration smectite mixed layer alteration. Sericite type of alteration, and something which is a adularia is a is a low temperature volume or low temperature form of potus feldspar which also is stable is also associated with the sericiting alteration zone around this kind of veins.

And since these assemblages are stable pH higher compared to the assemblages which have the alunite type of alteration minerals. So, in general they indicate that this system was operating on a with the fluid, which had much higher of the fluid was more towards more close to higher or mean pH which is almost like neutral with stability of the potus feldspar.

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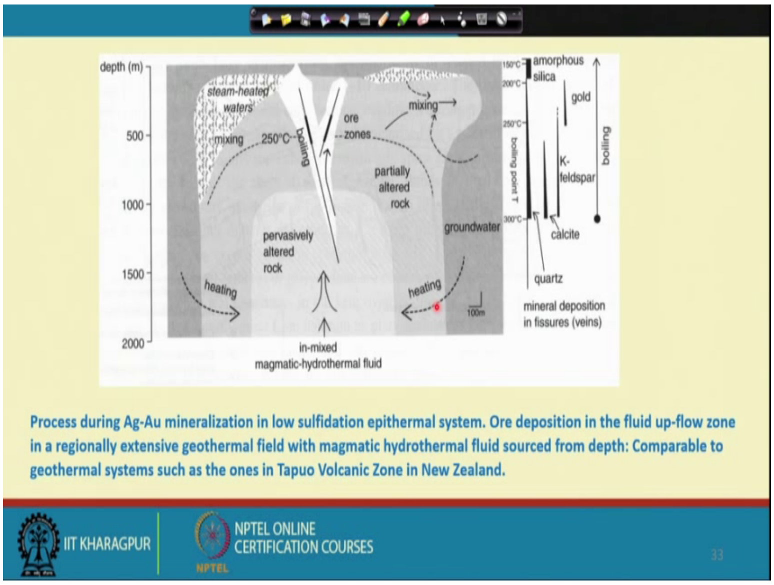

And so, this is a schematic diagram on the origin of such kind of deposits. In the low sulfidation, they are generally gold silver type of deposits. They deposit which occurs in the Kyushu province of japan the famous physically deposit belong belongs to this category, where we get these deposits in forms of discrete veins, and which has the alteration zones dominated by sericite and adularia type.

So, for these basically inferred from these deposits is that, they are more akin to the geothermal systems which operate in some of the active geothermal systems like we Broadlands Ohaaki geothermal system in New Zealand, on the Tapuo volcanic zone. Where we see a much broader scale of fluid circulation, where the mineralization is generally confined to the fluid up flow zones. The fluid generally the there is a convection hydro thermal convection cell; which sets up because of the heat that is produced by the by the intrusives and depth, and such fluids the in there in there flow to the subsurface they get ridger in silica, and they scatter the many of the metallic components from components and then in the off-flow zone. They undergo boiling, and which comes out with a very efficient mechanism for formation of the our deposition of the sulfide minerals from them.

So, these systems are very much comparable to the geothermal systems, such as the one in tapuo volcanic zone in New Zealand. So, this about the epithermal deposits in the young volcanic island. They do sometimes also have this fluid which are essentially within 200 to 250-degree centigrade temperature, and have a very significant meteoric water component. The pH of the fluid is within the stability field or potus feldspar, and also sometimes we were calcite in the in the mineralogy. And the minerals are deposited in fissures veins in such systems.

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Well from the present day hydrothermal systems operating on the young volcanic islands, we have we had a brief look at them. They are interesting as far as the present day as far as the ore forming processes are concerned giving us direct, indication of direct proof of involvement of such kind of fluid in mineralization. The geothermal systems like the one in the Broadlands ohaaki geothermal field in New Zealand, in the tapuo volcanic zone, and many other such geothermal systems are actively investigated. The fluids are sampled by through our reels and extraction of the fluid, and the mineralogy also are studied and the process of formation of these mineral the ore minerals of the base metals are understood, and if we along with the fluid chemistry fluid source and the dominant mechanism.

So, with this now let us move on to discussing a very, very important class of deposits. There essentially. So, from the continental, we will discuss now we will go towards the oceanic or the seafloor hydrothermal systems. Here on the purpose of showing this diagram is again we could see the pacific ring of fire. And I would like to draw your attention to the areas which are indicated by this is solid circles. And as you have seen them before, they are the mid oceanic ridge system of the lithosphere. Measuring about 55,000 kilometers in total length such kind of mid oceanic ridges have been investigated by going and going to the sport by submersibles, and seeing the processes that is taking place in one of the previous classes, some of the features such as black smokers which the black smokers which are observed on these this kind of ridge ocean ridge system.

