Mineral Resources: Geology, Exploration, Economics and Environment
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Lecture - 39
Mineral Exploration (Contd.)

Welcome to today's lecture we will continue our discussion on mineral exploration taking up some of the case studies and also some important principles, the philosophies behind mineral exploration. We saw how are you we effectively utilized the mineral chemistry of the indicator mineral and exploration of diamond difference kimberlite and the, that was one example which was more based on a methodology that is developed and it is very widely practiced.

So, today we will discuss something about the use of genetic models.

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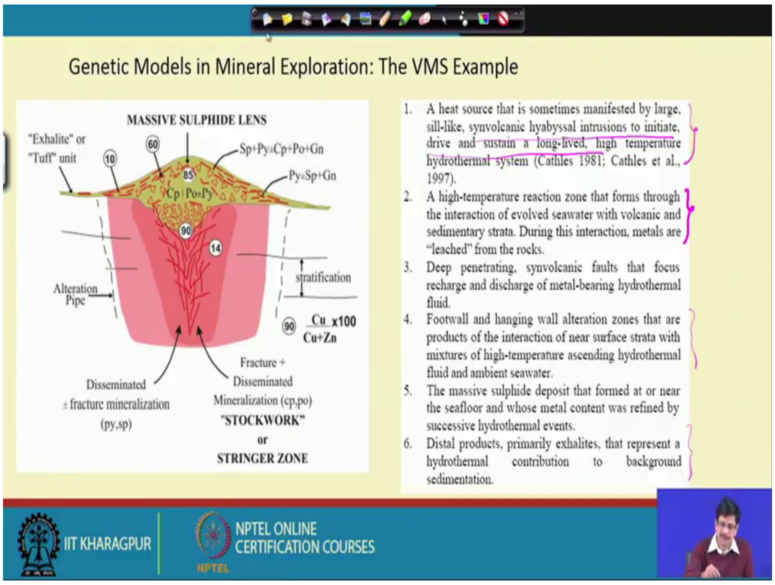

So, use of genetic models in mineral exploration, as we have already discussed we have seen through a wide spectrum of mineral deposit deposits forming by many different types of processes, seafloor hydrothermal process, land based hydrothermal process, magmatism sedimentation weathering and erosion surface sedimentation process and so on.

And study of these deposits have led to proposition of the hypothesis on their origin and this hypothesis on their origin essentially come from study of the key in the geological elements from in different magnitude and identifying such key geological elements. And then also the geological elements of the constituent elements when it comes down to processes which operated at a less dimension in a regional scale or in ore district scale and then coming again focusing on the processes which are operating in the in the deposit scale.

So, all these have to be taken into account when formulating any mineral exploration criteria which is based on the concepts of ore genesis. So, that still very indispensable for us we develop or we maybe that we keep on defining the concepts of ore genesis, but then anytime you think of exploration of any deposit type which I said before that today a mineral exploration is mostly targeted towards specific deposit, specific genetic type of the deposit of a specific metals. And I gave the examples say for if you want to explore for copper, we have to decide whether we are actually will be exploring for copper in the volcanogenic massive sulphide deposits which are likely to be quite widespread as they are in many of the cratonic blocks like the examples which we have consider.

Let us then have a look as to what we what kind of genetic model that we have developed, for a volcanogenic massive for taking the example of volcanogenic massive sulphide deposit, here the deposit model goes like this. We have seen this diagram before this is the figure stock work zone with it is typical alteration around this is a massive sulphide lens, sharp footwall contact and defuse hanging wall sorry sharp diffuse and footwall contact, sharp hanging wall contact with the hanging wall volcanics and one kimbersenic sediments and metal zone copper, zinc and lead kind of literal vertical zoning.

And this as far as the origin is concerned we have seen that we it could be thought of as a seafloor hydrothermal system initially starting with rift kind of a setting, where there should be constant and source of heat. Where the sea water is actually will be circulating in the form of very large convection cells where the seawater will get in through the fracture sea floor basalt and then encountering higher and higher temperature it exchanges component with the seawater and gets enriched with respect to the metals like copper zinc and silver, copper zinc and lead depending on what the deposit you are looking at like the fluoride syplus type or it is kuroko type.

