Mine Automation and Data Analytics

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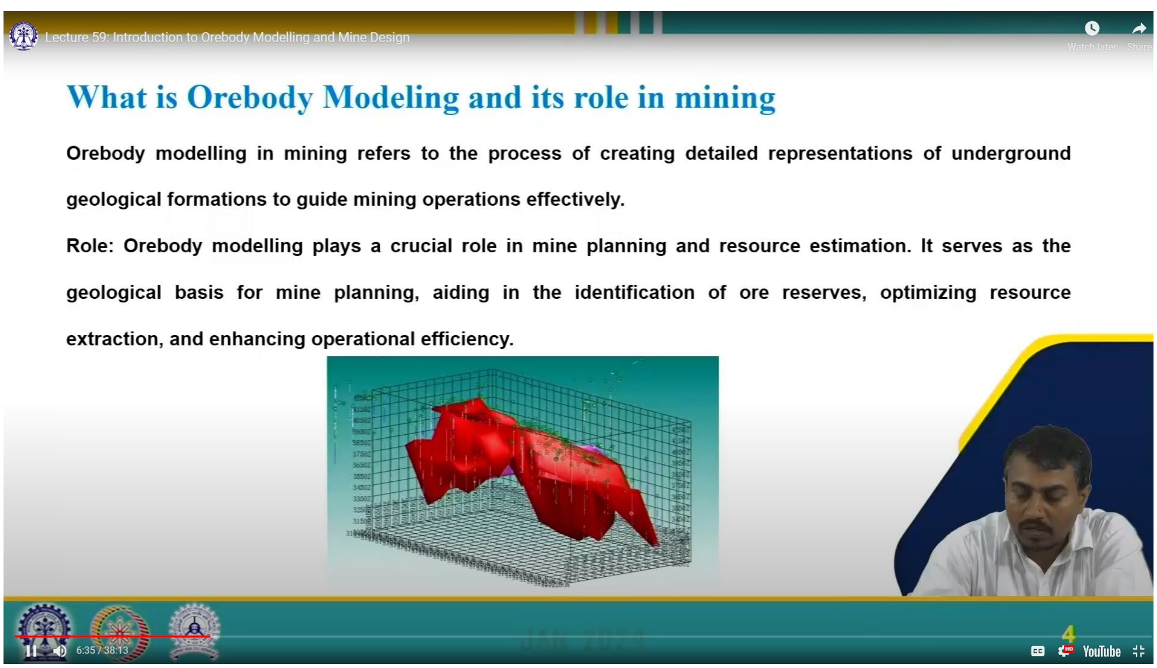
Week-12

Lecture-59

Introduction to Orebody Modeling and Mine Design

Welcome back to my course on automation and data analytics. Today we will discuss a topic that is very important for the mining engineer to start the mining, and that is orebody modeling and mine design. We all know that mining engineering is all about the extraction of minerals from the earth, below the earth crust. So, the first thing that the mining engineer needs to understand is how much ore is present beneath the earth or below ground, what the quality of the mineral is, the ore grade, and at what depth these ore bodies are basically situated or located. So, these are very essential information that is required for the mining engineer to start the mine, accordingly start the mine design, and based on that, start the actual mining process. So, today we will discuss this particular aspect of how to delineate the ore body and how this ore body modeling is helping in the mine design process because in this course we have discussed different aspects of mine automation and data analytics. So, in this part of the mining, the ore grade estimation, ore grade, ore body modeling is the starting point of the mining. So, the statistics that we have learned in this particular course will be useful to delineate, measure, and quantify the amount of ore present below ground. So, let us go into the depths of this particular interesting subject that is basically interesting for the mining engineers, geologists, geophysicists, and associated engineers who are basically associated with the mining engineering industry.

