Mine Automation and Data Analytics

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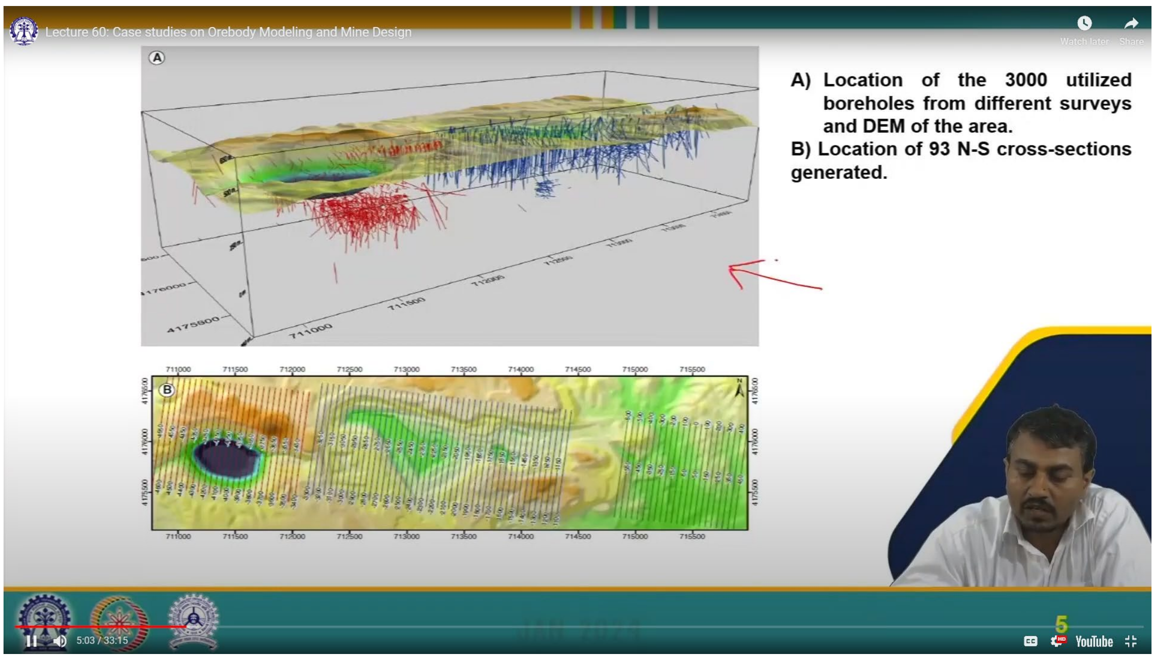
Week-12

Lecture-60

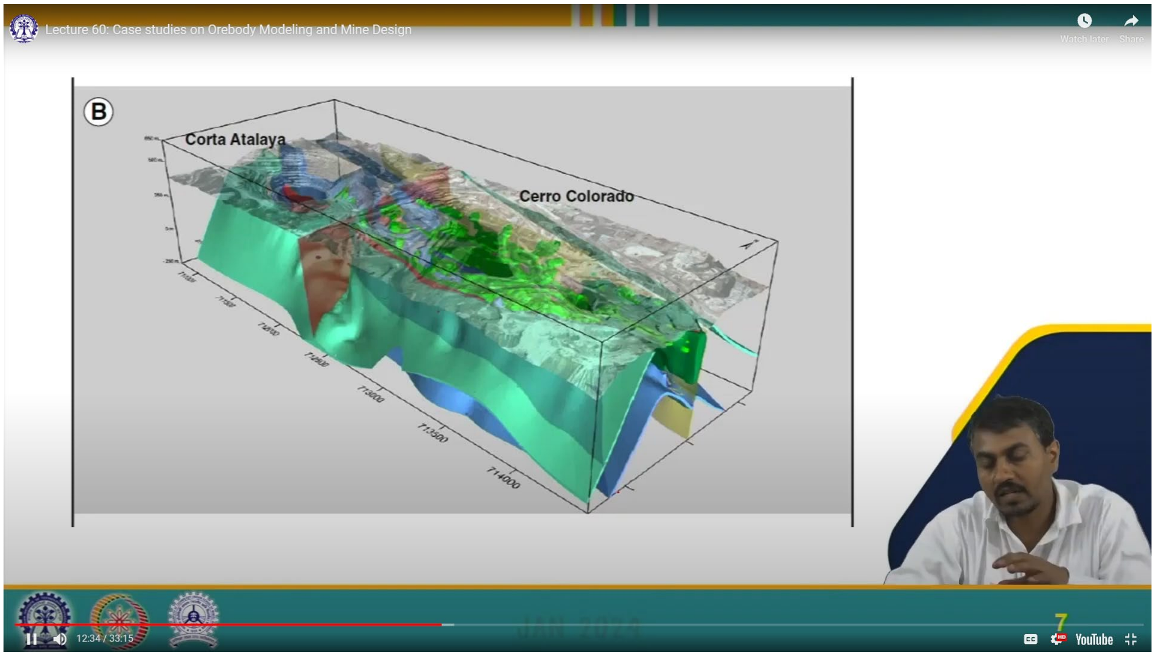
Case Studies on Orebody Modeling and Mine Design