So, here a number one that it, the heat source that is sometimes manifested by a large sill like synvolc, synvolcanic, hyabyssal intrusion to initiate and to drive the, to sustain a long lived high temperature hydrothermal system. This comes out this turns out to be one of the important key aspect of the genesis of volcanogenic mass massive surface deposit.

The high temperature zone that forms to the interaction involved seawater so, this is the outcome which we have seen deep penetrating synvolcanic faults they focus recharge of the or the discharge of the metal bearing hydrothermal fluid and we have seen that it has to have a initial impervious silica rich cap on it, which allows or which helps in developing of that fluid pressure and which is then again the fluid movement becomes fluid starts to move were to convert to the upper zones by synvolcanic faults.

Footwall and hanging wall alteration zone it comes with deposit scale feature and as we have seen here the massive sulphide deposit that formed at a near the seafloor whose metal content was refined by successive hydrothermal events, then distal products this is primarily exhalites that represent a hydrothermal contribution.

So, now if we with this kind of a framework, we would, we would like to we would like to just have a look.

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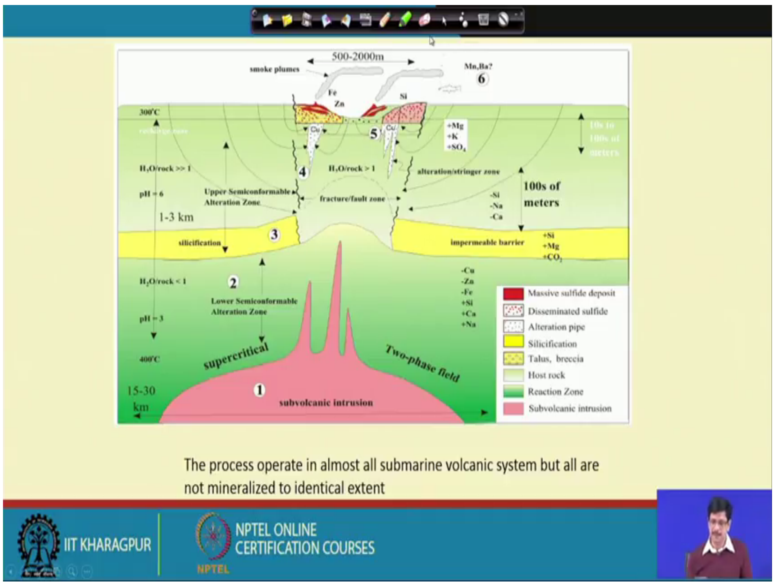

This is a, this is the model that has been developed which we had a brief look this is the impervious layer which will initially formed and these are the synvolcanic fault and these represents the, this represents the zone in which we are getting the volcanogenic massive sulphide deposits, the lengths massive sulphide lengths and the pyrope alteration pipe and we somehow have some idea about the different elements of the genetic model.

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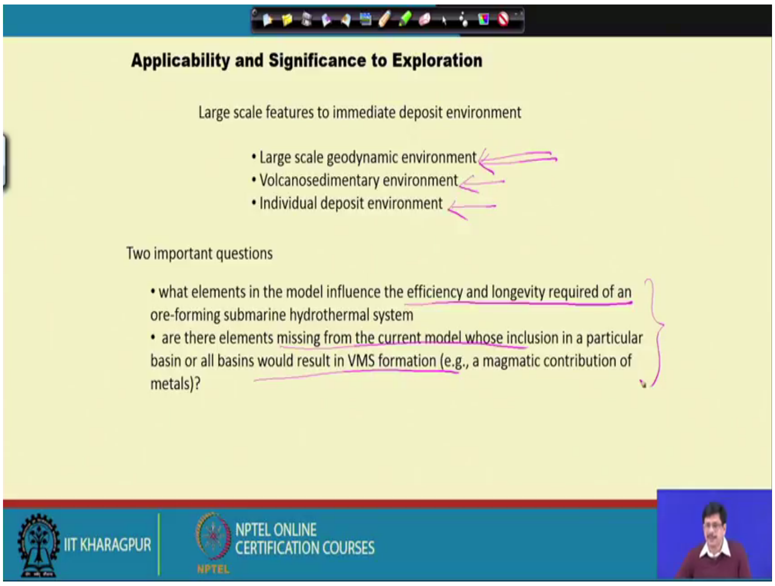