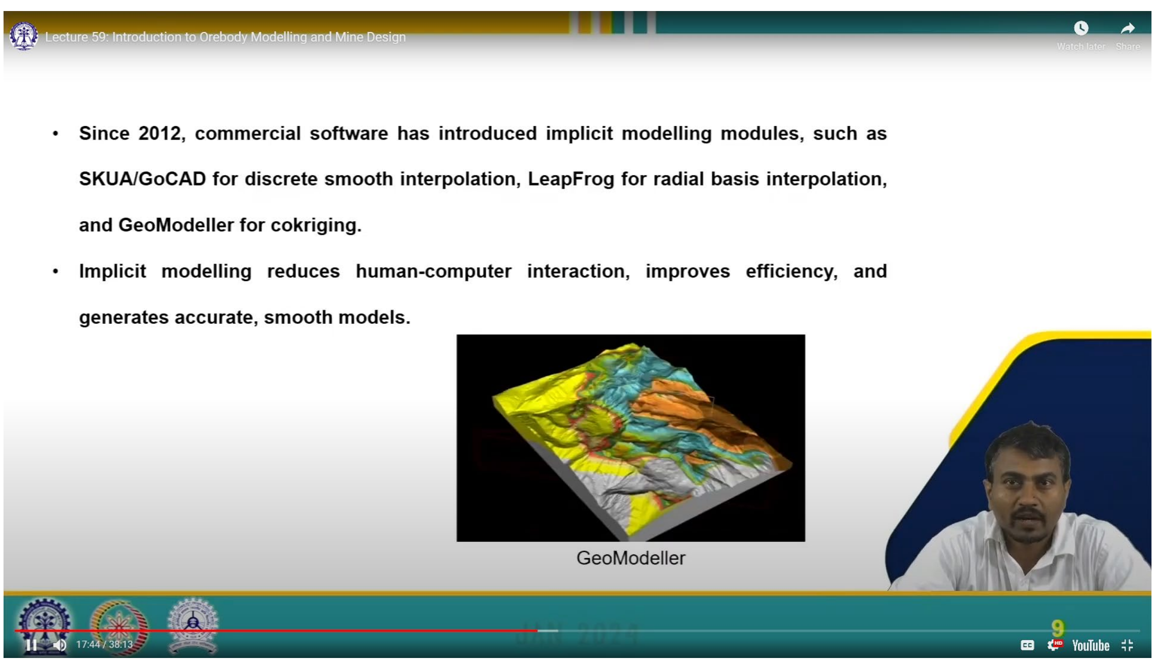
So, let us start that. So, in today's lesson, we will cover ore body modeling and its role in mining, then what is ore body modeling, and then the updating method for the solid model. We know that we are basically collecting the ore grade or information about the ore from different prospecting methods, exploration methods, or borehole methods. So, those are the point information, and those point information is from different levels. So, that will not be very useful to the engineers to understand what the specific location is and what the continuity of the ore body is below the ground. So, we need to reconstruct a solid model. So this solid model will help us to visualize and understand the shape of the ore body, the size of the ore body, the extent of the ore body, its length and breadth, its inclination. We need to understand that, so for that the solid model will help us. So, we will basically discuss these aspects with two case studies, case study 1 and case study 2. Then we will discuss the limitations of the ore body modeling because we need to understand that we are dealing with some big, unknown things below the ground. Only we have the scope to know something about the ore body based on the borehole data, exploratory data, and that too we have some limit that may be 50-meter interval or 100-meter interval we can do the borehole and get the information. But what about the middle? What about the remaining part of the spatial location? So, we need to assume something. We have to start the modeling, assuming something. So, we have a lot of limitations. So, what are the limitations that we will discuss here? Then the advantages: definitely, this kind of modeling is going to help in a big way for the mining engineers in the mining industry as well as make mining more successful and business-friendly.



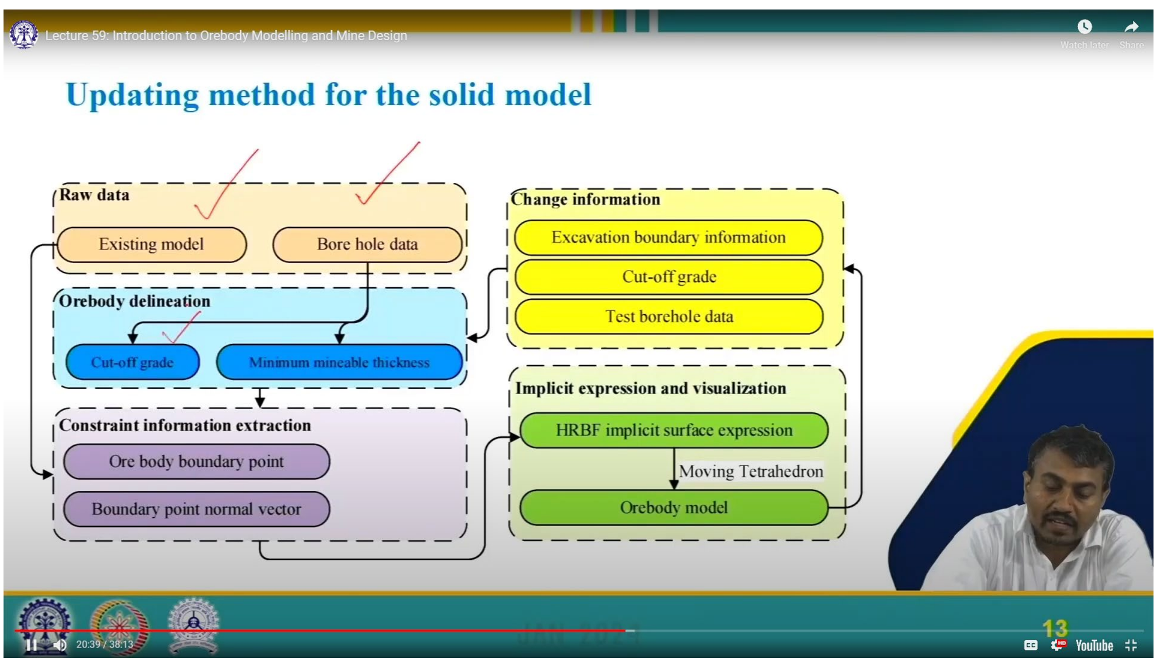
So what is ore body modeling and its role in mining? So, if you look into this figure, this particular figure represents a kind of interpolation based on some data points and its spatial extent in 3D, the presence of the ore, and with the contour, it basically represents that the ore body is continuously occurring. So, what is ore body modeling? So, this ore body modeling is a very important part of mining. Without knowing the details, without knowing the quantity and quality, size and shape, and location depth, mining engineers cannot start the mining. So, ore body modeling is the primary part of the whole mining engineering aspect. So, creating a detailed representation of the ore body and its geological formation, its extent, and its continuity is very important for us. So, this ore body modeling is an integral part of mine planning and design. So, mining engineers often use the surpac, the most popular software surpac, and there are many more programs mining engineers use for mine planning and design. So, the software's primary input is about the ore body, about the ore grade, its location, its spatial extent, its shape, and its size. So, to go further in that direction, it is very important to understand the body. So, here lies the importance of ore body modeling. So based on that, we can understand and target how much ore is going to be excavated from this particular mine site, at what level of extent or depth, how much in total we are going to remove from the ore body, and how much profit we will extract out of this mining based on the associated costs. So, it is a very important part to understand the feasibility of the mining itself because, when we are doing mining, there is a lot of investment. So, whether this investment will be returned by the amount of ore we are going to get or the amount of ore we are going to extract from this underground wealth. So, this is a very important part. Here lies the importance and the key to the mining process, which is ore body modeling.

