Mineral Resources: Geology, Exploration, Economics and Environment

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Lecture - 44
Mineral Exploration (Contd.)

Welcome to today's lecture. We made a brief journey through the principles methodologies of mineral exploration, and have seen a few case studies examples of application of various methods, and we have seen that it actually is combined method data, acquired from the methodologies like geophysical, geochemical and overall the background information on the geology, the rock type structures and all the details about the occurrence of an ore deposit that leads to a successful discovery of the mineral deposit of the ore body.

In this lecture and a few that is going to follow. We are going to discuss something which is very important vital part of the mineral industry, that the mineral deposit or the ore body once it is discovered, through this processes that we have seen, then it is actually subjected to a very rigorous analysis on its feasibility, it is the characteristic of the ore body in terms of its exploitability. And finally, the ore body been red to made ready before it is exploited of the ore body is developed, before the very first unit mass of ore is exploited or is recovered from the ore body by the process of mining by utilization of different mining methods which we have not discussed..

So, this goes by the general concept of mineral inventory estimation, because even if an ore body is discovered, even if its initial stage the quality and quantity that is estimated would remain tentative, and this process goes on, even during the process of production for the exploration, for a proper understanding about the geometry of the ore body, its delineation, all its quality quantity parameter needs to be constantly monitored, during the process of, even if once the exploitation process starts remaining.

So, if we can put it this way that from the four stage architecture, the first three stages that the reconnaissance and the detailed study and the target delineation that have been completed, and also correlating it with the classification of the mineral resource, as far the united nations framework classification, and the geological certainty that from g 1 to g 3 kind of stage that we have come, and before the ore body or the mineral deposit can

be categorised under a g 4. So, it is a lot of rigorous assessment and many studies have to be carried out for doing that.

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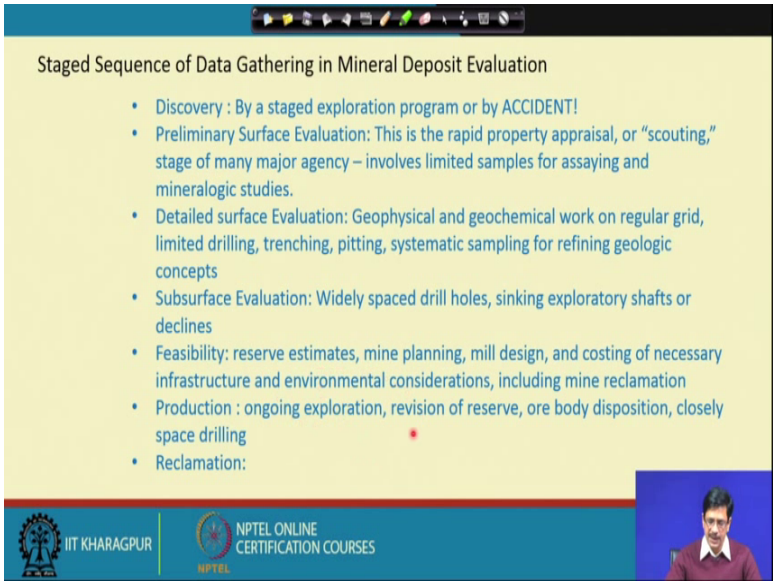

So, it is actually the discovery by a staged exploration program or even sometimes that ore deposit could possibly be discovered as a matter of chance. Although that could have been a systematic exploration program. So, the discovery, and then a preliminary surface evaluation, this is a rapid property appraisal or a scouting stage for many of the major agencies were involved in the mineral industry, and this involves limited samples for assaying and mineralogic studies. So, once the ore body geometry is worked out its existence, its 3 dimensional disposition in the crustal in associating normal crustal rocks is ascertained.