So, the hydrothermal activity associated with the ocean ridge system. We saw their photographs as so many such features can be seen. Some of the important localities which are marked here is the tag the transatlantic geo traverse snake pit, then the east the 21 degree east pacific rise. And so, the and many of these like this is a system which is geothermal system salton sea. This (Refer Time: 09:52) basin geothermal system, and there are many like associated with backups for example, the lavas in here.

And the sum of so, this entire ridge system either on based on the either placed on the mid oceanic ridges active drifting or on the backer. Such type of such locals are active sites of hydrothermal activity, and they result in hydrothermal mineralization. They are observed in black smokers, and sulfide chimneys which form on this kind of hydrothermal vents. And who are so very similar to the mineralogy of the deposits, which we are going to discuss right now which go on to the class.

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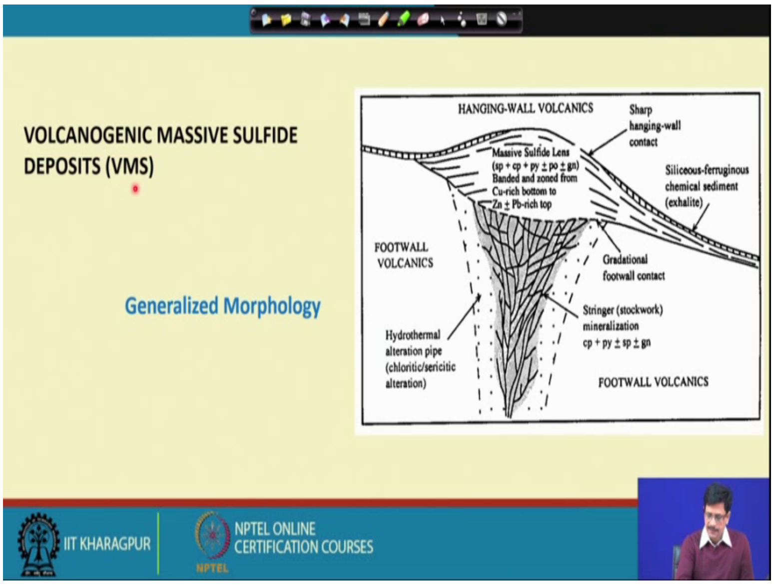

So, we have a class of deposits which and an important class important contributor of base metals copper led and zinc some amount some of some of them also do give metals like gold as by product. So, these are the volcanogenic massive sulfide deposits or the VMS.

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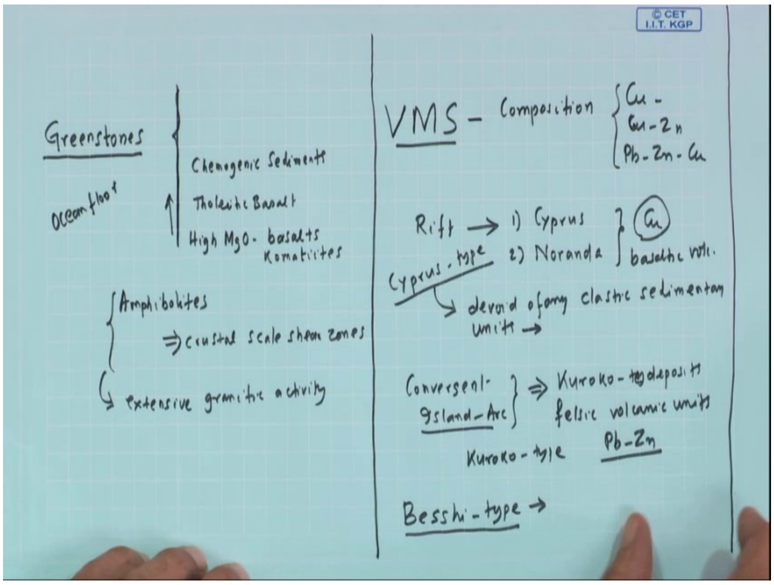

The VMS deposits in fact the VMS deposits, they have been variously classified they are classified based on composition like copper dominant, copper zinc, or lead, zinc, copper. We will not elaborate on this kind of a compositional classification based on the type of metal that is coming from these deposits. These deposits are associated they are essentially ocean floor hydrothermal systems and are associated with 2 broadly different kind of tectonic regime. The rift related regimes, they present in addition to what we see on the present ocean floor. There are some of the deposits like one occurring in the in the cyprus and the (Refer Time: 12:22) light built cyprus deposit.

