Mineral Resources: Geology, Exploration, Economics and Environment

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Lecture – 35
Mineral Exploration (Contd.)

Welcome to the lecture of today. We have been discussing about mineral exploration and have started our discussion on the geological methods. Although it is actually the geology which is at the core of it; we are looking for mineral deposits. And any other any piece of information that is to be generated by any other means is going to supplement this effort of actually discovering a mineral deposit and so the over and above of the geology is actually is the most crucial part of it.

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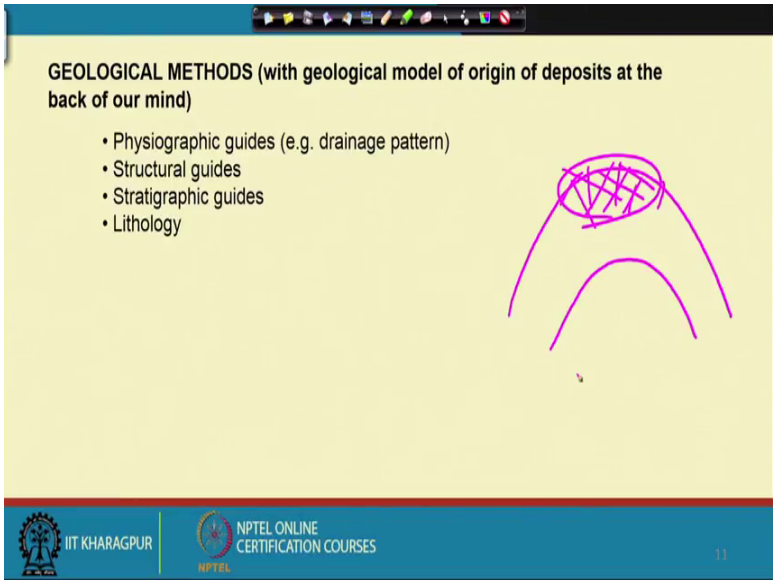

In our discussion, we talked about the different types of guides like physiographic guides, structural guides, stratigraphic guides. Guides as we have just discussed there could be large scale felts or folded terrains. In we have seen that in terrains where there has been affected by folding, sometimes there are enrichment of mineral the ore bodies in the different parts.

Say for example, if we take a take a fold, as we have seen from one of our morphology examples of so we generally see that the areas in a hinge, we get the mineralization either taking place in the fracture network where it is a essentially the zone of the outer hinge

part of zone of extension. And several such layers which are folded give rise to deposits which we name them as the saddle rift type of deposit, and many such situations many such deposit types which exist which have been identified in different parts.

So, folding in particular geological terrain will definitely act as an important structural guide. And also we have seen in situations like in where originally as since sedimentary accelerative deposit a (Refer Time: 02:40) deposit as a (Refer Time: 02:43) deposit or even sometimes volcanogenic massive sulfide deposit. They during the process of the deformation, they also get redistributed and there are parts which are much rich richer part of the ore is localized affected by structure. And mostly the way sometimes there are some plastic flow edge of the sulfide ore body from the limb towards the hinge zone towards the zone where the strain is high.

So, such some many such instances could be shown where many of the structural features act as guides or the indications where the exploration or the method of detecting the ore body or delineation of the ore body could be more focused and then large scale lineaments coming out of shear zones, giving rise to load type deposits which also extend for several hundreds of meters are sometimes kilometer scale. Like the ones, which we have shown in case of the (Refer Time: 03:50). And stratigraphic guides are also important because we do have the example of ores being localized in unconformities.