Then the ore body needs to be physically intersected by the process of drilling, and the basic purpose of sinking the drills, drill holes, is to get the samples of the ore body for analysis and what we call an assaying means analysing the ore body in terms of its chemistry, particularly the concentration of the metals of interest. For example, base metal or a precious metal or any of the metal that is of our interest. And in that stage the several mineralogic studies can also be carried out, because initially when we were getting through the introductory sessions of this particular lecture series, we were discussing about the importance of the mineralogical studies, especially the texture of the ore. The mutual inter growth between the ore minerals themselves, because an ore can

have a ore mineral of many different metals. For example, an ore can have minerals of copper, lead and zinc; say for examples chalcopyrite or galena sphalerite and there would be present in a particular texture based on the way they are mutually inter grown..

These textural studies are very important as we also discussed for at this stage, because an ore body even if it might be an ore body which is rich in zinc, but the way the minerals sphalerite might be dispersed in other ore minerals or the silicate minerals. Its liberation and recovery may become difficult, or may involve a lot more of expensive technology for which an ore body might not qualify to be called as to be economically exploitable. This is just a simple example, but there are many such studies which are carried out in terms of what exactly could be the technology that would be employed for recovery of the metal of interest. In that we also were discussing the case of uranium, because it occurs in common rocks like schist, the method, the technology that would be employed for recovery of the uranium metal would be different from the process which will be employed if the ore body is dominantly in a carbonate rock

So, several such studies which cannot be discussing all grade details were carried out, during the process of bringing it from the g 3 to g 4 stage. These are the studies which are essentially required, and then the details of a evaluation the where the geophysical geochemical work on regular grade, unlimited drilling, trenching. These are some of the processes, some of the methods which employed, trenchers are essentially elongated dip cuts which are made on the surface, where the ore body is not either poorly exposed or a exposed with an oxidised cap to get a better idea about its disposition and the trenches..

For example, in the hutti-maski schist belt, where the ore body is present in some 9 discrete gold bearing quartz reefs; one single trench which is cut for about a few kilometres could expose almost the entire geology of the reefs and gave some insight about the mode of occurrence and about the disposition pattern, which could be extrapolated to the deeper part.

Pitting and pitting pits are generally the shallow holes or other, you know kind of pits which are cut out on the surface to remove the overburden and to just get an idea about what the ore body nature could be, systematic sampling for refining geology concepts, and in this stage the drilling is also limited, because drilling is in the very expensive exercise and a limited number of drill holes are sunk..

Then the subsurface evaluation, which is done by widely spaced drill holes sinking exploratory shafts or declines, shafts are essentially the vertical pathway to ore to depart and to reach the ore body. We have not discussed much about the mining method, but we can just have a look at what they are. Declines are low angle passes to the subsurface, sometimes it is also made through if the ore body deep is not very strip.

And then the feasibility, the reserve estimates, the mine planning, mill design means the exact process which will be followed for recovery of the metal and costing of necessary infrastructure and environmental considerations including mine reclamation, they constitute the essential part of the feasibility study towards the, when this process is at its advance stage and then the production begins. So, by the time that the production begins means the ore body, we say that the ore body is developed means whatever initial amount of overburden is removed, and the ore body is starts to be getting exploited, and the ore is marketed, the revenue is earned and in that process..

As i said that the exploration further exploration, for revision of reserve, for more appropriate accurate delineation of the ore body in 3 dimension, and further refinement of the exact quality quantity parameters, they go on along with the mining process for the whole of the mine cycle, mine life cycle, which we say that the mine starts production and then goes to the peak of its production. Products continues producing as far as the estimated lifetime of the ore body, and then the quality declines, it goes towards the closing part of the mine life cycle and that the reclamation process is plan. So, this is the general sequenced study.

