# Mineral Resources: Geology, Exploration, Economics and Environment

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## Lecture – 46
## Mineral Inventory Estimation (Contd.)

Welcome to today's lecture. So, we will be continuing our discussion on the mineral inventory estimation methods, procedures in brief. In the previous lecture we had got ourselves introduced to the very basic ways in which the mineral inventory can be estimated. Before an ore body is made ready to produce ore by the chosen method of mining. And we just had a brief idea about the traditional methods such as the triangular method, polygonal method and the method when the drilling is done on a regular grid and estimation of average grade and the calculation of tonnage from that, which will be supplementing through handouts and worked out examples and exercises which will make the things more clear. In this lecture, we will briefly discuss about the importance of certain aspects.

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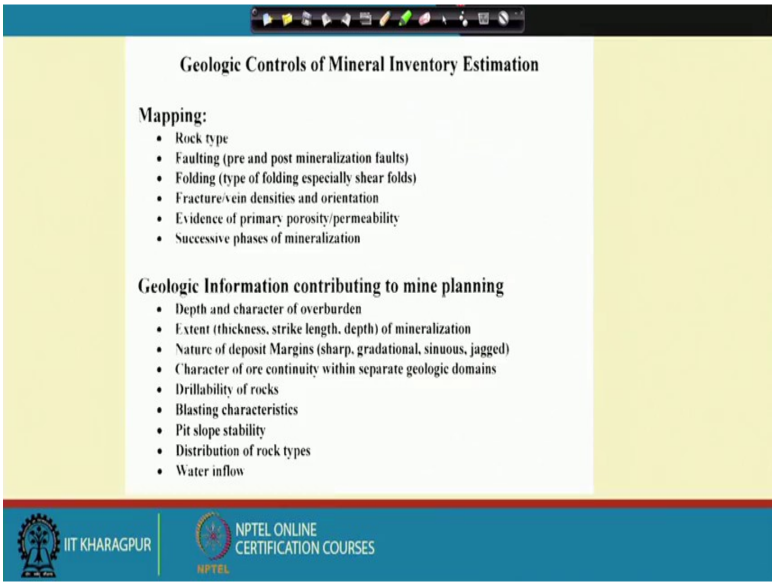


Because, what lies at the very basic background of all this mineral inventory estimation is the geology.

We need to establish the continuity of the ore body, the geologic continuity and the value continuity both to be ascertained. In many of the cases the value continuity and geology continuity might coincide. In some of the cases the ore body is only defined based on the value continuity, where there is no discrete distinguishable ore body as it happens in many of the cases. So, we will just briefly look at the geologic controls of mineral inventory estimation and what are the important points that we must keep in mind. As we have seen in many of the cases it is always that the more number of such ore bodies, their subsurface disposition reconstruction then the reconstruction of the geometry through successive sections, drill core and through loggings are very much essential. The more we see, the more we learnt about them, but what lies at the heart of everything is a systematic and accurate mapping, geologic mapping. So, geologic mapping can be thought of in a few numbers of salient points.

As far as the mapping is concerned when we were discussing about the 4-stage architecture and we saw that the last stage after we delineate the ore body through different geophysical and geo-chemical techniques. It is very essential to understand or to first map the ore body on a mine scale geological map. It generally could be a 1 is to 2000 or even 1 is to 1000 kind of scale on which all the details structural and lithologic characteristics could be recorded very minutely. Rock type is the most important aspect of it because that controls the mineralization sometimes in case of the strata-bound ores, where there is specificity for this particular rock type. And we know that there are certain rock types which are more amenable to interaction with fluids and their alteration zones which are produced and they become markers of the mineralization like we have seen in porphyry deposit.

So, rock type is a very important aspect. It is not only that, but the boundary between the different lithologic units also has to be very systematically and accurately demarcated on a mine scale geological map. Structure, say for example, faulting there could be pre- as well as post mineralization faults. Here the pre-mineralization faults might have actually controlled the mineralization. The post mineralization faults would have disrupted the ore body and would have made the the geometry of the ore body complicated, which needs to be very well understood. And since the mapping is on a surface, understanding the nature of the fault, the quantum magnitude of movement and the displacement etcetera have to be very well understood. And more importantly the pre-mineralization structures and the post mineralization structures have to be very well distinguished. Folding is also has the same implications.