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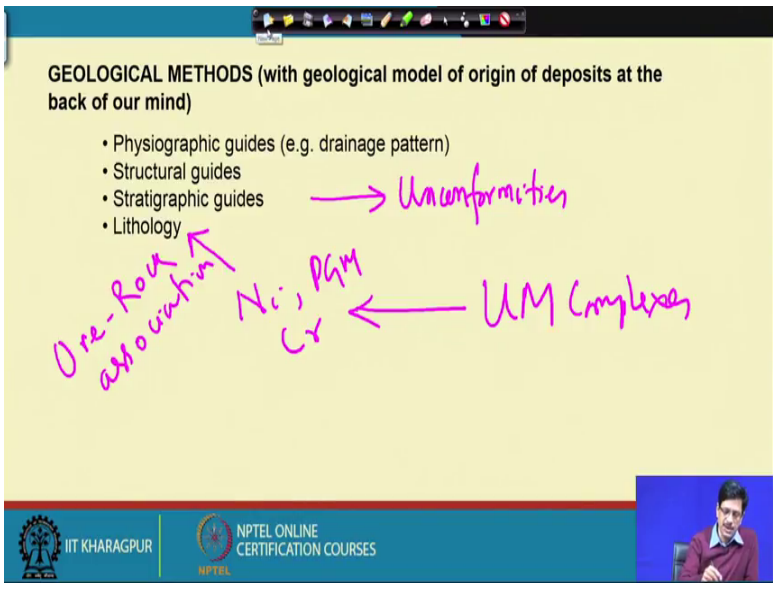

Of course unconformities also is a structural can be coming under, but they do sometimes also are important stratigraphic markers, and they act as traps in which mineralizing fluid generally deposit their metal content and give rise to very rich. Mineral deposits like the one we have seen in the unconformity control uranium mineralization in Athabasca basin and in other parts of the world, and then the lithology which of course, gives us the very fundamental idea.

For example if we are looking for nickel or platinum group of metal, chromium, then it goes it is very you have seen it very clearly that we have to go to areas where there are ultramafic complexes in the form of layered complexes or the bodies that we have seen that is true for even if we are looking for titanic (Refer Time: 05:03), magnetic ferrous magnetite deposit we do have to look for intermediate rock composition of the unearthed site which could be a part of this such kind of layered complexes or could be occurring as independent bodies like this are very complex that we have seen.

And many such rock so essentially what we essentially have put up or have proposed as ore rock or Ore-Rock association, before I put any more of example on this Ore-Rock association it would be rather relevant important to just recall.

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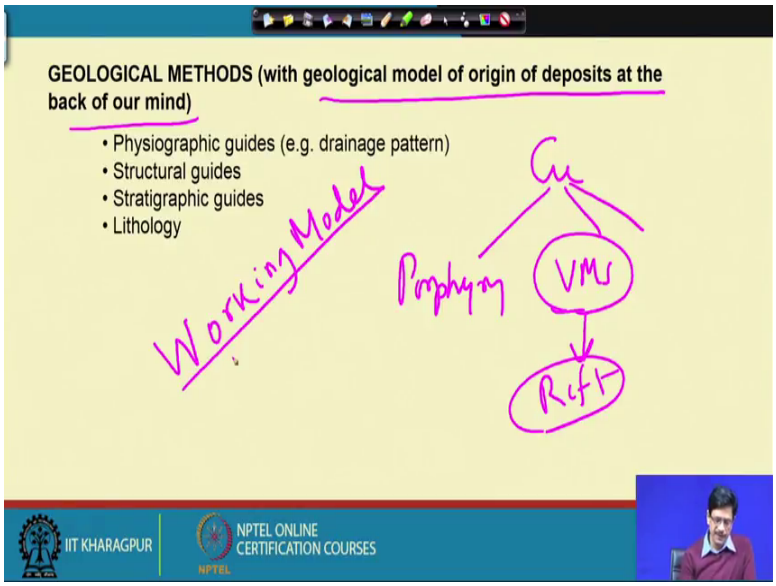

So, what we are basically saying here the geological model of origin of deposits at the back of our mind is actually is a fact that the mineral exploration program of today or mineral exploration when we think of exploration mineral exploration today. We

generally are targeting any particular metal or any particular metal of a particular genetic type. For example, if we talk of situations like we are looking for copper then we have to be very sure whether we are looking for the copper deposits which we are essentially looking for a porphyry type deposit or a VMS type deposit or any other deposit. Because we know that the geological setting the entire the way the geological processes involved in any particular segment of the earth crust or the lithosphere, they are different.

So, the exploration program or the criteria that is going to be used for this exploration program in different scales are going to be different for different type of genetic types. A program essentially targeting for copper in a VMS type deposit would be entirely different from a from a program which will be targeting for porphyry copper deposit which will be discussing one or two case studies here. Because so here the concept is that if we visualize any mineral deposit as a mineral system or a resulting from operation of geological processes in a particular sequence, and the optimum scale of operation of the process in each sequence which gives rise to a mineral deposit. A workable mineral deposit or a the deposit which will be meeting our quality quantity criteria so that process has to be thought of in all its scales.