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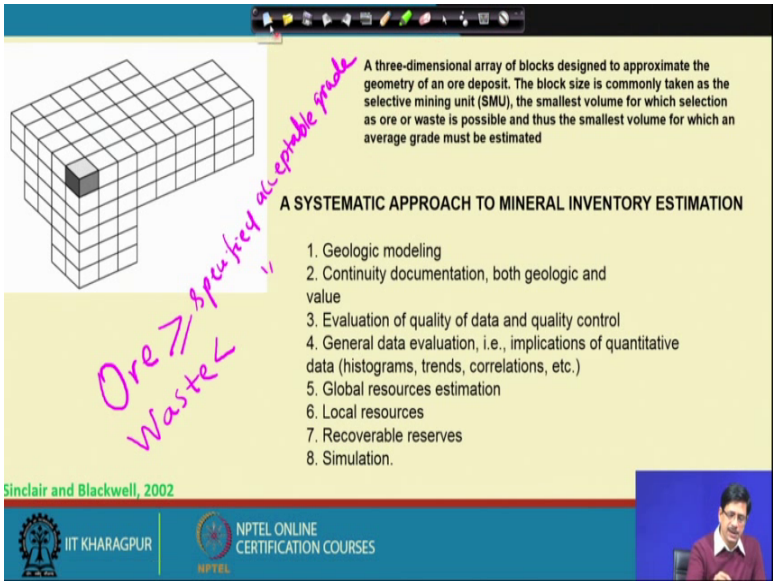

So, whenever we talk about an ore body, that ore body is to be mined and the ore body is in 3 dimension, it can be thought of as a body in 3D, 3 dimensional body. So, in this 3 dimensional body when will be working this body, take out part by part, portion by portion for our economic exploitation. So, it actually what exactly is, done is that when we report, we report something like an average value for the quality of the ore in terms of what we call as grade, representing a grade in terms of a weight percent of the metal represent ore body..

And this ore body within its life cycle of exploitation, is taken up part by part and its more conveniently rather more convenient to imagine that this ore body should be divided or discretized into constituent units, which you can call as the selective mining unit or the SMU.

And this SMU, this exact size of the SMU is very much dependent on the, and will vary from mine to mine or the deposit type to deposit type, but they can be visualised as of the, in terms of some several square metre cubic metre of the mass of the ore, in terms of the mining method that is used for this rotation for its, for the combination of the release of that part of the body by using explosives, the mining method and to be transported to the milling plant, to the plant where the final extraction of the processing of the ore is carried out. So, as a selective mining unit is the smallest volume for which selection of

an ore or waste is possible, and that is the smallest volume for which an average grade must be estimated, if we imagine that this ore body is several cubic kilometre in size..

So, if it is divided into some several square metre, sorry several cubic meter in size and there could be innumerable number such blocks. And as we will be seeing letter, so what we represent the grade. Grade is an average value, but then this grade whatever we connect in terms of the weight percent of the metal of interest; for example, copper, lead, zinc or gold. The grade is very unlikely to be same in every discrete point in the whole mass of the ore body rather the grade varies, which we will be seeing it in a little greater details the ore body vary and that ore bodies grade will vary in different directions..

The grade might vary in with depth, the grade might vary with the along the strike of ore body, the grade might vary across the width of the ore body, and it is very essential to ascertain that quantified that variation pattern, but what essentially is required, is that if we think of a single value which we report as the average grade of the ore, and accordingly we quantify the what is the amount of ore that is available in terms of millions of tons or billions of tons and also the metal by multiplying the grade factor.

And, so this values will vary, then we need to whenever the selective mining unit are being mined out it is very essential that we also know what exactly is the value of the grade that we are, the block that we are mining out, for many technical reasons for the mining operation for the planning and recovery. And the more importantly what we generally would be more interested in knowing, is actually whether it is an ore or waste..

So, if it is an ore means it must be greater than or equal to the value of the grade, specified grade, acceptable grade, specific specified acceptable grade we can say, all our quality quantity parameters, and, so waste would be less than this specified acceptable grade. So, within this ore body, it is very essential to delineate the part which you can call as ore or which you can call as waste.

So, that whenever the mining process is being carried out or the any of the particular unit is being taken out from the ore body, whether it is, it would be transported to the processing plant or it would go to a waste dump. So, all these are essential mine terminology. So, whenever the ore body is mined, what is designated as waste will be disposed in the form of waste term and these are the mine is accordingly designed. And,

so it is the initial exercise would be that to demarcate or the delineate the part of the ore which is ore body, which is ore, satisfying the quality criteria, whether it could be a waste, if its following or it is less than what we call it, and in this process what we the term that is used is essentially is called something called cut-off grade.