So the ore body modeling has three distinct components. First is the physical geometry, We need to understand precisely where the ore body is situated without knowing that you cannot design the mine. You cannot design where to put the shaft, where to put the incline, or whether we can extract this mineral using some open-pit methods or an underground method. So, for that, physical geometry is the primary part, okay, of the geological unit that hosts the ore body. The second part is the attribute characterization in terms of the assay and the geo-mechanical properties of all material to be mined. So, this assay is basically about the quality of the ore. So, for example, there is some representation that you are going to get 1 kg of ore after excavating 1 ton of material. So, 1 kg divided by 1 ton is basically what this represents. So, this is the amount of ore you are going to get, okay? Or in a material that, after some processing, you are going to get this percentage or this amount of gram of ore out of this ton. So, these are very important because in the international market, what is the price of the mineral, and based on that, after 10 years of mining and 15 years of mining, you are going to invest a lot of money, whether this will be returned in 10–15 years and with a good amount of margin of profit? So, understanding that, assessing that, definitely assessing that based on that, there are different financial issues that are related. So, here the attribute characterization is important. The third is the value model in terms of the economic mining of the deposit. That is why I told you that the economic aspect is very important, and for the economic aspect to make sure this much return will come. So, all this is equally important and contributes to the value chain of the mining process. So, our aim in relation to the ore body is to replicate the reality of the ore body as closely as possible using the available information. So, for example, this is the surface, and we found this kind of data—pointed data about the borehole, for example. So using the geostatistical method, some interpolation method, and some kriging method, we have to extrapolate the possible extent of this ore body in the underground. So, that based on that, we can design which part of this side the side will be, or from this side there will be some incline to start the mining, or we can start by boxcut. So, in reality, it relates to the geological surface and ore body shape as well as the physical distribution of the geochemical and qualitative parameters. So, we need to understand that in terms of that. So, for that, we need to do the ore body modeling, and here we have to understand one important thing: this ore body was created a million years ago, and there is a huge amount of process that goes through before that mineral is formed. So, there is some randomness, and there are some things that we do not know very well. We have to understand that we have to apply some science, some logic, some correlation, and some association rules, and based on that, we are going to define the ore body. So, it is a very complex process. It is a combination of different scientific science branches as well as engineering and the advances of 3D modeling so that we can realize and put forth the real ore body shape, which might be the same as reality or that there might be some level of error. So, based on some level of accuracy, we have to go through this process.