And a very ancient copper deposit occurring in the abitibi province sorry, in the quebec province in Canada which is the noranda deposit. So, these type of deposits do have something in common they are essentially copper ridge deposits, and they are associated with mid oceanic ridge type of extensional regime or rift kind of setting. And they are broadly known by the term as cyprus type.

The ones so, essentially these type of deposits are the open ocean mid oceanic ridges, where we could only expect the volcanic components. So, these deposits are essentially devoid of any clastic sedimentary units, because they do not get any sedimentation on this on the site where these rifting is taking place. But they can have thermogenic sediments, and the ones which are which are observed in the present in the because, these deposits as was also shown in the temporal spectrum; these deposits range in age from very old almost to precambrian to very recent. For example, the cyprus of the deposits which are associated omano few lights are very, very young deposits. The other the ones which are associated with convergent margin says island arc type, these deposits they occur dominantly in the Japanese island arc, which are the kuroku kuroko deposits. And they would have known by the name also.

So, these are these are essentially the copper ridge deposit. The kuroko deposits and there these deposits that essentially associated with basaltic volcanism. We do not get much of felsic and my counterpart there. Kuroko deposits are essentially associated with the island arc and are mostly associated with felsic volcanic units. Maybe some smaller other in it is a bimodal volcanism also could be present there. And there is a third type.

So, these are these are generally known as the kuroko type deposit. And they are essentially ridging deposit and a young deposit. They do occur a much later in the history of the geological history of the arc. And such older deposits are not known so far; where is the older analogues of the cyprus type are very well known. The third type of deposit the besshi type of depositor also. They are very much on they are also associated the rift settings. But because of their proximity to continents, these type of deposits which are also copper is deposit copper zinc deposit. There by virtue of their proximity to the continent, they do have a significant member of clastic sediments in them.

So, they are the besshi type. So, we will go into the discussion of these deposits with a schematic diagram, which is taken from which of course, is a very commonly visualized and this this is a kind of a generalized morphology because; and if we have to understand the ore forming process, we do have to look at such kind of sections; which is schematic and the generalize, but they do give us a bit of insight as to what has happened in the formation process.

So, these diagram gives a generalized section of the VMS deposit volcanogenic massive sulfide deposit; where we see is typical morphology if it would indicate that if a deposit is present we do not undergoing much of change in it is morphology, by later periods of any deformation or any disturbances. Then it should be one should be able to see such kind of a section in a typical volcanogenic massive sulfide deposit.

So, this is essentially will have a feeder dyke where it will be mostly various strange or a stock work zone. And these will be also be containing mineralization the strangers should be mineralized. And this mineralization this this essentially would indicate that there must have been the zone through which the fluid has flown fluid has been channelized, or the fluid has made it is way up in the for the mineralization to have taken place.

The major part of the mineralization is in the form of volvos lens; which is the massive sulfide lens. The name massive sulfide is derived from the fact, that these deposits are essentially ridge deposit there the grid of the metal like copper or led or zinc and can be substantially higher compared to deposits like porphyry copper where the deposit the degrade is pretty low. So, that is the reason why they are called as massive, sulfide deposits where the total amount in terms of tonnage could be low, but the grades are very high.

And so, this are fitted zone will be characteristically surrounded by an alteration zone. Because these are this this is the seafloor basalt and will be broadly categorized as the footwall volcanics. And in the footwaal volcanics when the fluid has generalized and also deposited sparsely deposited the sulfides in pyrite sphalerite or plus minus galena. So, this is this is invariably associated by a hydrothermal alteration zone, or you can say the hydrothermal alteration pipe which is essentially a chloritic a sericitic alteration, because alteration of the pheromone nation minerals in the basalt, basalt will essentially give rise to chloritic type of material. And this massive sulfide deposit once it is formed it also could be later on covered by the hanging wall volcanics, because it is a zone where concerned volcanic activity is going on with sometimes maybe a cameogenic precipitation of siliceous or ferruginous component could also be there.

So, this is a generalized morphology of the volcanogenic massive sulfide deposit, which you could see almost in any textbook that we could follow.