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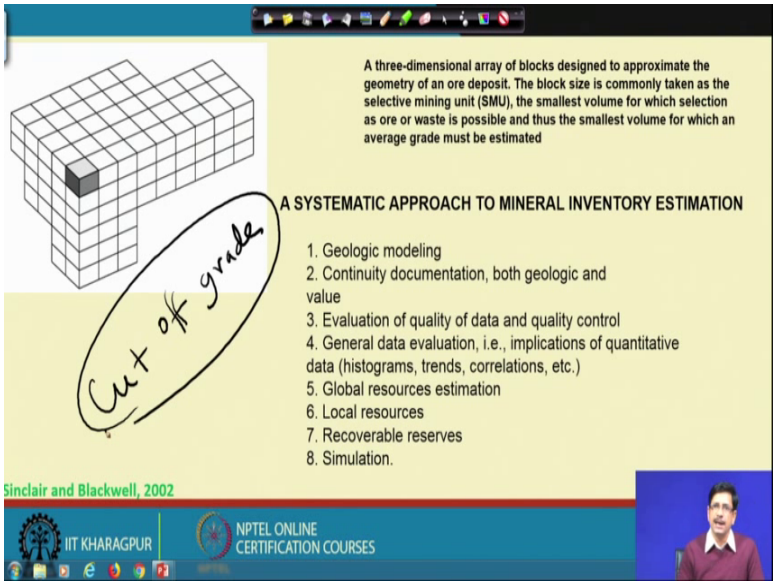

That means, if that particular, the average value for the block, this several cubic metres of material could be, if we define that specific acceptable grade and below and we call that as a cut-off grade, means anything that is less than that will be discarded. So, let us see what it is. So, here if we have a systematic approach to the mineral inventory estimation so, we do geologic modelling.

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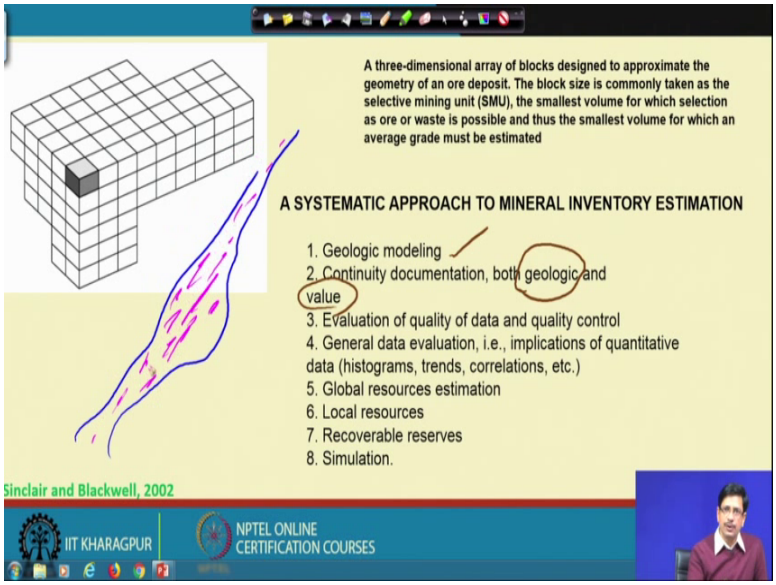

Geologic modelling, then the continuity documentation, because it is very essential that in this what we have designated as an ore body, depending on it may be extending for several hundreds of metres. I mean sometimes some kilometres in its strike length, in its width and its depth dimension going to sometimes even also in kilometres scale. So, the question is whether the ore body is perfectly continuous or its maintaining its continuity, and its continuity is in terms of as both as an distinct geologic entity..

For example, we may say that its quartz vein, which is continuing for a few hundreds of meters, but the is that same quartz vein uniformly mineralised all through its strike length and. So, that is the reason why we think in terms of a continuity as geologic continuity and as economic continuity, value continuity.