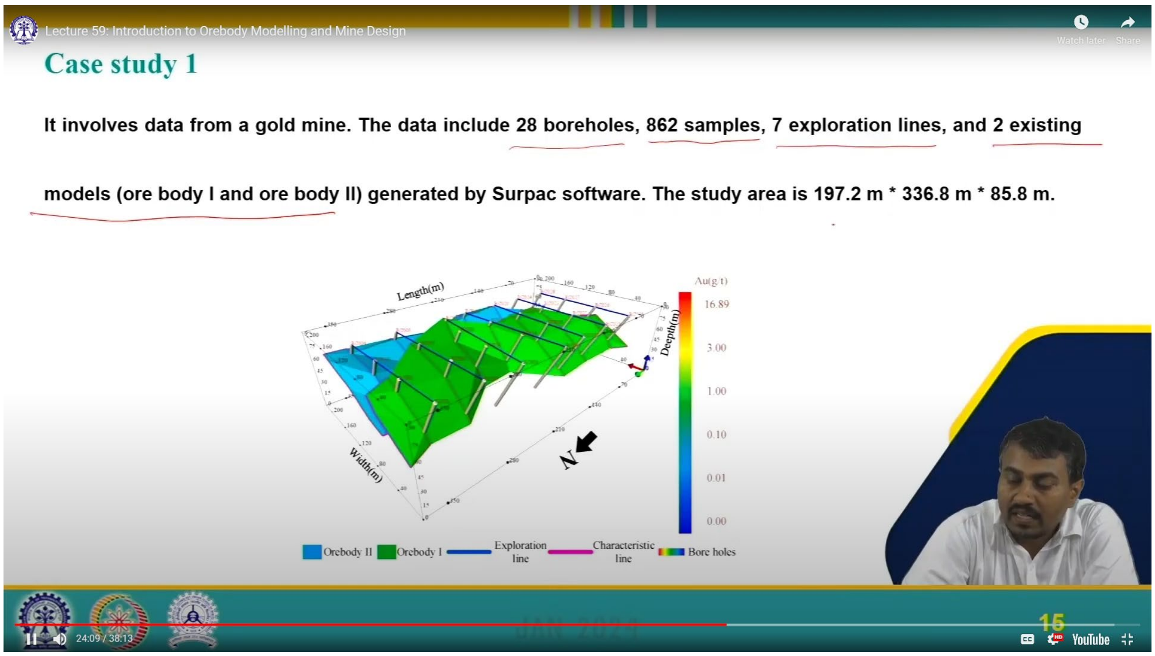
So what is ore body modeling? So, it is basically three-dimensional ore body shape that we are going to reconstruct using the data in the spatial geometry and its attributes, like the lithological data, the borehole data, the sampling data, the lab data, and the core we have collected from the boreholes. So, it involves bringing all the information together in one place and finally from the ore body in 3D shape. So, this 3D model provides us with a more intuitive representation compared to traditional geological maps and profiles, offering better spatial scalability. So, in terms of the plan or section rather than that, if I get a very good picture visualization of the 3D ore body and a spatial location is known, x, y, and z are known; x is easting, y is northing, and z is the elevation. So, in terms of that, it is very useful for the engineers to visualize to understand what is actually there. So the 3D model of the ore body is playing a very important role in mineral resource exploration, development, and evaluation. So, the profile connection method is the classic approach in 3D ore body modeling utilized in popular mining software like Data Mine, Surpac, Mine Site, Minesight, Micromine, and 3Dmine, and however, these involve a lot of manual interaction that you have to model, you have to assume, you have to go through, and we have to plot, then we have to reconstruct like that.



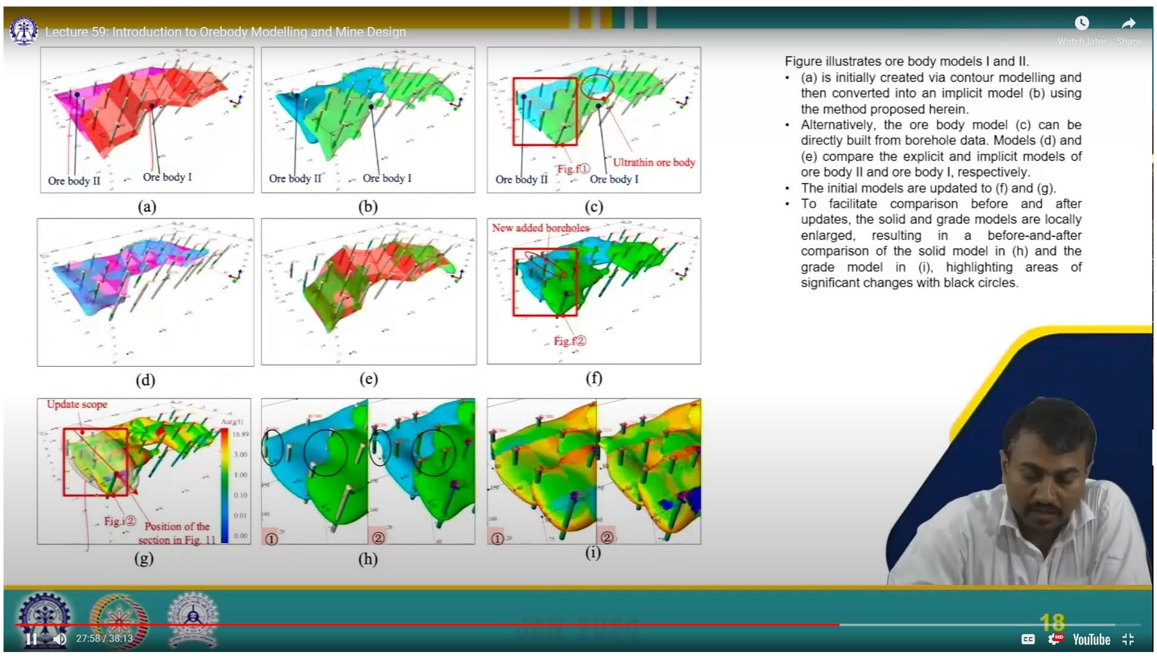
So, to overcome this, SKUA/GOCAD implicit modeling modules are developed that basically give a very good interpolation of the geological deposits and their shape, continuity, and spatial extent. So, these are available, and people are using them, particularly the GOCAD, which is basically developed for petroleum engineers, and the SKUA which are used by mining engineers. Leapfrog for the radial basis interpolation and geomodel are also used for cokrigging. So implicit modeling reduces human-computer interaction, improves efficiency, and generates accurate and smooth models using the advancement of scientific methods. So, this is the geomodeler picture, the representation in the topography. So, the existing ore body modeling software mainly focuses on the geological modeling using borehole data during the mine exploration. However, due to resource exploitation and continuous changes in ore body shape and attributes, the geological modeling data needs regular updates. So, the mine production process follows the principle of gradual change, necessitating continual updating of the models with incremental data because the mine is progressing and you have more knowledge about the ore grade. You update on the earlier version so that you have a better visualization and better confidence in the quality of the ore, the quantity of the ore, and its exact locations, and that really helps to proceed safely with the mining process and accordingly plan the mining process. So, the existing method and software package have limitations in updating geological or ore body models, highlighting the need for a better method. The three main updating methods for the geological models are: the first is model reconstruction, the second is macro script, and the third is a combination of the software programs. So, the model reconstruction method involves conventional or implicit modeling based on various interpolation techniques, but they are computationally intensive and very time-consuming. So, the macro script can automatically update models based on saved stratum connection relationships, but they may encounter issues with the new data. Combination of the software programs can update models effectively, but it requires mastery of multiple software programs and involves time-consuming human interactions. Updating method for the solid model, so here is the solid model. We have the raw data from the existing model, and now we have the borehole data. Based on the borehole data, we are getting some information about the cut-off grade and minimum mineable thickness based on what? Based on the excavation boundary information, mine is advancing, and we are getting more and more new information about the ore body, about its structure, about its shape, and about its quality. So based on that cut-off grade and the test borehole data we are using and that feeding on the software, we are creating a new ore body, and that makes it possible to delineate the ore body more precisely and accurately compared to the earlier one. Based on that, now we are going to define the ore body boundary point and the boundary point normal vector. So, these are the constraints for information extraction about the ore body. Based on that, we are going to the implicit expression and the visualization. So, here we are using the hermite radial basis function implicit surface expression. This is a very popular method used by geologists and mining engineers for ore body modeling, and because of the advancement of scientific methods, mathematics, and computational facilities, these methods are giving a better and better representation and visualization of the ore body, and they are integrated with the mine planning software as well. So, moving with the tetrahedron model, now we are getting the new ore body shape and size and its quality. So, this process goes on continuously throughout my life. So, this is the process of how ore body modeling is continuously helping, connecting, and reconstructing the mining method design and going ahead with the mining process.