So, then we have to see the applicability and the significance to exploration look and going down from the features which are the largest dimension largest scale features to the deposit scale district scale and the local scale. So, the large scale features which are immediately which obvious to us in the large scale geodynamic environment means a moment we are talking about volcanogenic massive sulphide deposit what is there at the back of our mind is that we are talk.

We have generally looking for a failure rift and a faith system and as we have seen in many of the cases to account for the presence of this a volcanic intrusion which more of a felsic type of nature we generally bring in either a backer kind of spreading center or even some mixed type of tectonic environment in which we can have this kind of deposit.

So, the first and foremost becomes in the crustal scale geodynamic environment and the identification of such kind of crustal scale features and the volcano sedimentary environment which we need to have and the individual deposit environment these are the three stages. So, the 2 important questions that we have is what elements in the model influence the efficiency and longevity required for an ore forming submarine hydrothermal system, because we might have been able to identify more than one process. But, the question is that which one of them is actually is most influencing the ore forming process is that is that could the if such kind of a critical process is existing and formulation of ours exploration criteria becomes easy and then are these elements missing from the current model.

As we have said that ore deposit ore genesic generic models they keep on getting refined based on any observation that is made later on or any kind of information that is coming in dependently from some other source. So, far as the metal source fluid source through revolution all these things are concerned it.

So, may happen that the model that is generated as a first working model may not have all the elements and it may have that some of the elements missing from the current model, whose inclusion in the particular basin or basins would result in a VMS formation. Means for example, when we try to ask the answer the basic query that if we talk of 2 identical geological environments one has a volcanogenic massive sulphide deposits the other 1 does not have.

So, in that case it becomes very important to ascertain whether this absence of a mineralization in one particular region. So, far has not been identified is can it be ascribed very precisely to the absence of certain element which is the, which are actually out of some process.

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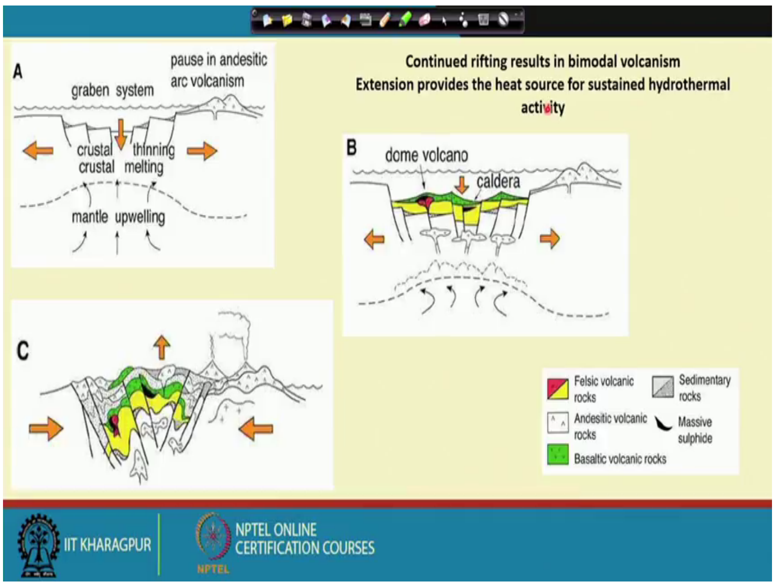

So, this is how the situation could be depicted that this is a, this metal upwelling and then there is crustal scale tinning and the upwelling of the a semi sphere and formation of the basaltic crust and that part of the mid oceanic the system is deformed with is an extensional as regime. Where there normal faulting and all these things are taking place here and then this is the initial stage and then this is it leads to deposition of this, this is the impervious cap that is shown here and the faults and these are the small sub volcanic bodies which are forming here which are responsible to providing the heat and these things under goes kind of a collapse caldera collapse.

