Mineral Resources: Geology, Exploration, Economics and Environment

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Lecture – 32
Mineral Exploration

Welcome to today's lecture. We have kind of completed or finished our discussion on the first aspect of the course, the according to the design of this course the lecture series, the geology or the science behind the mineral deposit formation, the different types of deposits that result from various crustal processes, processes which result of the interaction of the lithosphere, hydrosphere and atmosphere. The way they evolved in time, giving us a very big broad idea as to how the metallogenic processes have evolved in time. Sometimes we are in a position to make a good correlation with the processes that is operating presently with deposits which formed in the distant geological past.

Sometimes they do not seem to be agreeing sometimes they agree, and our pursuit or of our endeavor of investigating more and more on these deposits, we will continue; with the hope that they will enrich us with the knowledge which will be effectively utilized for discovering or such deposits in areas which are otherwise not known to be existing in those parts of the continents.

In course of discussion we also brought into the topic of these resources of the seabed which we did not look in to it much with any greater details. We only discussed about the occurrence of the seafloor hydrothermal systems, sometimes resulting in rich mineralization of melted metal sulfides, like copper to lead and zinc. And the seabed being a very rich resources of the pharaoh manganese nodules; which are just not important for their iron manganese content, but also for the their content of nickel and cobalt which the metals which are more important than iron manganese at the present context.

So, we now move on to the second component of the lecture series. This that mineral exploration and we will see how much we will be able to discuss on this how much of insight we will be able to get. How much of our knowledge on ore deposits were able to effectively utilize in exploration for the mineral deposits. And so, to begin with, let us first talk about a situation that once. So, any mineral deposit a mineral a in our body a

mineral deposit, which is quite diverse in terms of it is size, in terms of the metal content for example, a deposit of an abundant metal like iron and aluminum will be present in terms of billions of tons, and in areas of even 100s of sub square kilometers; whereas, a deposit of gold will be measuring only in terms of a few million ounces and we will be just about a only a square kilometer or a few square kilometer area as a deposit, although there could be some belts in which many such gold occurrences would be there in a particular terrain like what we have seen in case of the ones which are occurring in the greenstone belts.

Though there is wide diversity, but once so, the ore deposit essentially is an economic commodity for us. So, this has to be utilized for the economic growth for various industrial purposes is raw materials, and for the growth of the industry.

So now before we begin our discussion on mineral exploration, let us first talk about these mineral deposits or mineral resources as a special type of resources. We find the some specialties are there in these mineral resources. So, what are these specialties? Number one is that these deposits are exhaustible, nonrenewable; in the sense that the quantity of the deposit of the metal which is present in a deposit, if it is taken out how the rate at which were we were exploiting them, which is always on the rise that the demand is increasing, and the rate of for the park up we can take a measure like a per capita consumption of a particular metal is on the rise.

So, the time that these deposits the time frame in which we are utilizing this deposit, exploiting this deposit is too, too, too short compared to the time frame in which the deposits form by nature. So, they are all practical purposes the deposits are exhaustible; unlike any other resources that we talked about, where the exhaust ability of the non renewability does not come into picture.

So, the one the deposits are uncertain. So, we have a whenever we talk of any deposit, any resource, somehow we have some idea about the quality and quantity. Where is the mineral resources there is a lot of uncertainty about their quality and quantity. There is uncertainty about the usability. Because today we do not know, I mean what is going to the technology future and what is going todays any metal or any particular mineral, it is usability as to what is going to be the future technology is not very well known. So, that

is there is a bit of an uncertainty about the usability, which is not the case with other resources.

They are finite in quantity any ore body we measure, we calculate by many different methods which will be seeing through our discussed course of discussion; that whatever quantity it is it is finite. It's so infinite. So, it will be the particular rate at which we start exploiting, it will get finished, get exhausted in a particular frame of time, maybe in case of abundant metals, like iron and it may last for about a few 100s of years.

In case of critical metals of scarce metals it will be only in terms of a few decades of few tens of years. The other situation with the mineral deposits is that the depth dimension is not known it has to be again to be investigated to be estimated to be assessed that whenever there is an ore body up to what death depth it extends, and which is important for us. They are a result of complex geological processes. They do have locational and distributional peculiarities.