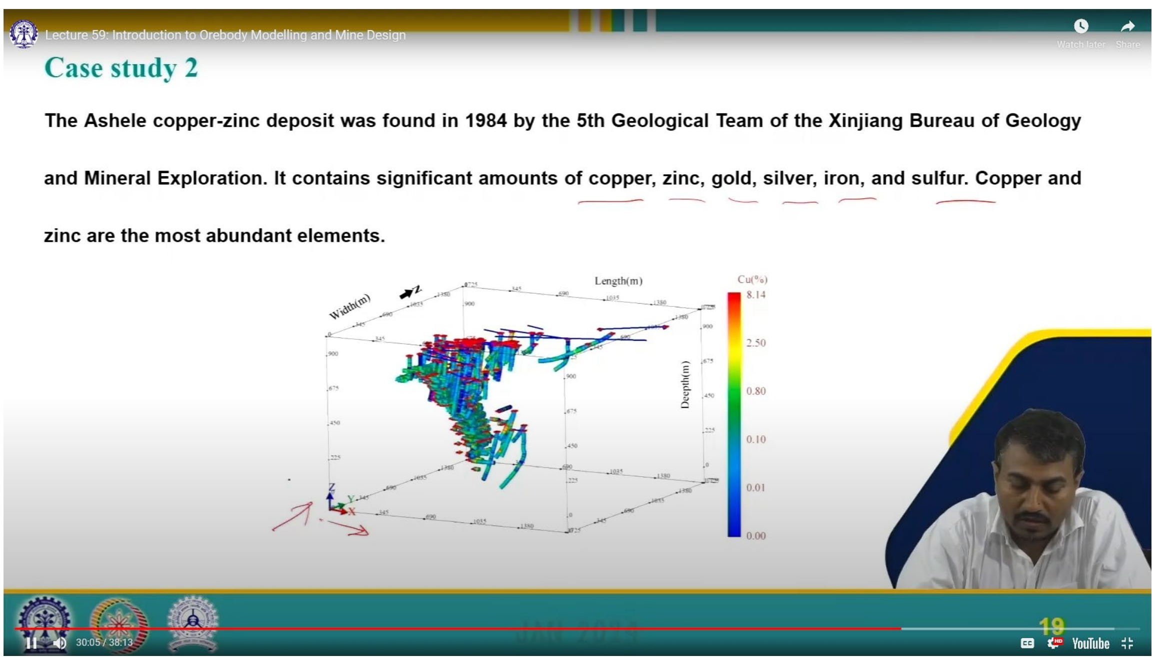
So, step number one is the ore body delineation according to the cut-off grade, and the minimum mineable thickness of the ore body boundary is determined. Step number two is the extraction of ore body boundary control information. The ore body boundary control information includes the coordinates and normal vectors of the boundary points. Step number three is the implicit surface calculation by taking the coordinates of all ore body boundary points and their corresponding normal vectors calculated in step number two, as shown earlier. The equation can be established to solve the undermined coefficient in the implicit surface equations.