For example, if we moment we talk about volcanogenic massive sulfide deposits let us say of a cypress type volcanogenic massive sulfide deposit what immediately comes to your mind is that we need to have a rift kind of a setting. So, if we are looking for a VMS deposit in any old terrain in anywhere in the earth crust, then we have to look for first we know that in terms of a large scale operating process, it has to be either a oceanic or the oceanic setting, rift kind of a setting in ocean floor or maybe sometimes in a very close proximity somehow there could be backer could be some kind of a convergent margin over somewhere there to give rise to a felsic rock which will be giving will be contributing the fluid and so on.

So, whatever is the situation, whatever you have visualized, and we have come up with something which we call as a working model. As a working model on the genesis of any deposit type all these we have seen, the whole spectrum of mineral deposits of all the metals that we have seen. So, this working model may be suffering from many shortcomings or many deficiencies or in terms of accuracy or there are many opposing views to any proposed genetic model. But if that particular genetic model could be translated, so if this working model of the genetic model that we are talking about.

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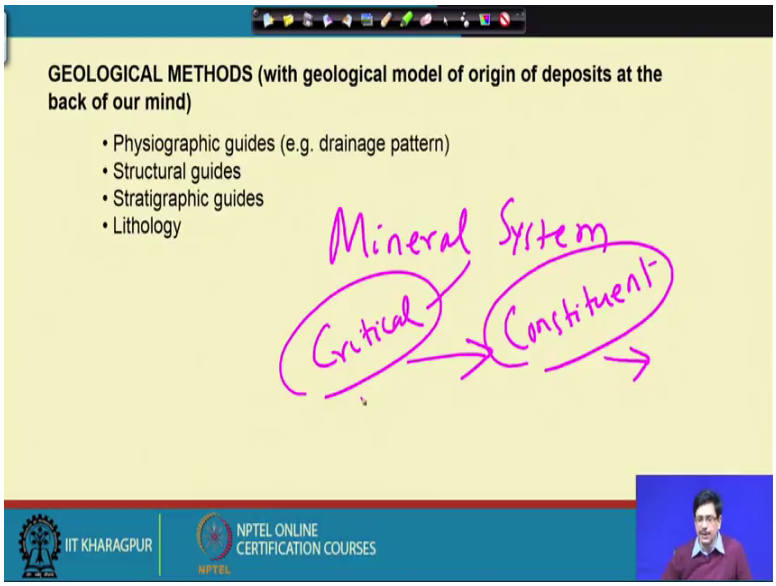

If we can say that it a mineral system, so this mineral system has some very critical processes then the example that we have seen for example, volcanogenic massive sulfide deposit in which a rift has to be present in any case it has to be a on a rift setting. So, identification of the presence of a failure rift type of condition anywhere in the continental crust, it gives is the first criteria that has to be satisfied if we are making a program of exploration for VMS deposit in that part. Then there will be certain so that will be the process which is the highest or the largest scale that is operating.

And when we go down in the hierarchy, we will see something that is some kind of constituent process constituent process are coming to a region scale or it to a regional scale then we see what are the processes that are identifiable. There is a constituent process in terms of the rock type that is occurring there, and the kind of a fracture pattern that we have seen in the ocean floor rift systems and so on.

And then again we can go to the next lower the local scale processes constituents. For example, in case of a VMS deposit, it is a stock work feeder pipe, which shows it is the typical type of alteration then that which will be in the scales of only say it is a 100 of meters or even less than square kilometer kind of area. So, they are the constituent process is very much governed by the local scale processes. So, we have to see that each process has to be translated into its target identification kind of elements starting from

the largest possible scale to the deposit scale for example, the alteration characteristics in that particular deposit would.

So, if we get that those kind of very typical alteration that is observed in VMS type of deposit, then we become more sure about existence of such deposit, then we go around go along go ahead with our target delineation procedures using many different techniques. And finally, end up with drilling kind of exercise to prove the existence of the ore body. So, it actually it is very essential that what exactly so the mineral exploration today is oriented in that way its targeted towards discovery of a certain genetic type of deposit of a certain metal or a group of metals. For example, we can have an elaborate program for exploration of kimberlite pipes, in any of the cationic blocks of the country, we can have an elaborate exploration programs for unconformity type uranium deposits in selected areas where we heard the geology is favorable and so on.