Because we have seen in such cases as the pre-mineralization folding, the crest part or the hinge part of the fold is more in more intensely mineralized compared to the limbs giving rise to saddle reef type of structures which we have seen before. And in case of an existing ore body being  folded we have also seen that there is plastic flowage of the sulphide ore body and there are areas in which there are thickened part of the ore body. And they have to be very clearly understood and their important in the inventory estimation. Fracture densities, fracture in the vein densities and their orientation, similarly it has to be worked out which particular orientation of the veins are more mineralized than the other and the fracture density how it controls the mineralization and the evidence of primary porosity or permeability that would have affected the focusing of the fluid-fluid movement.

So, in that case shear zones are very important and they are also manifest in the deposit scale. And the successive phases of mineralization also are to be ascertained. And the factors which actually contribute to the mine planning are like this. First of all, the depth and character of overburden which we also already have discussed in terms of strip ratio because the oxidized cap or the weathered horizon above the ore body is an important parameter, which has to be estimated and accordingly the development that is required for the ore body to be mined is planned. So, generally these points would more contribute towards surface mining process. Extents, its thickness, strike and length and depth of mineralization which we have seen right from the beginning by indirect methods such as geophysics, electrical resistivity methods and other kind of methods are employed to understand 3-dimensional disposition pattern on the ore body and their thickness.

And we have seen that ultimately it is the drill holes, intersection of the drill holes that only give us the most direct evidence. But at the beginning stages these drill holes are far widely spaced and the nature of information that is obtained through the initial stages are remained tentative. The nature of the deposit margins, this is actually very important because sometimes the ore body has a very sharp boundary with the host rock, sometimes the boundary is very traditional and diffused or sinusoidal or zaged. So, this sometimes is a problem if when we are selecting or we are having the selective mining units, the volume that is being decided as to be the selective mining units. In that case, if the contacts the dimension in relation to that becomes an important aspect which we will be discussing shortly is very much dependent on that actually the contamination of the ore with the waste which causes dilution.

And so, nature of the deposit margin is also very important to be ascertained, character of the ore continuity with separate geologic domains, reliability of the rocks because generally hard crystalline rocks are very difficult to be drilled. But accordingly the proper drilling method has to be chosen and the different types of problems that is encountered in ore derivation and the drill core loss etc. have to be very well worked out. The blasting characteristics because as we all know that to recover the ore to exploit the ore from the ore body we need to disintegrate it blasted so that the ore and the waste are recovered and then transported.

And so, in that case this is very much technical and the exact amount of explosives that would be required to release a particular mass of rock can be well calculated. Pit slope stability, because as we just show through some sketches that a surface mine as it progresses to greater depth, also has to progress laterally so that a particular safe slope is maintained and in many of these situations with the rock type has to be favorable for maintaining such pit slope and special preventive measures are taken for that. Distribution of the rock types and the water inflow is also another important point.

It is not only that it will affect the process of mining, but many of the situations the water itself gets contaminated and which will be seeing in the concluding part of a lecture series about the environmental impact. So, the water inflow characteristics has also to be very well studied.

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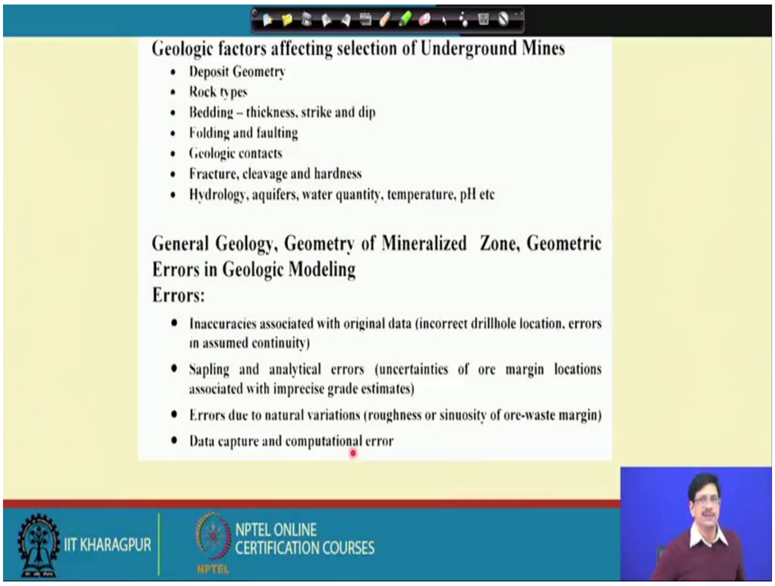


Now if the other geologic factors that would be important for underground mines will be the deposit geometry of the ore, the rock types because these slope and the stability of the rocks are far more important criteria in underground mine. Then in opencast mine bedding thickness, strike and deep folding and faulting they are also equally important. Moreover, when it comes to the underground mining, the faulting has to be very well delineated, the fault zones because they will be creating they will be posing some additional stability problems, geologic contacts. And then hydrology that is the water seepage problem if the mine is deep enough.