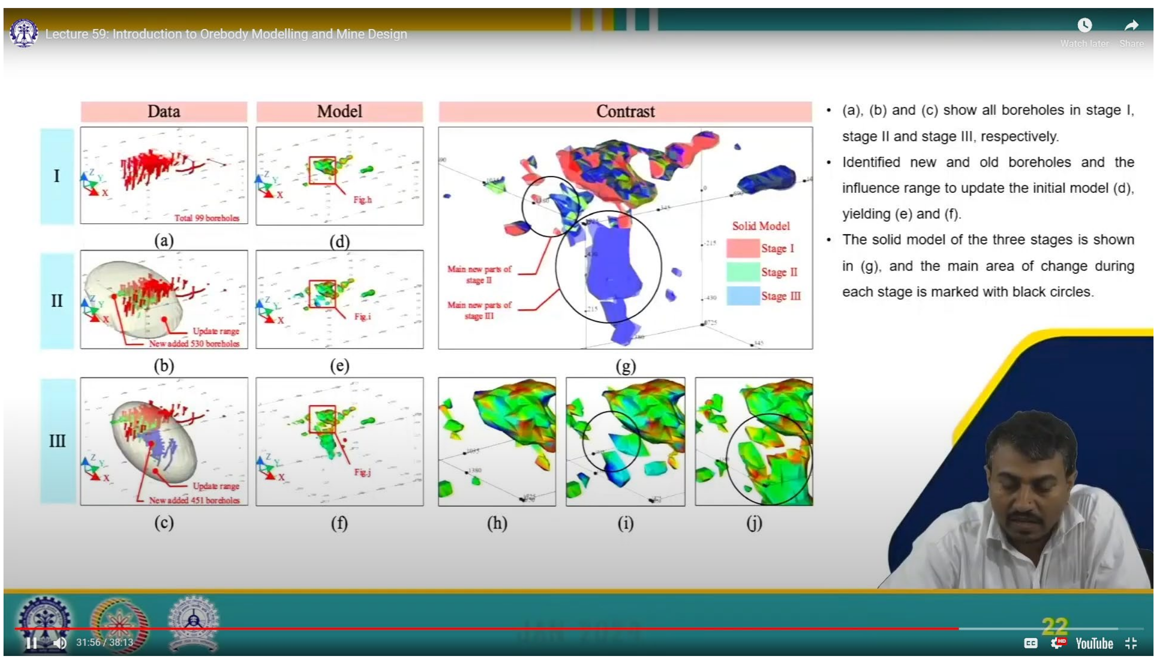
So let us discuss one case study. So, this case study is about the gold mine, and we have 28 borehole data from 862 samples, 7 exploration lines, and 2 existing models, ore bodies 1 and 2, generated by the software surpac and the study area is not very big; it is 197. 2 into 336. 8 into 85. 8 meter extent. So, it is not a very big deposit. So, now here you can see this is the ore body 1, and this is the ore body 2. Now we will show you in the subsequent slides that based on these are the boreholes, and one borehole lithology is shown here, the percentage of the gold in terms of gram per ton excavation. So, this is the northing, this is the y, and this is the width; this is the easting, and this is the z elevation. Now, if new boreholes are done and we are getting new information about the ore body, some information is already extrapolated based on some ISO contour maps or some kind of interpolation method. So new information is basically giving a new picture and new data. So, that data to be updated, that data to be updated, and subsequently how this data update is done and how the mine progresses, that is what I am going to show you today. So, the model update, so the initial model, they create the model of the ore body using different methods, including the including the profile connection method and directly from the borehole data then the comparison. Here we compare the models and find that while they match at drilling points, there are significant differences in area between the boreholes. So, the contour modeling method respects borehole data better, resulting in thinner ore body models. So their method is based on recent borehole thickness but may miss extremely thin areas, reducing model volume. So, also, their method considers a curved surface transition between boreholes, potentially increasing model volume.