Say for example, if you are looking for porphyry type copper deposit which we know are very rich sources of copper then we have to look for areas where we should be getting value subduction kind of setting or kind of suture kind of setting. And then we should get the desired cal klein magmatism in the form of what we have seen in porphyry copper deposits. And then come to the deposit scale processes as to how many different phases of this of felsic into zips are there whether the alteration zones are they are not and so on.

So, these framework they provide the basic framework on which the geological methods of prospecting is based which operates from the all the stages. Because even if a particular drill ore body is being intersected by a dual core, the samples when they brought up the samples are examined and the mineralogy and not only the mineralogy the very minor features of these textural characteristics of the minerals in the ore which will be very crucial for its commercial utilization would also be studied. So, in a geological study actually is very continuously done from the very recognition stage to even the project evaluation and till the stage that an ore body is still made ready for its exploitation.

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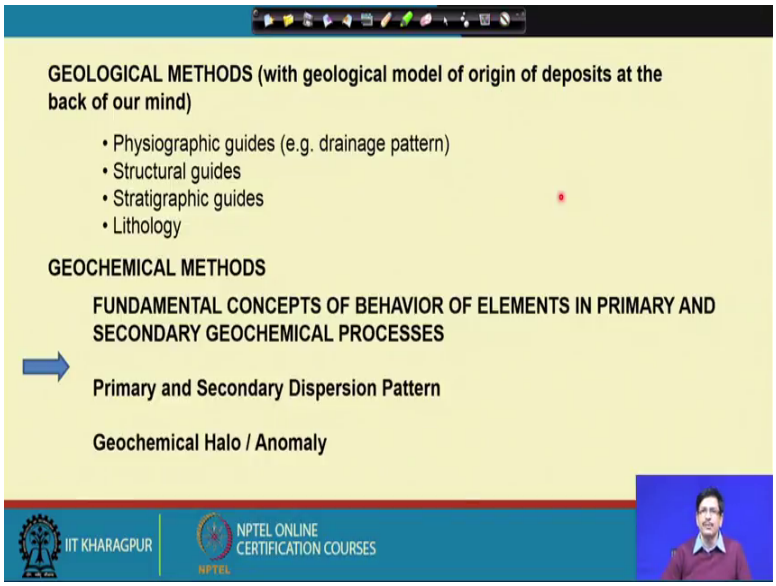

Then we talk about the geochemical methods. So, geochemical methods essentially we use our fundamental concepts of the behavior of elements and the behavior of elements in primary and the secondary geochemical processes. So, when we talk about a process of a magmatic melt being generated and there the elements are the incompatible elements getting more angriest in their particular melt and that melt is getting crystallized to form a rock in which it is given rise to a hydrothermal system, and it is the elements are getting fractionated. And this is essentially the concept in which this a case of primary geochemical process or primary dispersion.

And then the if that primary process has been able to give rise to an ore body at the enrichment of any particular metal to a higher value, higher commercial value, economic value and that particular ore body has come into existence has existed in the crust. And it is subjected to secondary processes of weathering, alteration and interaction with its environment rock with formation of soils and so many things. So, there the behavior of that element in the secondary geochemical cycle giving rise to the secondary dispersion pattern is the one which we need to understand properly to formulate our geochemical methods.

And what essentially we are looking for in the exploration program, we are looking for essentially anomaly or the halo. We have already while discussing the attributes of mineral deposits. We define them as representing anomaly in the crust, where the

concentration of any of the metal or not more than one metal is above a certain value. So, our basic objective is to identify or to establish the presence by understanding such anomalies in a reverse way. The ore body is concealed then I have great depth and then we have to do some systematic study. So, as to establish or so as to identify what kind of an anomaly it is.