And now this stage we are finding that it is actually now the tectonic movement has just reversed, now from an extensional regime it is jains through a compressional regime where the all are the early formed volcanogenic sulphide deposits the different other units are actually folded. And so this is the continued rifting it is results in bimodal volcanism extension provides the heat source for sustained hydrothermal activity. So, this kind of, this kind of is a hypothesis giving the different the way the processes operated to reformation of the VMS deposits.

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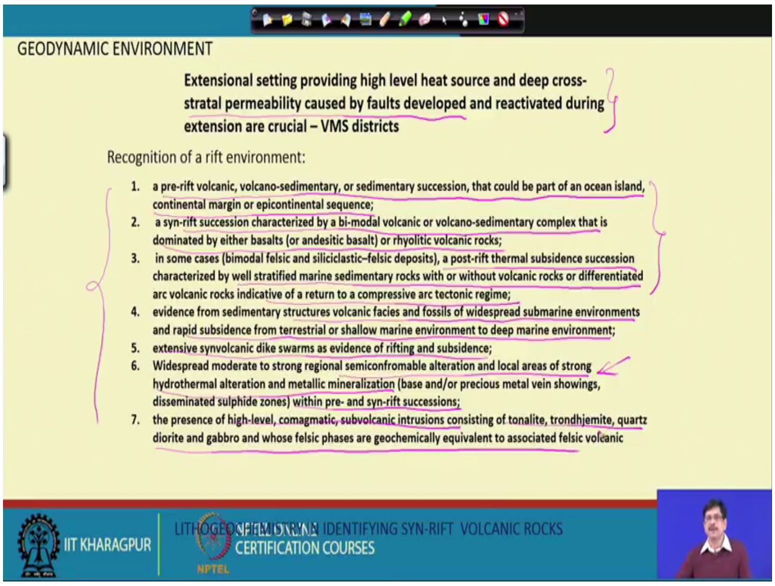

So, now we will try to find out that what, what kind of large scale features or deposit scale features, minor scale features that we should be looking for. So, extensional setting providing high level heat source and deep cross stratal permeability caused by faults develop and reactivated during extensional are crucial. So, this is the geodynamic environment, that the reactivation during the extensible and the this permeability caused by faults developed and reactivated during extensions are crucial for the formation of a volcanogenic massive sulphide deposit.

Now, how we will be basically recognizing rift environment. So, the recognition of the pre environ pre the rift environment would come from such kind of elements, that the pre rift volcanic volcanogenic sedimentary or sedimentary succession that could be part of an oceanic island continental margin or epicontinental sequence less number learn.

There could be syn rift succession characterized by bi modal volcanic volcano sedimentary complex that is dominated by either basalt or andesitic basalt or rhyolitic volcanic rocks. So, in other cases there is there are when we get bi modal felsic and siliciclastic felsic deposits a post rift thermal subsidence which you have seen from the sketch that we just saw the post rift thermal subsidence succession characterized by well stratified marine sedimentary rocks with without volcanic rocks or differentiated arc volcanic rocks indicative of a returned of a compressive arc tectonic regime.

So, these are strictly based on the model that you have built up that works as a genetic and it is a working model and then for this basically being a discuss theories and how that that working model could be called could be translated into an exploration formulation of exploration criteria and see how it will work. So, in that case what are the different elements that would be required for the identification of the first component there is a major scale rift environment.