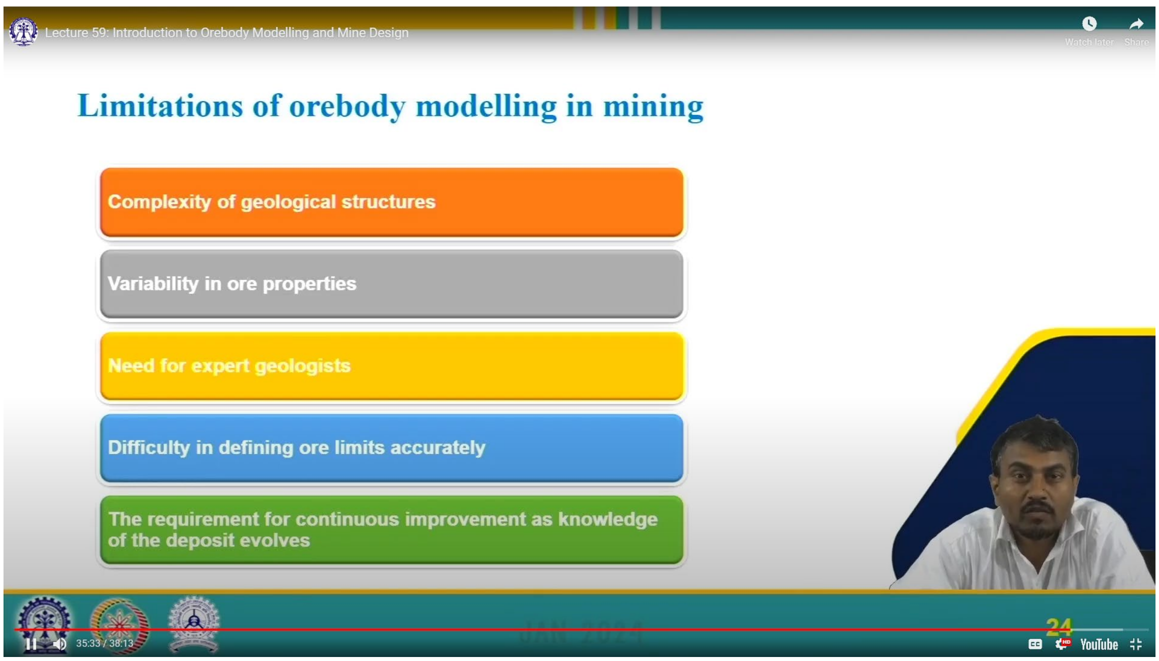
Updating the model-so they get new borehole data and use an algorithm to update the solid model, resulting in an updated model. They then calculate the influence of the new data and update the ore grade model accordingly. So, now the next step is the change in model. So, here we compare the local changes in solid model and grade models before and after the update, and we find that adding new data increases the local ore body thickness and changes its ore grade, especially in high-grade areas. So this is the representation you can see. These are the ore bodies 1, and these are the ore bodies 2. So, here in this area, the red area, we have done some new boreholes and we have got some new information. So, how is this new information going to change the contour map of the ore body? This is basically shown here. So, the black circle basically highlights the significant change in the ore body. How does it help? It helps in different ways. So, if the grade quality is high, it is found in the new data. It is valuable information for us because ore grade is not uniform throughout the ore body. It's a random process, and ore grades are continuously changing. But we have a customer target. We are supplying and selling our ore to a customer. So basically, there is some agreement that we are going to supply this quality ore continuously over a period of time. So, certainly, if we are basically facing low-grade ore and with the new information we get, there are chances of higher-grade ore. So, then we will plan the mining process accordingly so that we can mix the higher-grade ore and the low-grade ore. So, that by mixing, we can achieve the desired target of quality, and we can basically maintain the business and go through the business. So, this way, these updated models help us to design, progress, and manipulate the mining process, which helps continuously progress the mining.