Then it will invariably be crossing the water table and it requires special measures for the drainage of the water from the mine and the chemistry of the water also becomes important for the healthy working environment in the mine. And such kinds of problems are more frequently encountered in coal mining, but then metal mining also has such problems. And the sources of errors, mineral inventory estimation, the various methods that we are using they are so prone to errors because every point we could possibly be committing an error in all these points that will be discussed in determining the boundary and the calculation of the or delineating the ore and waste in relation to the selective mining unit. So, inaccuracies associated with the original data if the drill holes are incorrectly spaced or the incorrect assumptions on the inferred continuity, which we will be seeing through some examples now. The sampling and analytical errors, there could be uncertainties of the ore margin locations in an area.

And sometimes there are areas where we call as outliers where very abnormally high value of the grade is present, but that is not a usual feature but, such kind of sampling creates problems for the calculation of the average grade for the global estimates, errors due to natural variations, the roughness and sinuosity of the ore waste margin, data capture and computational errors. So, because most of the work related to ore body geometry determination, estimation of the quality and quantity, they are all very much computerized these days and they are also prone to many of the errors.

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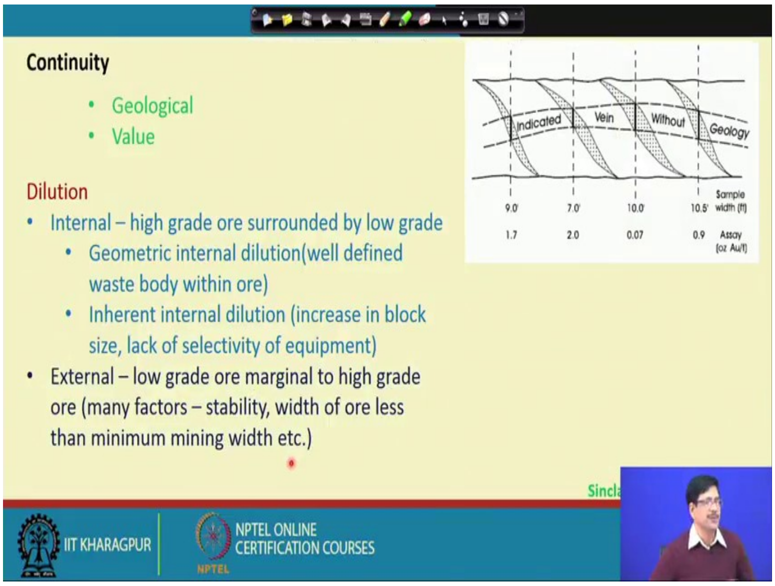


The computer might have some problems in the software or the extrapolation routines and many of the features. While discussing the contouring also we saw that the contouring software may be very aesthetically good in making very smooth contour surfaces but sometimes they do not look into the intricacies of the data.

So, you just have to through the couple of quick examples we can always demonstrate, what actually we mean by this continuity, geological and value continuity. Here is a small example, say what we see here it is a hypothetical case that there are some sigmoidal dilational veins we generally are encountered in many different deposit types. And suppose that, this particular area has been drilled with a drill holes spacing have been shown here.

And each drill hole has encountered a certain width, a certain thickness of the mineralized sigmoidal vein and if there are series of such bore holes which has intersected the ore body for this particular thickness, then it is very usual for any extrapolation either manual or done by any automated method to interpret in terms of a continuous mineralized body in terms of a vein or a sheet. And one can always calculate extrapolated volume and the density and then a tonnage can be calculated, which will be grossly wrong because what will be calculated based on this is a continuous ore body will far more than the amount of ore that is present in such a separated sigmoidal veins. So there are several many such examples which could be cited in many of these situations.