Welcome back to my course on automation and data analytics. Today we will discuss in some case studies how geo-statistics and the advent of different software are used for modeling the ore body at two mine sites. We will basically discuss two case studies. In the last lesson, if you follow closely, we have discussed the principle of ore body modeling, its importance to the mining industry, and its link to the overall mining value chain. So, in this lesson, we will elaborate on this concept in further detail and on a deeper level, with some good examples that are publicly available. So, let us go to the case studies of the ore body modeling and its relation to mining. So, today's lecture is on two case studies: one on the 3D geology model for a rio-tinto mine in Spain and another on the ore body modeling in India and, more particularly, in Singhbhum. It is very near to us, so these two case studies will show us how the concept of geo-statistics and the advent of different modeling techniques and interpolation techniques help us get a better and deeper insight into the ore body.

So, let us start that. So, in this case study, we will discuss a case study of the rio-tinto of the Spain of the Iberian pyrite belt, and here we will discuss the different data that we have collected from boreholes here we have 3000 drill core logs. This is a very high drill core log. This is a very high number of drill core logs, and it enables the construction of 93 cross-sections and 6 plants. So, these are all 2D, so these cross-sections and planes are 2D, and we have 3000 drill core logs. Now, using this, we have to develop the 3D model, the structural model, the digital elevation model, the digital surface model, and finally the 3D shape of the ore body. So, these models reveal to us the physical geometry of the ore body and its relationship with mineralization and the carboniferous trans-tensional tectonics. In many deposits, it has been found that the ore grades have a good relationship with the width, the depth, and so many other parameters. So, that is why in the last lesson we discussed more on the limitation side, that we need good expert help, good geologist help. So, a good geologist, a learned and trained geologist, has that kind of information and intuition about the patterns of the ore grades or deposits underground. So, this is the picture that represents, the location of 3000 of the borehole data that was collected in different surveys, and this is the digital surface digital elevation model. So, for the for the digital elevation model, we want to elaborate in a few sentences.