So, the same quartz vein so, if its quartz, quartz vein, then it may be that, it is not exactly. So, it may be containing the ore minerals in it and may be that. What is basically meant is that, if we take a, so it is a distinct geologic entity, and its continuity geologic continuity can be defined with respect to the sharp contact that it as with its host rock. Whereas, this continuity also can be thought of in terms of the metal grade that whether the metal grade of a particular metal is also continuing the same value in the direction of the strike of the dip and the width..

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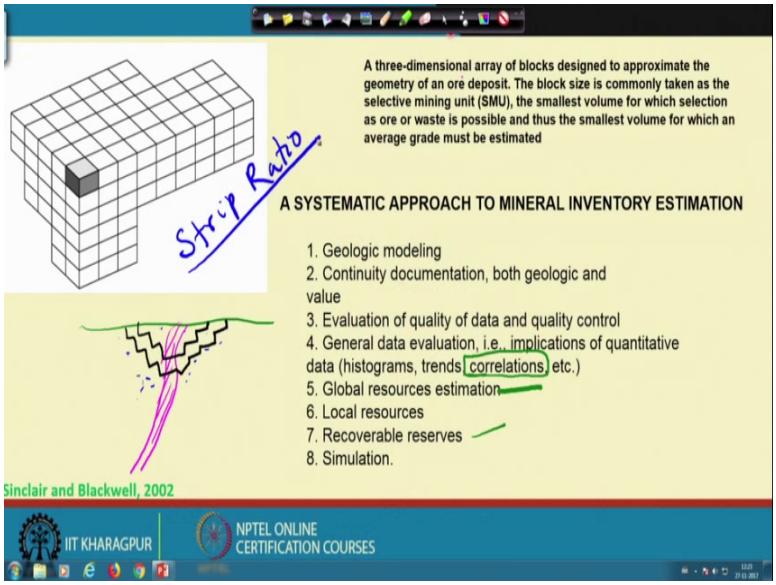

So, these two parameters are also extremely important to be to know, evaluation of the quality of data and the quality control, general data evaluation implications for quantitative data, histogram, trends and correlation which we will not be, because these are simple some exercise sometimes done, if it is a ore body containing more than one metal, then what is their mutual relationship a simple statistical exercise tells that was. The global resources estimation, because what we say that this is the ore body and we are assigning a single value as the grade of the ore body, then on that waste what we estimate is basically the global resource.

And then where we divide the ore body into different selective mining units, then and then we can always discretise that ore body in terms of the reserves in different blocks and a more importantly what is the recoverable reserve. Sometimes the recoverable reserve may not be the same as what we have in terms of the quantity that is present. For example in an ore body which is exposed to the surface or is very near to the surface and this quality quantity parameter might be such that it will be favourable for mining by a open pit mining situation which could be something like this..

If this is an ore body and it is exposed, so either this could be taken out through, by taking out like it is basically essentially is an open pit which will go on increasing in its lateral extent, it will go on increasing in its lateral extent go deeper and also would spread laterally.

And in this process if the material which will be removed and assuming that what all is actually in the surrounding of the ore body is the waste, is the waste material, waste here. So, as we go deeper, the amount of material to be removed per unit mass of the ore to be exploited, which is essentially is known as the strip ratio, is an important parameter.

When mass of waste or ore that is to be removed to get a unit mass of the ore, we can call it as a strip ratio. And here the situation permits that if we, depending on the quality and quantity of this ore body, it may permit that we could do it by an open pit method, and where the recovery of the ore is almost nearly 100 percent, because the ore body could be removed entirely, but if the situation is such that we have an ore body.