For example, the most cases the residual concentration deposits like a bauxite deposit. Because the process of residual concentration generally starts from the surface and migrates towards the deeper part and there usually very very irregular controlled by the fracture density and the rock composition, and the way fluid has interacted with the rock. So, they result in very irregular geometry of the body and if there has been a very improper or incorrect placement of the drill hole locations then they can always give rise to very highly overestimates of the actual of the metal in terms of the ore that is present there. And there are many such case histories where such kind of initial overestimate of the a tonnage of the mine has resulted in abandoning of the mining project in many parts of the world. And the other situation which is very important here is the dilution. So, dilution is essentially the process in which an ore could be mixed up with a waste.

So, this dilution could be either internal that is high grade ore surrounded by low grade ore, for example we can just draw it here.

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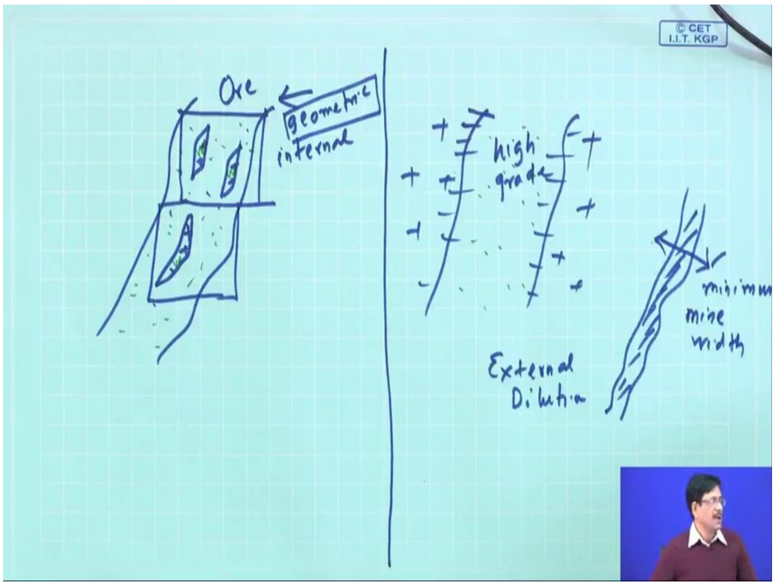


That suppose there is a vein, mineralized vein and this mineralized vein has some caught up fragment of the host rock through which the fluid has channelized and may cause the mineralization by the placement process. So, here these are the domains in which the value of the grade will be so low and they are essentially waste. But if they happen to be in magnitude or the dimension happened to be smaller, then the selective mining units suppose the selective mining unit is like this, then invariably the ore , if this is the ore part and this could have been designated as waste. But because of the selecting mining units, this blocks have to be mined and this has to be labeled as ore.

So, this ore invariably be contaminated by some portion of the waste and there is nothing can that be done about it and that is a case of an internal dilutions. So, this internal dilution could be because of geometric internal dilution. There is well defined waste body within the ore what exactly have said this is actually would be a case of internal dilution. And this geometric dilution and the other type of dilution are inherent internal dilution. Even say for example, any particular mining equipment which is mining the ore body in the blocks, the exact delineation of the ore and waste could not be obeyed by this process of mining and this is also sometimes become very inherent. In this process some amount of ore will always be contaminated or will be picked up and transported as ore to the processing plant. And the external one the low-grade ore marginal to high grade ore for example, if we have an ore body like this This is the country rock. And if the boundary is not that very sharp, if the boundary is diffused then actually it will be this part will be the high grade and there will be a gradual lowering of the grade to the country rock in which there will be a zone of low grade and in which there will be invariably this low grade ore will get mixed up with a high grade during the process of mining. Sometimes also it may be caused because of stability issues for example, the nature of the rock.

And sometimes also it might so happen that if an ore body is being mined in an underground mining where the minimum mine width is this. If this is the minimum mine width, which is more than the width of the ore body then there will be some amount of dilution which cannot be avoided. So, in this case this is an external dilution and these are the cases in which the dilution is geometric or sometimes it is inherent.