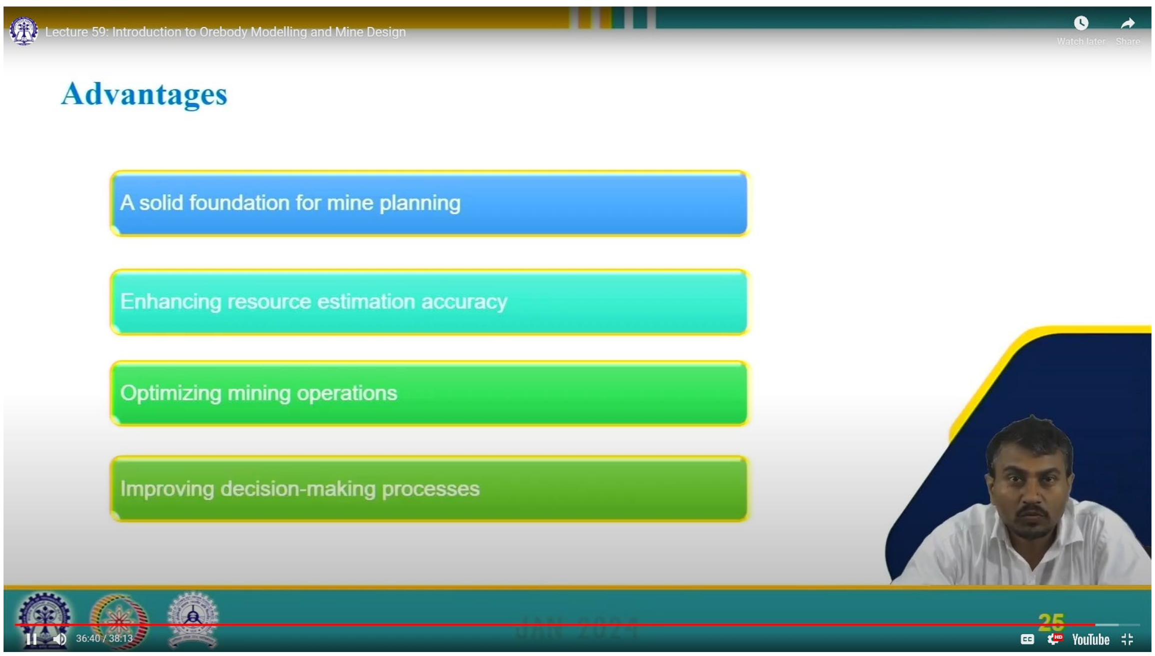
Now for case study 2. Here we have the copper zinc deposit of 1984 by the fifth geological team of the Xinjiang Bureau of Geology and Mineral Exploration. its significant amount includes a significant amount of copper, zinc, gold, silver, iron, and sulfur and copper and zinc are the most abundant elements, so this is the data. This is about the east, this is about the north, and this is about the elevation. So this is the data about different ore grades. This is the geolithology percentage of copper found. So, based on this color code, you can understand. Now the analysis of the mineral grades. Around 80,000 samples were used to analyze the grades of copper and zinc and for this study, copper samples were chosen. So, the cut-off grade, the minimum grade considered economically viable for mining, was set at 0.5 grams per ton. 0.5 grams per ton. Okay, now the exploration stages and the borehole data. So, there are 1075 boreholes, and these borehole data are divided into three exploration stages. The gradual addition of the borehole data we found in this study gradually added boreholes according to different exploration stages to simulate updating the ore body solid models and the grade models. In stage 1, initially they started this process using 99 boreholes, and these models are the starting point, but later they are updated. In stage 2, they add 530 new boreholes, calculate the range of updating the models, and then update both the entity and grade models based on the data that we found in stage 1.



This is basically the data you can understand. So, a,b,c is the data of different stages, and based on that, we are basically finding out the differences in the area that has been founded by this black circle. So, these are the areas where we found the new grades. The new quality of the ore grades is added based on the new borehole data. So, this process continuously goes on through the life of the mining process, and it helps the mining industry to remain competitive in the market and to economically exploit excavated minerals and progress in mining. That also gives more and more confidence about the delineation of the ore body in its precise location and accordingly channelize the drift and the galleries. The stage number 3 they add 451 number of borehole data and continuously they update the models. So now they compare the model and see how it's changed. So, it has been found that in three stages, stage 2 updates mainly the middle, and stage 3 updates the focus below the model. The verification result shows that their algorithm effectively determines the scope of the model updates for different exploration stages and adapts well to updating both entity and grade models based on new borehole data.



Now let us discuss the limitations of this ore body modeling. We have already discussed that we are dealing with the ore body that is below ground. So, we do not have very precise information or very detailed information about the ore grades and their spatial locations. So it's a very complex geological structure. So, there are a number of challenges to correctly identify its position and its grade in its entirety. So, as I said, the quality of the ore is not the same throughout the ore body and it varies. So, identifying precisely the change of grades in a precise spatial location is very important, and that is the challenging part for the mining engineers. The need for the expert geologist has found that these are the natural deposits, and these natural deposits have a history. Based on the study experience in different sites and based on the different formation stages, the formation history, and the process of formations, the expert geology learns from the data they have already faced in different parts of the world. So here, the role of the expert geologist is very crucial, and that basically adds to the modeling process, and it's very difficult to get a very expert geologist everywhere. Now the difficulty in defining the ore body limits accurately, where its starting point is, where its exact boundary is, and where the end points are, is very difficult, and the requirement for continuous improvement as knowledge of the deposit evolves is very challenging.



Now let us discuss the advantages. There are a hundred advantages, and without this ore body modeling, we cannot proceed as I said. So, a solid foundation for the mine planning so based on this ore body models all the mine plan all the mine activities everything related to the mining is basically based on these ore body models so it's a huge impact that is creating in the overall mining value chain and it enhances the resource estimation accuracy these models this gives us a good amount of confidence that with a 95 certainty we are going to get this amount of ore in this kind of area at this level. Optimizing the mining operations helps us to optimize the mining process in several ways, and that is basically the advantage, and finally, it improves the whole decision-making process of the mining because it's leads, guides, and basically carries through the whole mining process, so this is the base, and continually this base is updated with new information, which helps to progress the mining process.

So these are the references. Let me summarize in a few sentences what we have covered. So, we have covered what ore body modeling is, its 3D representations, and its characteristics. Then we have provided an overview of the principles and methodologies involved in modeling, emphasizing its resource estimations and its relation to mine planning. Then we have explored the technique for updating the information on the ore body models with newer and newer borehole data and how to compare the accuracies and how these changes are guiding the process of the mining process, and we have shown with two case studies that we have discussed the challenges and limitations associated with the ore body modeling's uncertainty and complexity, and we have explored the advantages of ore body modeling in mining that include resource estimation accuracy, optimized mine planning, and reduced operational risk. Thank you.