For example, the ore deposits are not just very located in very convenient places for us to go and just take them out. But there they would be in the inaccessible part of the land, where the mineral deposits are located perpetual there once the deposit is there, it will possibly not be getting destroyed. Barring the situation that we discussed in the very beginning of this course, about the self destruction of the cannibalistic recycling of our ore ours own processes, which destroy the deposits in certain amount of time. But that possibly is in the geological time scale not in the time scale of the human civilization.

So, any deposit which is there will be there for eternity until and unless the deposit is being exploited. It is does not get destroyed by any process any in in short time duration.

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And the these deposits, the mineral deposits they are peculiar in the sense that they do not abide by any geographical boundary, we have seen one example says the Cooper Seifer, they use body of couple bearing shear which extends for 60, 600,000 kilometers in Europe, and occurring in many different country like Poland Germany. There are many examples in the Indian context also even if we talk about state boundaries.

So, mineral deposits they will be transgressing through the geographical boundaries. And the relationship with economy is also something very interesting. And that is the reason why we say that we have to formulate a bigger that is also a little bit of an uncertainty that how the mineral resources are going to be exploited, and how the economy will grow. We will take up a few such cases where we will demonstrate. That it is not always true that a mineral deposit a country will be getting the full, economic benefit out of a out of presence or existence of a certain mineral deposit or not.

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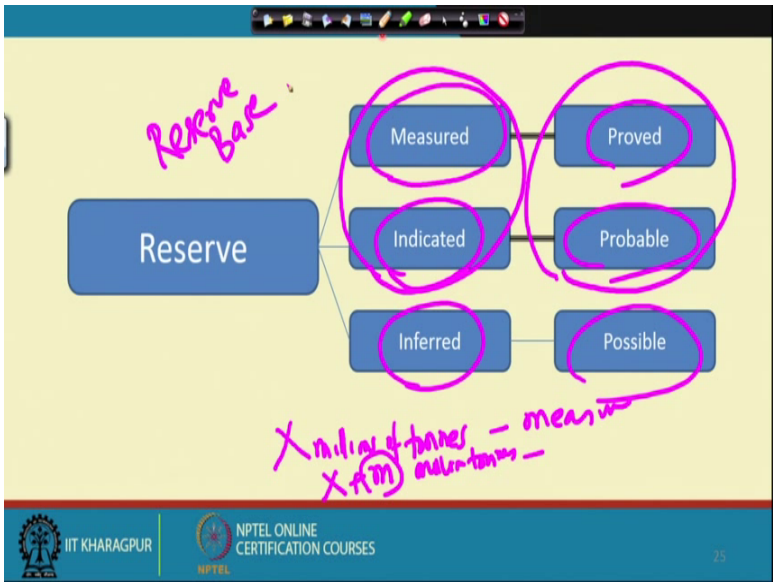

So before we go so then it is it is a important that we do classify these mineral deposits. Before we will go for the classification of the mineral deposits, let us first get our self acquainted with some of the terms which are used in the context of mineral deposit. Whatever quantity that the mineral deposit a body and ore body would be present in the earth's crust, in it is dimension in space length breadth and depth.

So, it will be a quantity which can be measured, directly can be measured, and calculated and we will use a word which is called as reserve for that. That is the reserve of that particular metal that is be in terms of a few billions of tons, or millions of tons, or millions of bounces, or in in case of liquid resources like, fuel oil we express in terms of billions of barrels on running case of gas trillions of cubic feet.

So, that is what exactly the terms reserve is quantity that is to be to be reported. Because whenever we didnt give much of a statistical data about the mineral deposits, but every deposit the figures that one would always look for is what is the reserve of that deposit in terms of if it is a metal or multi metal deposits a deposit of copper. So, it is say that, what is the total amount present in terms of millions of tons. So, that one can make a make a calculation, the tip that particular metal will be produced in certain millions of certain tons or certain thousands of tons per year, then how many years this particular mine is going to last.

So, the reserve we basically categorize is measured indicated and inferred. So, measure is the one means we say that measured is here is this is measured means, the quantity is actually very certain, that we can tell that this much of the metal in the form of the ore is present in the ore body. A little less certain then that will be indicated. Here the degree of confidence will be little less than the, what is to be reported as measure, but it would be quite probable. And the one which is inferred means about, this is just by using our extrapolations or speculation we can say that.