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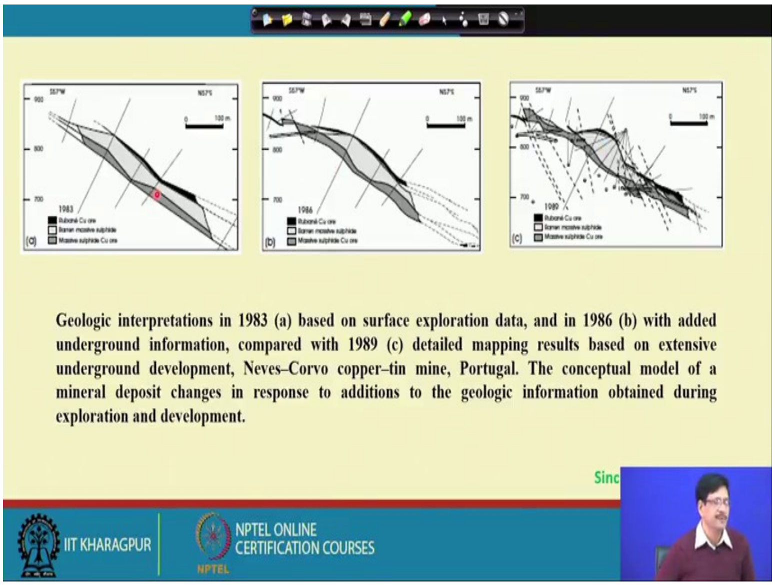


So, here there are some very interesting case has been depicted here, as to how the idea about the geometry of the ore body can change with the progress of the mining, when the mining process is started.

For example, this diagram (a), where there is some limited drill holes which were initially put. And based on this initial drill hole logging and the extrapolations the ore body geometry was worked out to be something like this. And the tonnage the total quantity of the metal has been estimated based on a based on an inferred geometry of the ore body in this way. With the progress of the mining and after the ore body gets got exposed in the mine so then larger number of ore drill holes which were put into the mining for exploratory purpose. It is clearly shown this. This has been taken from the book of Sinclair and Blackwell. Where this scenario is of 1983 this is the scenario of 1986 and this is the scenario of 1989. So, here by this time when the mining work is progressing and the ore body is getting exposed at different levels and is being intersected by closely spaced to drill holes the way it is shown in the figure c.

So, going from a to b to c we could clearly see how the ore body geometry could get refined and in addition to that, the calculated average grade and the calculated total tonnage will also be different from what it was originally estimated. In many such situations like the one which is shown here for the Neves-Corvo copper-tin mine in Portugal. The situation is that the global reserve may change or may not change that may not be of serious consensus, but the local estimation of the reserves in terms of the blocks or in terms of the selective mining unit will change and that is going to affect the scenario and that will affect the process. So, this is just one example.

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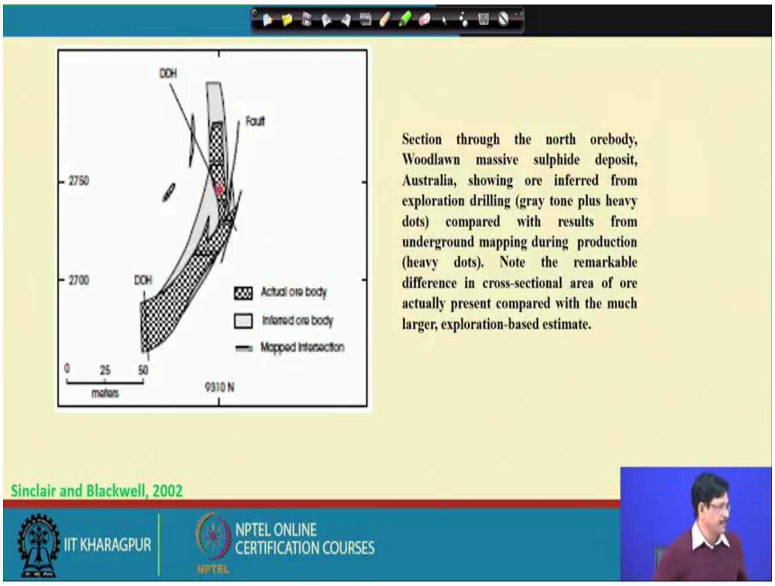


So, this is a second example in which a section has been through the ore body Woodlawn massive sulphide deposit in Australia; is showing the ore inferred from exploratory drilling. So, what was initially shown by the exploratory drilling program is the entire part which is shown as grey has to be the ore body.

So, that is the inferred over body. So, after the progress and after the ore body geometry was later on well walked out; it was found that the actual ore bodies actually containing only a small, less of the volume than it was initially estimated.