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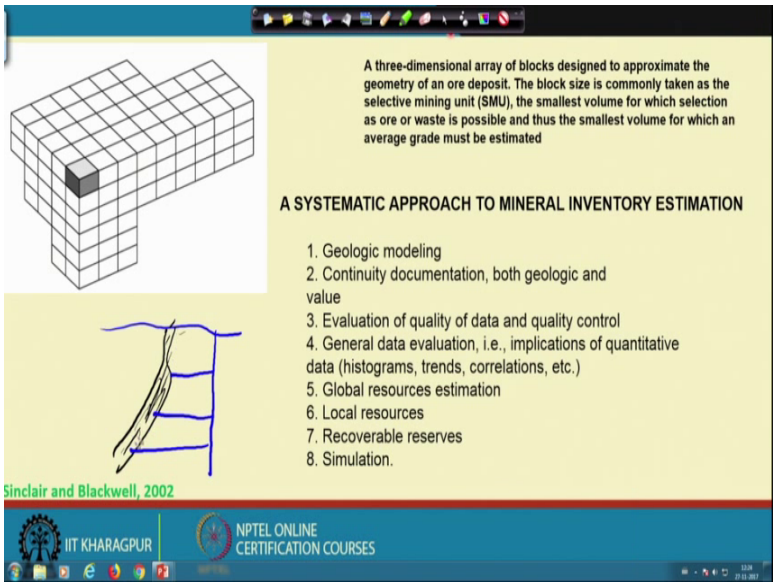

And depending on the quality and quantity parameter, the strip ratio, the mining method by which will be employing, it would be more feasible to go underground; like what we think here is a vertical shaft, and take the ore out by intersecting it perpendicularly, and then using a method which will be underground method, and by which possibly the it would be feasible, because in the underground method the recovery will be always less than what it is in case of a surface mining or a opencast mining or open pit mine.

So, in that case, the quality quantity parameter of this ore body, because underground mine is definitely more capital intensity, more expensive and, so the quality quantity

parameter for this ore body would be feasible for a adopting a method by which it could be mined by an underground method.

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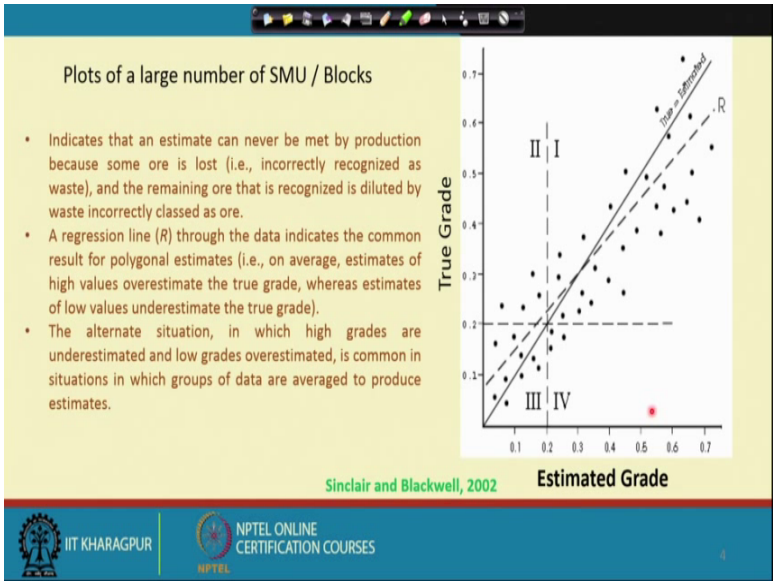

So, just coming to the situation of our dividing the entire ore body into discrete units called the selective mining units. So, the selective mining units each have to be estimated with their with the grade in terms of the metal content, and this diagram on this side is a plot of something which you can say that the estimated grade that we measure, calculate by using some cut calculation procedure, and what could be the true grade of that particular unit, because we are taking in average and this black dot here, are representing the in many number of such kind of selective mining unit blocks whose average grade has been determined.

Now, the lines here, the solid line here is actually the situation which is ideal that the true grade and the estimator grade are exactly the same and we are on this line, which is a correlation line which is 45 degree line 1 is to 1, where it could be the most ideal situation, but we could see that this line, this plots is the points are plotting in a good amount of a band of scatter, where there are four possibilities and the point that the intersection of this two dash lines. The two dash lines are representing something which we call as a cut-off grade. Means the grade below which the material can be labelled as waste.