So, for example, while reporting the quantity of any particular mineral deposit, we may say that this x, x millions of tons of is measured, and x plus m million tons. So, this m is actually the come out which will look to be quite probable, based on data which possibly would be would be reliable, but not that very closely spaced or not very certain as we will basically we going to the procedure of reserve estimation will be clear at that time. So, that is the, which would basically be. So, this measured and indicated together could be basically be the one which can be projected as the reserve base.

So, the one which remains is totally speculative, which can only be further proved to increase the reserve of a particular deposit is basically inferred and the equivalent terminology which were used. For a measure we can say it is proved offer a indicated we say probable, and for inferred we can say possible. So, when we take these 2 together, proved and probable or say measured and indicated together. So, this actually constitutes something which is called the reserve base. It is just not only that in terms of the degree of confidence or the degree of certainty about their quantity parameter. There is also something else to it, we will just see.

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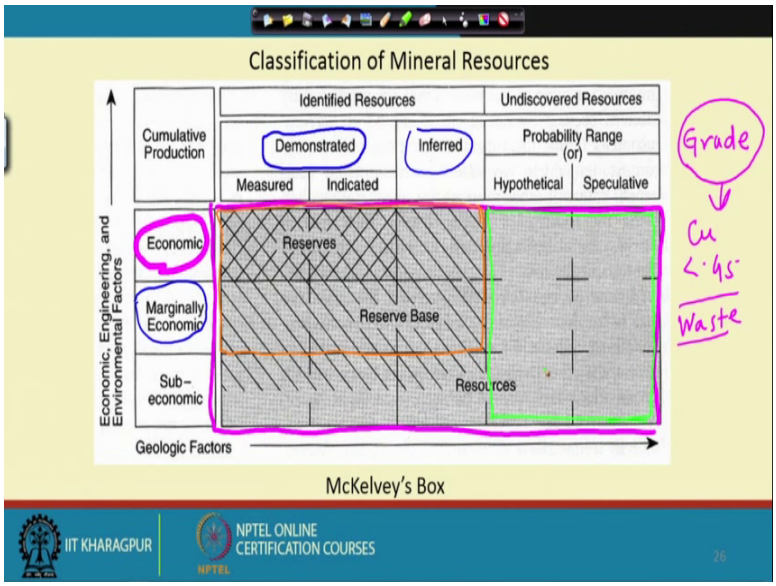

So, this is a classification scheme of mineral resources. This is very popularly known as the McKelveys box. So, as well just discussing about the classification is to reserve and resource. So, this box this grey part total, this gray part total is basically the resource. Out of which we just if we go by the terminology of measured indicated and inferred, the one which is measured and indicated is basically being shown as reserve.

And inferred so, here we have 2 different 2 axis the horizontal axis is indicating geological certainty, and the vertical axis is actually representing the economic viability. So, in the economic viability, we can have economic marginally economic or sub economic. So, economic actually will be coming out from the suitability or for the economic viability in the sense that the material which we are taking out is ore, from that the metal of interest of the metals metal or metals of interest can be extracted at a profit depending on the current technological advancement or the current technology of the extraction is available.

So, it is essentially that is what economic engineering and environmental factors altogether, mixed on one, and within those constraints, whatever material is coming out to be usable, and that will be taken as our ore which will be subjected to processing and for the beneficiation or extraction of the metal, which will be considered as the reserve, measure red and indicated. Now from the measured indicated, even though we might

have we might have calculated the total quantity that is present in a particular ore body, but the entire quantity may not satisfy the quality criteria.

For example so, from there we will further define these terms later. So, what we say as a grade, gray of an ore. And so, this grade of an ore essentially is something which is acceptable in terms of the quality of the ore, which can be amenable to further treatment processes to is requires investment, and also further is extractions processes which is also involves investment. So, the total amount of cost that is invested on getting a unit mass, of the particular mineral or metal should be satisfied and is basically defined by something which is called a grade, and the lower most limit of the grade has to be fixed by us.