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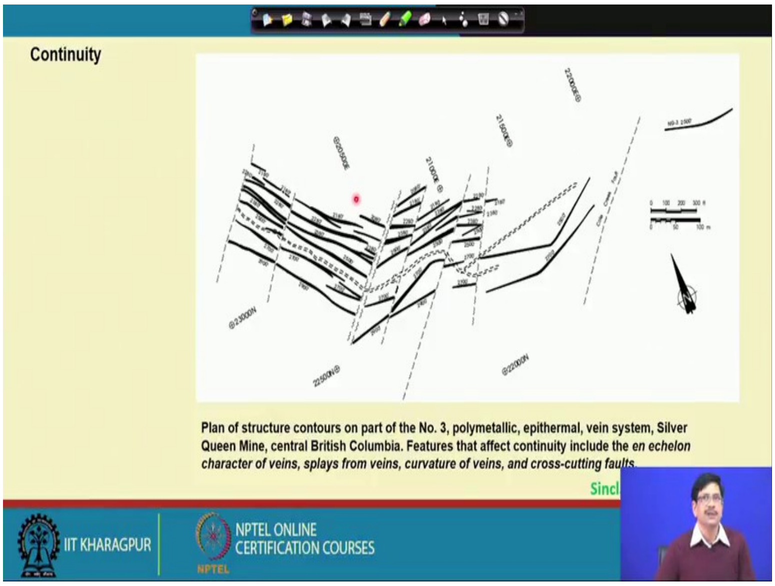


Here is a situation where we could see that what exactly affects the continuity. So, here is a picture from the volumetric epithermal vein system in the silver queen mine in central British Columbia, as has been cited in this book. This is the main mineralized part the number 3 poly-metallic epithermal vein system in that mine and where you could see that these are the locations of the faults; these curve lines representing the faults. And we could see how the fault has disrupted the ore body and even also a change in the strike towards the northeastern part can be seen. And so, the features that are affecting the continuity; in many of the situations for example, in some of the veins, sometimes they form the initial pattern.

So, these kinds of features only tell us that how important it is to work out the subsurface feature and the geologic continuity of the ore body for a proper mineral inventory estimation.

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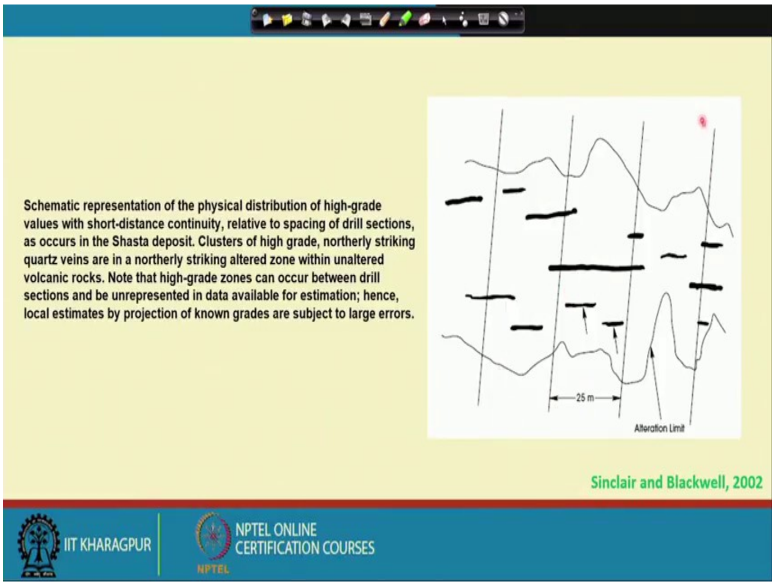


This is been this diagram has been again from the same book. So, this is a representation of the physical distribution of high grade values with short distance continuity, relative to spacing of drill sections as occurs in the Shasta deposit clusters deposits and the clusters of this high grade northerly striking quartz veins. So, this is the situation where we could see this black part or the mineralized veins. And the drill holes are represented in these lines here. This is the boundary between the alteration rock unit and the ore body. And, what is seen here is that such kind of a preliminary drilling work will invariably with the ore body disposition and the nature of mineralization is such; that many of the mineralized lenses will be missed by the initial drilling program or even if on this basis if the extrapolations are done they will be also be wrong and they only can be rectified by later stages of work which involve more of drill holes and like the previous examples.

So, these 3 examples in succession give us an idea as to what exactly is meant by geologic by the continuity of the ore body and how the geology in terms of the nature of mineralization, the presence of structures, pre and post mineralization structures, how they are important in this process, and how they affect the mineral inventory estimation. So, to summarize, here we just had a brief and basic idea about the mineral inventory estimation, which can be learned through some exercise, some worked out examples, which will be posted, which will be discussed in the  materials that will be sending.

Thank you.