Evidence from sedimentary structures volcanic facies and fossils of widespread sub marine environment and repeat subsidence from terrestrial or shallow marine environment to deep marine environment, extensive synvolcanic, dike swarms as evidence of rifting and subsidence widespread moderate to strong regional semiconfromable alteration and the local areas of strong hydrothermal alteration and metallic mineralization.

So, here we are coming from the scale now we are zeroing down or coming down in the scale to deposits scale process where the hydrothermal alteration and metallic mineralization with pre and syn rift successions. Presence of high level comagmatic subvolcanic intrusion this is for the sustenance of the heat or driving the hydrothermal convection same it could be tonalite, trondhjemitic or quartz diorite and gabbro. So, these are all coming from the rock associations that we have seen in our study of the volcanogenic massive sulphide all across the world in different types of settings and the volcano sedimentary environment and the recognition.

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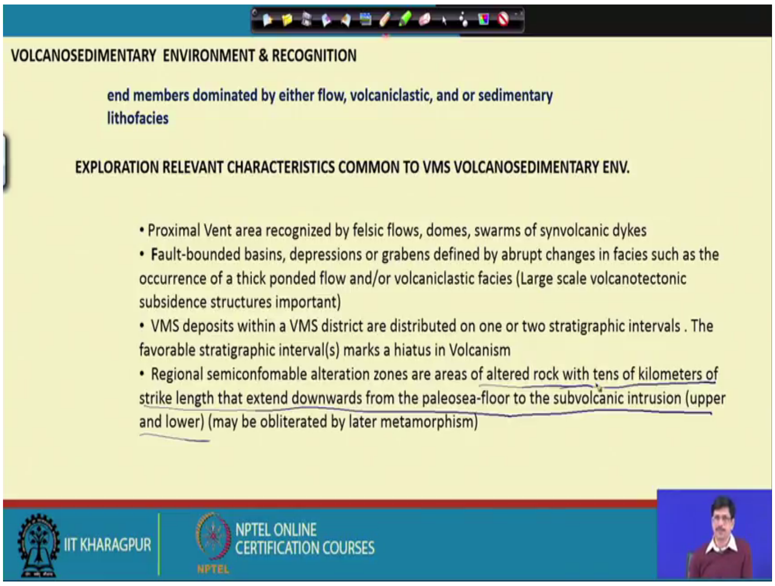

So, n numbers dominated by either flow volcaniclastic or sedimentary lithofacies and the exploration relevant characteristics common to VMS volcano sedimentary.

Such a proximal vent area recognized by a felsic flows, domes swarms of synvolcanic, dykes fault bounded basins depressions or grabens defined by abrupt changes in facies such as the occurrence of a tick pounded flow and or volcaniclastic facies VMS deposits with a VMS district are distributed on 1 or 2 stratigraphic intervals. This is actually very important when you come to the district scale feature that the VMS districts are distributed on 1 or 2 stratigraphic intervals a, favorable stratigraphic intervals marks a hiatus in volcanism.

So, that is what is the time during, which the massive sulphate lengths is would form. So, it should mark a hiatus volcanism and after which will have the greater volcanism will be forming the hanging wall volcanism, volcanics and regional semiconformable alteration zones are areas of altered rocks with tens of kilometers of strike length that extend downward from the paleosea floor to the subvolcanic intrusion.

So, this is important, because if we think that in a in a VMS district will we, will be expecting once we identify a when you rift kind of rift for this all this volcano sedimentary succession and the tectonic evolution that we saw.

Once we identify then we will be looking for and we expect that there could be at least many such deposits will be occurring in a particular district and we will have regional semi conformable alteration zones are the areas of altered rocks with tens of kilometers of strike length that extend downwards from the paleosea floor to the sub volcanic intrusion which we have this is a part of a model the part of a model that is proposed.