For example, if we take a take a take an ore of copper, then if the copper weight the percentage of weight in an ore is less than 0.45. Let us say for example, then that particular material even if it is in ore and you have calculated the total tonnage, but anything any part of the particular ore body where the concentration of that metal falls below 0.45 weight percent, that cannot be considered as an ore, and that will be go that will be discarded as waste.

Now, the situation is that, why this y axis is kept, because the economic engineering and environmental factor, where something is economic and something is marginal economic over here. So, the difference between the economic and marginal economic, might turn out to be a matter of time. Because it might so happen that the technology which was available before, where which was able to extract metal from the particular ore, only when it is grade was above certain particular limit, but later on with the advancement of technology, it may be possible to treat or to process that particular ore with still further lower concentration for it is further processing and extraction.

So, in that under in that condition, what was marginally economic might become economic. So, this boundary is essentially very dynamic. And what is considered as sub economic means the ones which the material or the concentration of the particular metal is so low that possibly in a foreseeable future also it could not be considered as an ore giving a small example the gold deposits that we were talking about in the Indian context.

When they were initially discovered, the concentration of gold was possibly of the order of 10 15 or 20 grams per ton or ppm. Even sometimes when we see the bonanza type of gold deposits where the concentration of gold can go to 30 grams per ton 30 ppm, and initially depending on also the economic factor like the amount of investment that is put for extraction of a unit mass of the particular metal, and the price at which it is sold in the market will definitely decide that.

So, possibly 50 years back a 1 gram or 2 grams of gold per ton of the ore might have been discarded as waste, but at this present time with the increasing price of gold, it might be considered as an ore. This is just an example. So, this is how the these boundary although this is put this becomes this dynamic and this is very transient. But then this gives us a framework in which to classify the mineral resources into different categories.

Now, the other thing to know about in this whole McKelveys diagram is that, the one which is measured and indicated is put under the category as demonstrated, and the one which is inferred is kept separately, because this is the part of the resource about which we do not have a direct evidence, or a direct proof, or we have not physically direct intercepted or sampled the ore.

So, then from this so, here the measure and indicated which is coming out to be reserve, and then when it is again combined with whatever resources which is inferred and up to marginal economic. So, this will be the box which will be the reserve base. So, this will be the reserve base, only up to this. This is a reserved base. Now you could possibly recall when we were plotting about the quantity versus crustal abundance. We were essentially plotting the reserve base versus the crystal abundance.

Because by plotting the reserve we would not get a clear idea. So, we will we will have to take into consideration, the material which are considered to be economic at this particular point of time, and the materials which might which also is likely to become economic in the foreseeable future this also have to be combinedly together considered to give you the idea about what is the total amount available with us. And that is how is the log of reserve base versus log of crustal abundance was plotted on our diagram which were we used in the introductory part of the lecture series.

Now if we look at the full box. So, then we are classifying it broadly into identified resources and undiscovered resources. So, this particular box is entirely unknown for us.

This particular box, and one might wonder that if this is the subset of the resources that we have already discovered, and this the area which is undiscovered. So, as it looks like the proportion that we have maybe having a lot more to discover, but there is no certainty on that.

This is absolutely very schematic because you never know the whether the area that is represented in terms of the undiscovered resources which are hypothetical and speculative; which is basically our probable kind of resource. They may be either very small in their size proportion compared to what has already been discovered or maybe even be very large.

So, this is the part which we are not very sure, and where the entire domain or exploration is based on that. That we maybe in a we may possibly be able to discover a lot more large other deposits, then what we already have or the other school of thought or rather the exactly the opposite view could be that well, we have possibly explode or we have was possibly discovered, whatever we have we could discover, and what whatever we have that is possibly the end of it and we possibly do not have much more to add to that. That could be the other, but somewhere if we could take a stand which is really intermediate between the 2, that we still can explore.

For example as i was telling only 30 percent of the surface of the artists, that is available to us as the continents on which we are able to explore. And we also know that the volume or the area, the total area which you can call them as virgin or has never been seen by human eye is also shrinking or at least nonexistent right at this point of time. So, the only way that we can think, that we will be able to increase the total quantity that is available to us is the hope that we will be adopting some newer and newer technology for our exploration, and exploitation as well; because in the very beginning we when we were discussing about where exactly we get this ore deposit, we said that we are restricted to very adjust about top to 3 kilometers and maximum 5 kilometers from the surface.