So, if we divide this entire plot to 4 quadrants; 1 2 and 3 and 4. So, this quadrant indicates that the average grade, the estimated grade and the two grade are nearly the same, or there is been a more or less is relationship which is meant. So; that means, it is a correct classification of an ore as an ore, where the value is above the cut-off grade. Whereas there will be a situation where the quadrant 4, where its actually is an waste, but it is wrongly classified as an ore, because its it wrongly estimated to be greater than the cut off value, where its two grade is actually less than the cut off value.

The area 3 is, we can correct situation where the waste is represented as waste, and in 2 where the waste is actually represented as; sorry the ore has been misclassified as waste. So, this situation is very common in any mining practice, and this the this indicates that an estimate can never be met by production, because some ore is lost incorrectly recognised as waste, and because the mining practice is such the way the selective mining units are release from the main ore body and are transported during that process there is every possibilities its rather is a rule rather than exception that some ores will be classified as waste and will be discarded, and some waste will be included as ore and will be taken to the plant and this kind of (Refer Time: 28:40) common.

So, the regression line through the data indicates the common result for polygonal estimates that is either an average or estimates of high values overestimates a true grade; whereas, estimates of low values underestimates the true grade. Then the alternate situation in which high grades are underestimated, the high grades are underestimated and low grades are overestimated is common, in situation in which the groups of data are averaged to produce the estimates. So, in this context there is one parameter which is important for us.

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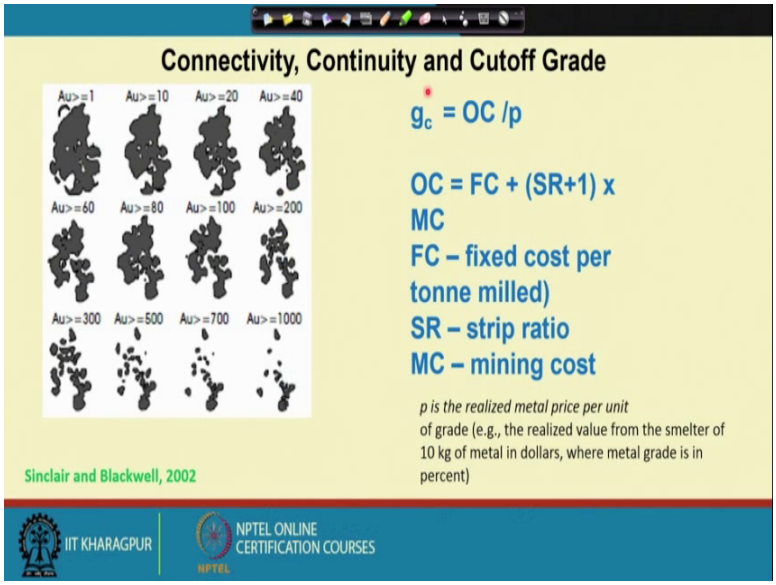

So, we are talking about this. So, we have already spelt this term out let us call the cut-off grade, cut-off grade is the g c, g c is represented as cut-off grade, and this cut-off grade is definitely it is a lot more of elaborate explanation, but we can just see briefly what exactly it is. So, it is a parameter OC divided by p, where this OC is basically is an operating cost. So, the operating cost is equal to the factor cost plus this, the strip ratio plus 1 into the mining cost MC is mining cost..

So, now the factor cost is all include shape of the capital of the equipment and all the initial expenditures that is being made for the development of the mine, and this strip ratio we have already define strip ratio plus 1 into the mining cost. So, the mining cost will be the operational, the cost that is used including all the other cost and factor costs and this FC is the fixed cost per tonne milled, SR is the strip ratio and the p is the realized metal price per unit of grade.

So, since this is the p price unit is as for the reviling price of that particular metal. So, then the cut-off grade, whenever we are we are going to mine any particular ore body, the cut-off grade could calculated using this formula, and so that is the value which we just saw in the previous plot that can be used for classifying the material to ore and waste, and there are many situations in which misclassification takes place, because of some inherent factors which will be discussing in the next class.

Thank you.