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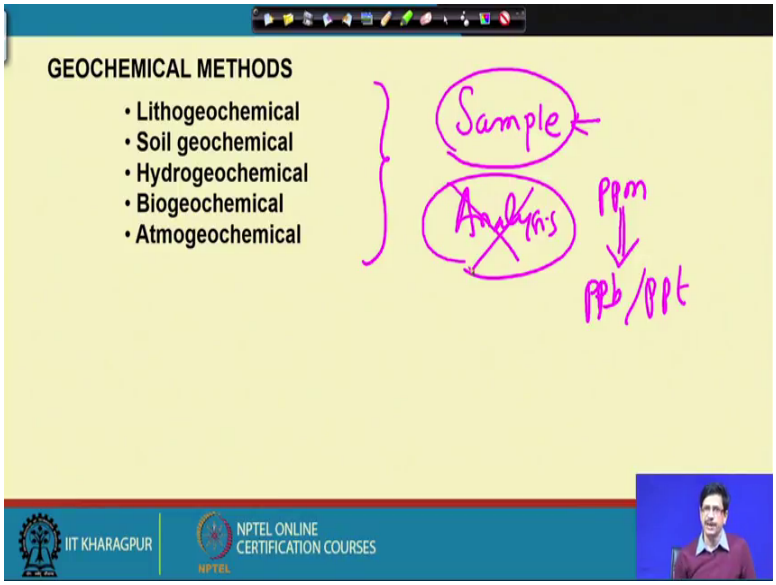

So, the geochemical methods based on what material we are using it could be a lithogeochemical where we are using the rocks as our samples for analysis, it could be soil geochemical or pedogeochemical method or pedogeochemical survey where we were using the soil as the material for our analysis. Hydrogeochemical, we are using water from different types of water bodies, it could be stagnant surface water, it could be ground water, it could be river flowing water, and there we are analyzing the water for the concentration of different metals of the metals of our interest. It could be biogeochemical that the plants that grow on the soil wherever there is a mineral deposits we can sample the plants, take different parts of the plant and analyze them. And can also find out whether they representing any normal or elevated or a anomalous value.

And atmogeochemical these things have also come into practice of late to sample the air in the region where there could be certain mineralization of metals like uranium from which we can have a main essence of some air gases like xenon, which could be their

concentration could be higher. And we could analyze them and could establish or could help in detecting the presence of such kind of mineralization.

So, all these as we can see here, all these basically are dependent on one thing which is very important in a geochemical method prospecting, we are concerned with two things, first is a sample and the other aspect is the analysis. They can be treated in two independent ways. So, sample is essentially the thing that is the decision that we are making on what is essentially a representative sample from what we want to analyze a rock or a soil or a plant. So, here an improper sample can always lead us to erroneous results. And we can see them in a little bit of details when we discuss about the geochemical method. Analysis is also important in the sense it depends on the capability analytical capability.

If we look if we think of what was available before three-four decades or five-four five decades, then the instruments where which were available for analysis their concentration ranges were pretty high they could possibly go up to only parts per million kind of range, but now with the revolutionary development in the field of analytical geochemistry with many high precision equipment that available to us like an inductively coupled plasma mass spectrometer.

And there is where we can or many other kind of situations where we can go up to parts per billion or even sometimes parts per trillion kind of analysis on concentration which can be measured in represent the analytical equipment which are presently available. So, this has been a great this has been of great help in geochemicals exploration program as a whole and identification of a geochemical anomalies which was not possible in the distant past. And we are not going to discuss much about the analytical the equipment or the principles on which this can analytical equipment work and because they beyond the scope of this particular discussion.

So, we will only be talking about in brief about the geochemical methods. So, one thing we can keep in our mind that we are talking about the primary and the secondary geochemical dispersion pattern or the mobility of the metals in different environment.