We might even think of going for the deep, and might even we have developed technologies to give us the indication of what is lying at depths which are greater than that, and we should be in a position to explore them exploit them or even the other part

of it is that we could also start. Exploring on the ocean floor, and start getting the exploiting those inflow resources. So, these are the ideas that we can have.

So, this is a classification scheme that is known as the McKelveys box. If you see standard textbooks, we can you can see there are lots lot of such diagrams, which are used. So, this is essentially for mineral resources there are many such classification scheme proposed for coal, and other kind of resources which I am not touching not discussing here, this gives us a introductory idea and which is important.

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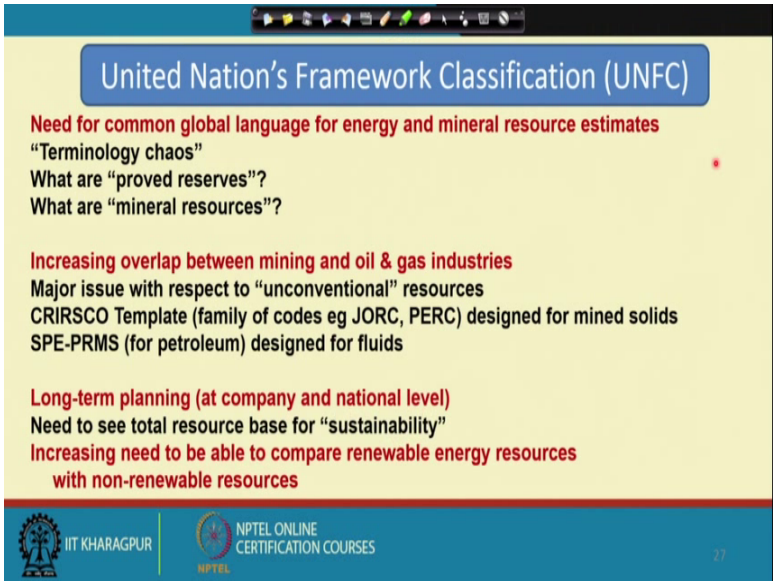

When we were discussing about this categories of the mineral resources in terms of reserve the reserve base, or what basically we can call we can if we take the whole thing of the whole box together, we can call it as a total resource base. And if someone asks then what is the ultimate available resource or a particular metal, you could possibly say that well the average crustal abundance of a particular metal, take the volume of the total crust multiply the density get the total mass of the crust, and then multiply that factor of abundance in terms of 10 to the power of minus 6.

Say for example, take a copper which is 50 ppm, and if you multiply the total mass of the crust and that is possibly the ultimate available resource for the particular metal. And but we all know that we would not be able to get that, we will be getting what actually be the ultimate available resource will be much less than that, which would has to which has to satisfy the quality quantity parameters. The problem with this it is not exactly the

problem, but there are lots of non uniformity in reporting the mineral resources by different countries different parts of the world.

So, that is the reason why the United Nations adopted a framework classification which is very widely known as the UNFC, or the united frame or classification. That arised because of because to have an uniformity in reporting of mineral resources of different countries. And so, there they must have been because some people are reporting in terms of measured indicated and inferred as possible probably. So, prove probable and possible and many other different ways, which can be the resources could be expressed. So, you need we need to have a have a common uniform code of reporting of mineral resources, and united nations framework classification was proposed for that.