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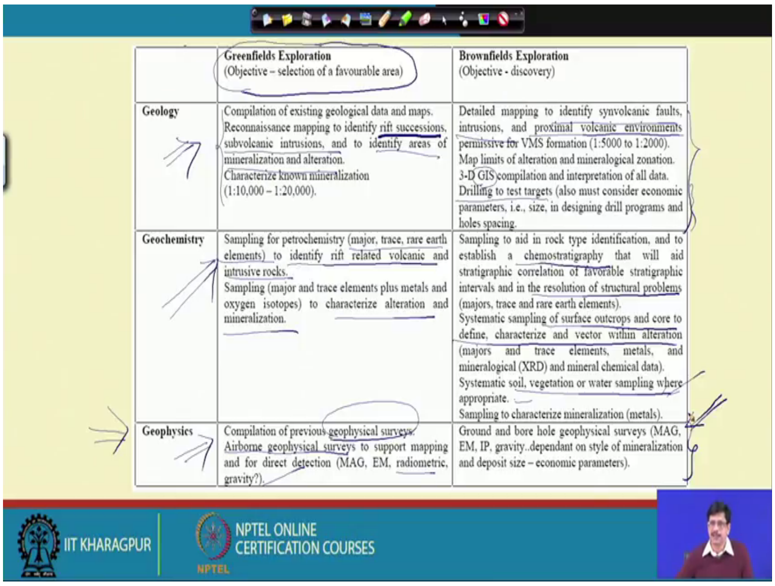

Then we can have a look on the as we when we started the topic of mineral exploration we introduced the subject of mineral exploration there we get ourselves introduced to these 2 different modes of operation of this mineral exploration.

One is the Greenfield exploration as you said that in any particular area where there is known one deposit occurring or there is no report of any parti any such deposit which is occurring there and with some idea of the geology and where an exploration program is actually being contemplated from the from the very beginning.

So, here the geology that has to looked for is that or the way it should go in a Greenfield exploration program the comparison of existing geological data because this data these area is only supposed to be having recognition kind of information that is available could be the very small scale geological map and also it could be it could be helped by availability of many of the areas scale or regional scale geological map and the geophysical anomaly maps. Such as the aeromagnetic map anomaly map or the airborne geophysi the gravity anomaly map and all these geological information could be you tuple and the reconnaissance mapping to identify riff successions.

So, that becomes as we discussed and to identify a rift succs because in any case that element has to present there in respective of whatever the way the it is involved later on subvolcanic intrusions presence of subvolcanic intrusions and to identify areas of mineralization and alteration. So, hierarchically moving down from much larger scale features to deposit scale features and then the other aspect that also could be looked into here is that if a window. We have said that no 2 occurrences could be could be same in all the state or no 2 occurrence will be identical to each other, in each mineral deposit occurrence is unique and has some features which will always make it distinctly different from others.

But since we have we are in the process of putting them up, adding them up together to the different groups I mean by I have an a classification scheme. So, we could always go going to a look the characteristics of a VMS deposit which occurs in a different terrene where some insight could be obtained.

So, that these will serve or the basic information based on which we can go on to explore in Greenfield and geochemistry sample sampling for petro chemistry a major trace and rare earth elements which you know that they will be the kind of volcano sedimentary sequence that you have been looking for a theolitic basalt or any subvolcanic intrusion and the fluids and the in terms of the a trace element characteristics, rare earth element pattern and all these could be could be could help in identifying a rift related volcanic intrusive rocks.

So, these are these all have being cant being periodically and constantly being contributed by pathologists in tectonic discrimination of the rock types coming from different tectonic regimes such as rift or continental conversion zones they have very well characterized by their chemistry. Specifically with respect to the trace and the rare earth elements, then sampling major and trace elements plus metals and oxygen isotopes to characterize the alteration and mineralization.

And then the geophysics as will be also be same as case studies they do volcanogenic massive sulphide deposits do have a very interesting and geophysical the very interesting contrast as far as the physical properties are concerned like magnetic gravity and electrical properties by virtue of the sulphide minerals that they have in good con, good content good concentration. They could be very well the studied by geophysical surveys as I told airborne they could be also local scale ground geological ground geophysical surveys airborne geophysical surveys and to see it a larger scale.