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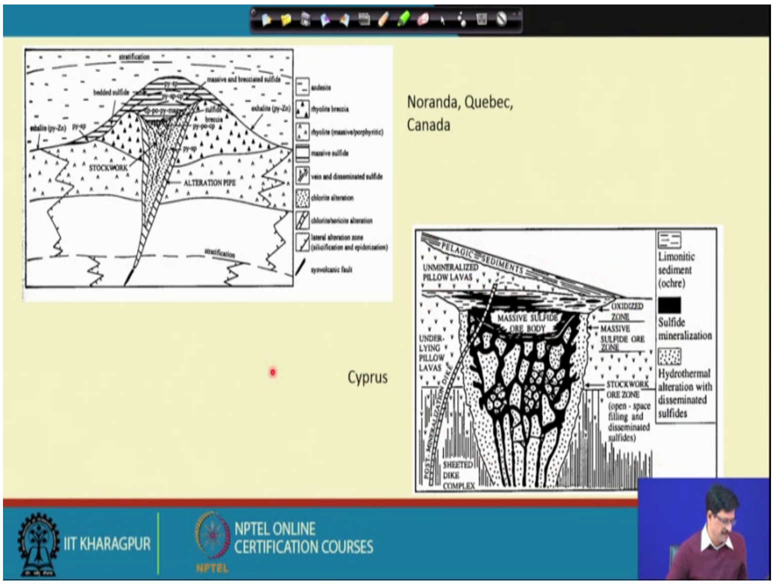

Now, on that backdrop let us see a cross section of the deposit that, I just mentioned is noranda in quebec Canada. And this is the cross section of the cyprus deposit, where we would roughly identify this footwall and the hanging wall units. And they do have some kind of a zoning and here is the in case of an noranda deposit the stock work zone is here is the alteration pipe. They feeder stock work zone. And roughly there is a bit of a zoning of the metals; where we see copper and giving rise to going to trapper part is mostly zinc ridge. And similarly, we have a situation where is from the cyprus deposit; which is essentially being a sheeted dicomplex, and a postmenarison dyke which is traversing to this ore body. And these are the predict very clear-cut indication about the seafloor activities the unmineralized pillow lavas and the pelagic sediments.

So, this is a typical cross section of a cyprus type deposit, when the cyprus deposit.

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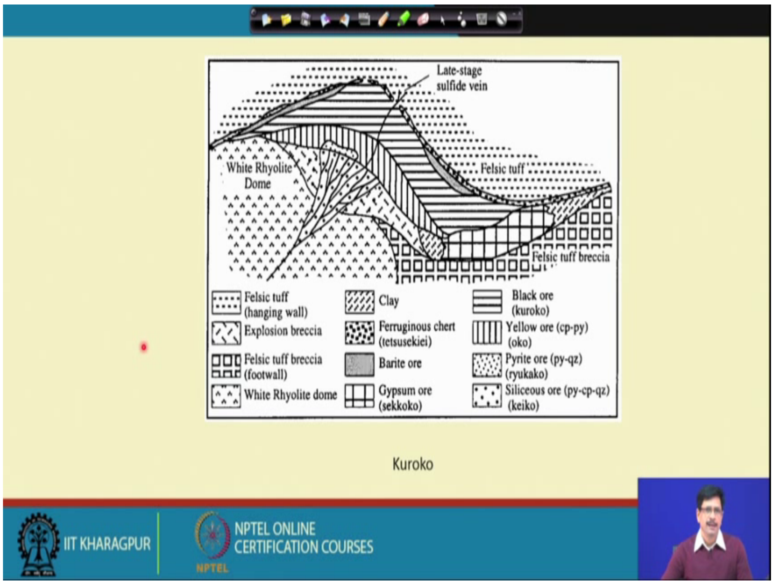

And this one is from the is a typical cross section of a kuroko deposit; where we see that the essentially the rock is felsic rhyolitc dome. And there is also this late stage sulfide veins, then the top and this is the feeder dyke. And in in the kuroko terminology, they call they this ore is known as the black ore which is shown here as this blanket of the black ore. And this is the yellow ore which is pyrite pyrite, and the black ore is essentially led ridge ore. And it is also associated with some barite. In the in the in the assemblage barite as well as gypsum, indicating that the sulfide other the fluid, which is essentially the seawater.

So, these class of deposits this volcanogenic massive sulfide deposits their seafloor processes. So, seafloor processes means, even invariably we will have a substantial component of the sea water as the dominant source or source, and for hydrothermal fluid in these deposits.