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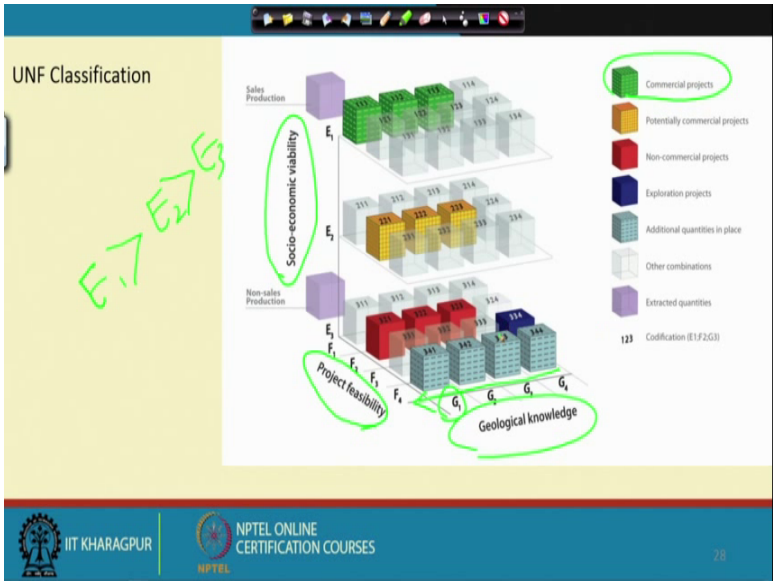

We let us go and let us have a look of what this united nations framework classification is, what we saw in the McKelveys box, what was presented on a 2 dimension with a geological certainty on one axis, and the techno economic parameter economic feasibility on the y axis; of this is a little bit more elaborate and is a little bit more convenient on the on the on the way of expressing the type of resource to which it belongs.

For example we can have a socio economic. So, what is presented here is the first is the socio economic viability. So, this is the axis 1. So, here this is divided into E 1, E 2 and E 3 because any particular mineral resources in order for that particular deposit to be

qualified, as an ore body and the investment to be made on it are exploitation. It must also meet certain socio economic viability, even environmental parameters also included in that; which we will be discussing in the last part of the lecture series about the environmental impact.

And so, what is it what is going to be it is impact on the socio economic because one deposit might turn out to be pretty rich, in terms of it is metal content in terms of project feasibility also it might turn out to be reach, but then it might fall off not been able to meet the criteria of socio economic viability.

So, this socio economic viability is absolutely qualitative is E 1, E 2 and E 3; where E 1 so, in this case E 1 is greater than E 2 is greater than E 3; means the bottom one would be considered is the least viable, and the top one is the most viable. And the y axis is project feasibility.

So, feasibility is actually coming from this consideration that once a deposit is discovered. It is quality quantity parameters are estimated, whether the investment on that particular project would be feasible or not, which will be also considering during the course of lecture, what essentially understood by this project feasibility. One deposit may be reached, may be the quantity may be very high. But it may not still be very feasible on to in to invest on this particular project. Because the demand of the particular metal may not be that very high in the market, and there could be many other possibilities.

And the third is the geological knowledge. The certainty about the geological the existence or the existence of the particular deposit whether how certain we are. So, in most of the thing that we are going to follow is basically is that. So, G 4 is the lowest followed by G 3, then G 2 and G 1 means, if we are if we are labeling some deposit is belonging to G 1 means it is quite certain, that we know it exists. And it is identity is established. It is dimensions in terms of length period of kind width, is also established to a great degree of certainty. Compared to 1, where we could possibly just speculate that a particular deposit might be existing in a particular geological terrain. Because it satisfies certain geological conditions as far as the knowledge our knowledge is concerned. And if you remember we also while discussing the attributes of these mineral deposits we discussed.

That an ore deposit occurrence is essentially is something like a chance in nature because given 2 identical geological setup, one cannot say with any degree of confidence that in one case if a deposit is occurring the other case a deposit is also will occur.

So, we will continue discussing on this before we go to exploration, and the whole objective of exploration is basically to make to go from G 4 to G 1 in this direction. And also make so, look of look for projects which are basically be called in f one means the highest feasible and also economically most viable. So, the blocks which are shown in the color one are essentially the commercial project, which is in operation, where the deposits are being worked out and the metals are being produced.

And the ones which are given in say for example, this one, this 3 4 4 is essentially there is absolutely it is out of I mean there is no known. All is about that this additional quantities in place. These are the exploration projects 3 3 4. So, this nomenclature only results in labeling the deposits in these 3 digits; so 3, 4, 4 to 1, 1, 1. So, 3, 4, 4 which is absolutely the one end of the spectrum, where is 1 1 1 is something which is a commercially most viable and the commercial projects.

So, we will continue discussing on this before you go for the mineral exploration in the next class.

Thank you.