And then magnetic electromagnetic and radiometric methods could always be utilized and as you know beginning of the introduction of the subject of mineral exploration, we got ourselves reminded that success successful discovery of any mineral deposit is essentially a synthesis of information obtained from all different methodologies and techniques. And then when they are all treated to synthesize together then only it leads to mineral deposit discovery because it gives us reinforcement of many different information from many different sources which will be converging towards the common thing.

And then situation in case of Brownfield means where there are some districts or some regions which are already identified in larger scale and then we would like to examine that whether we could have we could get some more of such number of occurrences of VMS anywhere nearby any how within the ore district. So, detailed mapping to identify a synvolcanic faults are intrusions and proximal volcanic environment permissive for VMS formation proximal VMS environment will always be indicating that there should be a fidder or pipe with a typical stock work mineralization and alterations.

So, map limits of alteration mineralogical zonation, 3 dimensional GIS compilation and interpretation of all data. So, we as of now we do not have much the work introduce this subject of GIS, but this is the as. So, we will be discussing sometime later on this GIS that is geographic information system is the most widely used current technology of synthesis of information, compilation of information using very simple concepts of data integral data synthesis data integration in space. Because whatever is our purpose we are always talking in terms of any particular event or any deposit that is occurring in spe with respect to inth reference to space that is the any other to we are talking about the geological conditions and the what about tectonic interpretation we are making and we are we essentially targeting to get those localized parts of the points. In point the areas where the most likely occurrence of a VMS deposit.

So, in the ground field exploration drilling can always go on wherever there is a suitable target that is identified also must consider economic parameter there is size designing drill because these are more of economic parameters which also will be discussing. In case of geochemistry we can go to sampling to aid the rock identification and to establish the chemostratigraphy between aid stratigraphic correlation of favorable stratigraphic intervals. It is because we have seen that they sometimes restricted to particular stratigraphy horizon and resolution of structural problems, this is also very important whenever we get deposits which deformed like those which represent in the old arcean cratons such deposits with a definitely underground some amount of deformation or metamorphism.

There it is very essential to work out the different episodes of deformation, the stages of deformation and the very nature and the ways you it is very diffi very essential to understand any amount of disruption of modification to the original morphology of the ore body that has taken place.

Systematic sampling of the surface outcrops and core to define characterize and vector with an alteration and then systematic soil vegetation water and sampling which is appropriate with some of them will be a part of geo geochemical prospecting that will be discussing a little bit in principle.

So, to sum up and then we can always go for ground and bore hole geophysics geophysical surveys and magnetic electromagnetic induced polarization gravity and depend depending on the style of mineralization. It will be discussing it is very much even though there are lots of such techniques that are available to us sometimes one works better than the other and depending on the specific geological conditions.

So, this is how we can go about are the so the model is with us. So, the genetic model, likewise we can think of any other deposit type lets for example, the low type gold deposit in the archean granite greenstone terrines. There the gold concentration in the rock or the loads that we talked about will be too v small and negligible to give any very distinct geophysical or geochemical signatures. There also it is very important that we also take into consideration the genetic hypothesis of the models of the genesis that have been ore genesis that have been proposed and involved and based on that to identify which are the critical processes such critical processes or the constituent processes and the deposit scale processes have to be well translated into exploration target or the fixing of the targets target identification h which can be done.

And, so we do with this and as we will be seeing the as we have already discussed through all the entire spectrum of deposits starting from magmatic, 1 magmatic sedimentary paleo pressures and the volcanogenic massive sulphide deposit the young the epithermal deposits in young volcanic islands and the unconformity related deposits all these deposits. We have seen that their origin is the where they have originated has been proposed which can be very well correlated with the geological elements identifiable geological elements which will be very very useful in formulation of the exploration criteria.

Going to the field and actually finding those geological elements and then supplement or adopt the information with whatever surveys geochemical or geophysical survey that we do we finally, need to the discovery.

So, thank you. So, we will be continuing on this.