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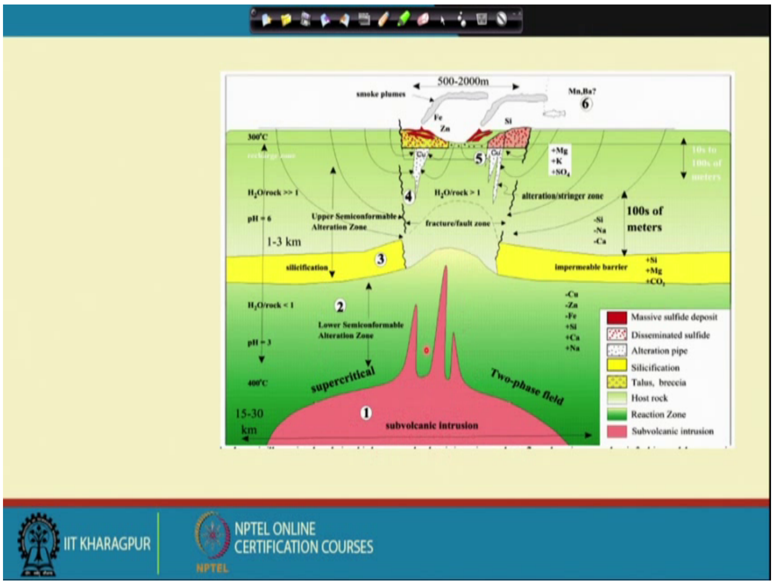

And we can have a look on these kinds of models, which have been developed for formation of this kind of hydrothermal massive sulfide deposits.

So, essentially the zones which is shown over here are the depositional sides of the sulfides, and what we see here is that, it is it is a large scale hydrothermal circulation, and this is the sea surface. So, since this basalt essentially it is a setting which is a mid-oceanic ridge type of rift as an extensional region, where the seafloor basalt is as we saw some of the previous diagrams that the seafloor basalt is faulted and this pretty much fracture in the top part. And that allows the sea water to percolate or to go down through the fractures in the in the distal part of the system away from the volcanic center, and this fluid which circulates. And moves to the deeper part gets heated up exchanges component with the seafloor basalt.

This has been one of the very important topic of work to understand the sea water basalt interaction and exactly what is happening to the fluid of nature of the sea, because the fluid which is the hydrothermal fluid here is essentially the modified seawater. This seawater is circulating in the deeper part and is getting heated up and once it get heat that is heated up, because of the buoyant buoyancy of this fluid it will ridges on this kind of zones. And will finally get discharged on the seafloor on this kind of zones the discharge zones or the vents and give rise to this mineralization.

Now, what happens in the subsurface is shown with this. We need to have a constraint source of heat which is provided by this a volcanic intrusion in the system. And this zone is essentially is a very low fluid by rock ratio h 2 by rock is less than 1, and that is how it is a zone where they chemistry of the fluid is rock buffered. And the pH is low. So, this low pH of the fluid and resulted in layer which is an impermeable barrier, mostly ridge in silica. And that helps and then the this is the if we look at the. So, the fluid which is essentially within this zone is dominantly zone in which the fluid is transporting. And then it is being focused.

So, we need to get the fluid focused, and the focusing of the fluid is done by some of the fracture and for zones which are there in the seafloor basalt is; since it is dominantly it is essentially zone of extension. And this is how the mechanism works, and with the within the 2 broad regimes in which the lower regime where the water by rock ratio is less than 1, and the fluid is mostly rock buffer with very low pH. And then we come here, the water by rock ratio increases to much, much greater than 1, and the pH also changes or increases to close to 6. Within top 1 to 3-kilometer depth of this seafloor. And that is how the deposition of the sulfides takes place and they give rise to.

So, they do have a very so, this this model which is actually developed by looking at the present-day seafloor hydrothermal systems are being are actually applicable to the older analogues; such as the older VMS deposit that we see in in areas like the noronda deposit or in some of the older ones, and the young ones like the cyprus and omono few light VMS deposits. We will discuss about these a little more details as to what exactly is the mechanism, how this kind of a conviction cell works and what the different possibilities; because whenever we talk of the situations like we saw the generalized morphology of a volcanogenic massive sulfide deposit.

What we essentially mean is that this should be the situation for the deposit which we call as a proximal VMS; means, which is exactly in situ or exactly close or on the where site where the fluid activities going on the seafloor. There are situations which, which is also possible that we may not get the deposit exactly on where the fluid is being discharged, but a little away or in some distance away from the zone of venting of the hydrothermal fluid. Those kind of deposits we call them as the distal volcanogenic here distal, VMS deposits mineralogical in many of so, they will not be this kind of a feeder, pipe or the alteration zone will be missing from those deposits. But they still will be in terms of mineralogy and in terms of the mineral content there will be identical there will be similar.

So, we will have to will see briefly in the next class as to what causes a proximal VMS or what causes a distal VMS. Or what kind of what happens to the fluid which circulates within the fractured zone in the hot basaltic crust. And what happen or whether the fluid that is discharged on the vents are adjustable just the same, one type or there could be many different types of such discharge fluids; which will cause the mineralization either is a proximal or distal VMS.

So, we will continue in the next class.

Thank you.