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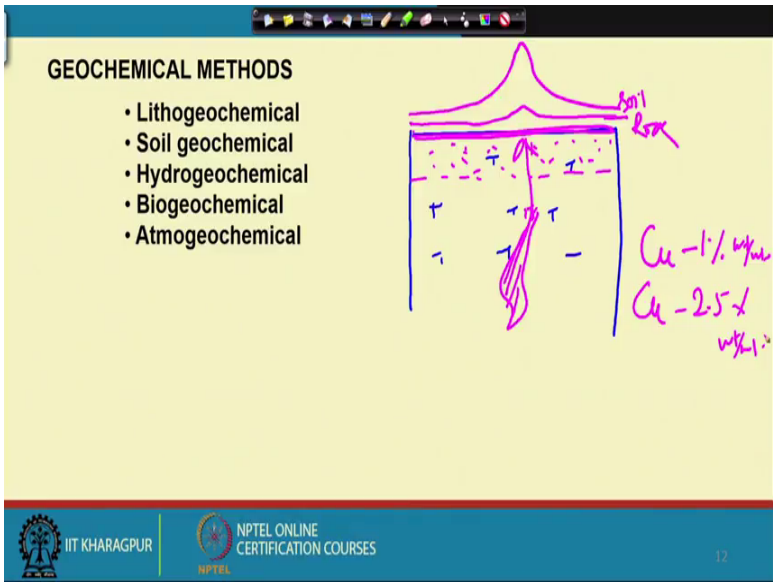

If we take say for example now if this is a situation in which in a crustal rock, there is it a deposit is somewhere hidden. Now, depending on if whatever is the metal here, so it is surface expression or what we are essentially we will be able to sample or look at the situation where it is on the surface. So, it depends on the medium in which this body is placed. If it is only through just crystalline rocks hardrocks, where the rock has not been whether to soil then the rate at which the well if that particular metal would have migrated in a concentration gradient would be much slower compared to what would have happen.

And then the constant so if we measure the concentration on any particular any traverse trying to find out the concentration and this is supposed to be there the immediate particle distance here, the concentration is supposed to be the maximum and the concentrations who died away when we move away move from perpendicular direction in either way. So, if suppose if it is a rock, the kind of analysis or the concentration profile which you will get might look like a situation which is a very small or sometimes have been imperceptible or inconspicuous or even less than what I have shown here. Compared to the situation where this ore body on top of it is actually is a zone of soil. Zone of soil where there are soil pore spaces and the pore space is filled up with water and the mobility of the particular metal particular element within this soil column or this part which I call as overburden the soil.

So, then the concentration which is exactly above when it is a soil it could possibly become a much more prominent. So, this situation correspond to where it is rock; the second situation may be soil. But, both actually be representing the presence of that ore body of the same dimension same quality and the same quantity, but the reflection on the surface could be different.

So, here if we just make a visualization of this diagram that conditions remaining same if this particular ore body happens to be a far more richer can suppose this is an ore body where copper concentration is say copper concentration in the first case. Suppose they are covered by the same material either rock or soil. In the first case the copper concentration is say 1 percent, it might correspond to a anomaly which will be small. Whereas, in the other case suppose the copper concentration is about say 2.5 or even more than that weight percent, so we will have a higher anomaly.

So, the situation that I am trying to depict here that what essentially we look for in the geochemical survey geochemical prospecting program to systematically sample, the sample is a very important aspect of the work, because a proper improper sample will be give erroneous result and in terms of the secondary dispersion or the anomaly of the geochemical halo that we get for different types of deposits or different situations it might be it could be so very diverse so very widely varying situations. So, that is why the interpretation of the anomaly becomes a very, very tricky and important exercise in the geochemical exploration program, so that holds good.

So, if we are doing going for a program where the situation is that the ore body is only concealed under rock then in the lithogeochemical so we are sampling the rock if the ore the ore body is covered by a layer of soil. It is a soil geochemical method, where we are sampling the soil or the hydrogeochemical. So, we have to so this needs very well thought out plan for the sampling. And it needs a lot of pre sampling study which is essentially goes by the name of an orientation program. And this particular method we are actually adopting when we are in the third stage where actually we are going to the process of delineation of target means getting preliminary indication of presence of such kind of a ore body from our reconnaissance and detailed geological mapping. We are sure that there is a ore body is existing and we are going for its delineation in space in the subsurface. So, you are using this technique geophysical method also will be employed in this particular stage.

So, if we want to just summarize for this particular weeks course that we started. With this completed our discussion on the Indian deposits, and then have had briefly caught into the topic of mineral exploration. Trying to understand actually what we are exploring for this for the classifying the resources in terms of their identified and unidentified resources, constituting the resource base of any particular metallic or mineral resource. And then understanding the basic purpose and look at the various stages of their mineral exploration from reconnaissance stage onwards.

So, we will be continuing our discussion on this topic of mineral exploration with taking up a some case studies.

Thank you.