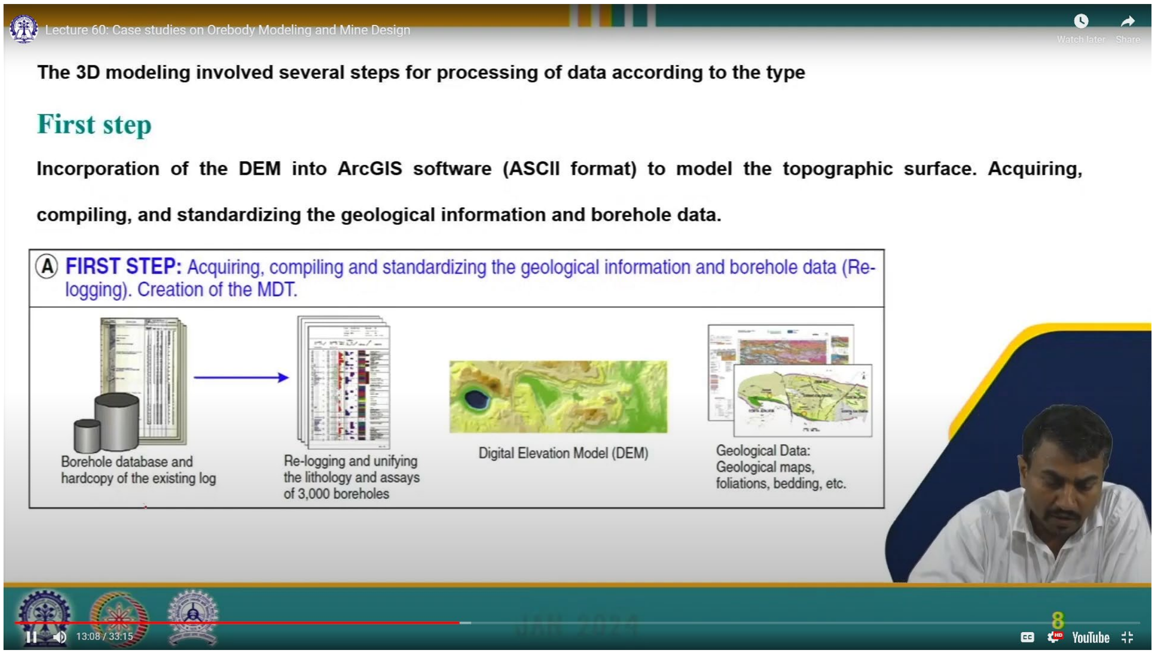


This is a 3D computer graphics representation of the surface elevation, removing the buildings and vegetation. This basically shows how the elevations ups and downs change over the spatial extent, and now it is based on the different surveying data, and the advent of the leader scanner is helping us to get a very high-resolution DEM map. There are many more methods that basically give us the DEM, and if you search on Google, you will get a good amount of information about DEMs of different countries. For example, US DEM is available in the public domain, which is okay for research use. Any researcher can get permission to use the data. So, very high-resolution DEM is available; similarly, for the other countries, it is also available. So, this is the DEM, so this DEM is very useful for surveying, very useful for geological modeling, ore body modeling, and related to earth modeling, okay? So, this is a very useful technique, and this particular



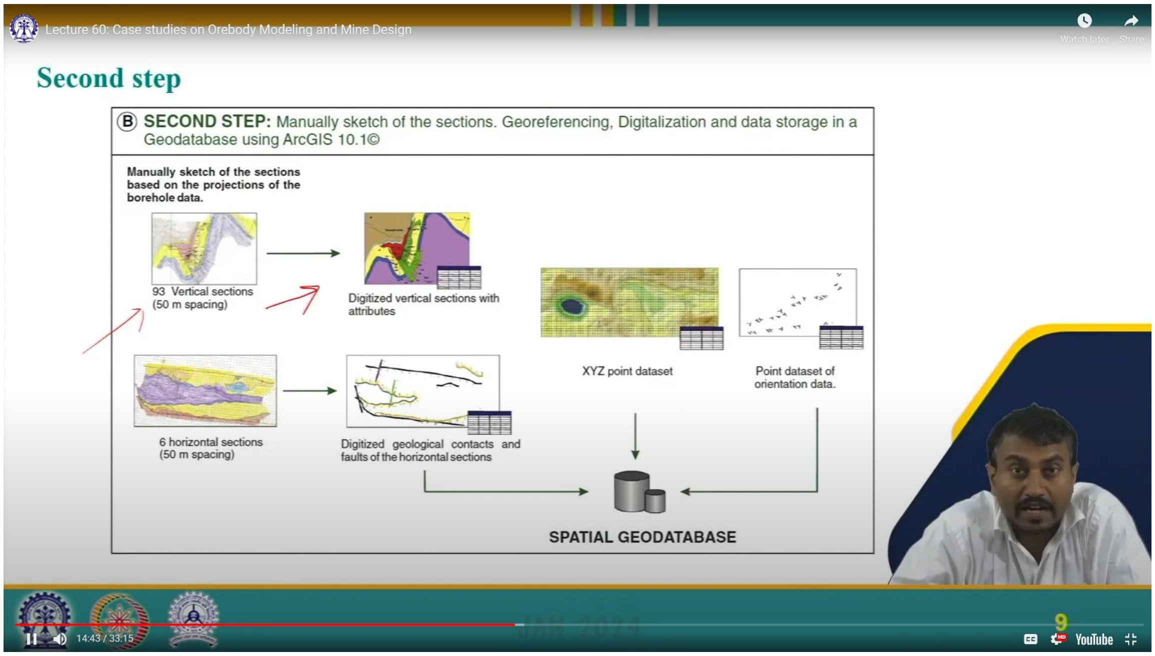
picture shows us the sections north-south cross-section generated. There are 93 cross-sections generated north-south. So, from these cross sections, we are going to get some information in the spatial extent of this side as about some information about the ore and its body, its geology, and its structure. These cross sections may also have information about the different geological discontinuities because these geological discontinuities are a very important part of the mining process. We have discussed in the last lesson the importance of ore body modeling to mining and using these DEM and the ore body models, the 3D reconstruction of the ore, the 3D model of the ore, and the different features that are present in the geology, particularly the geological discontinuity, which plays a very important role in the choice of the mining methods, the types of mining design, the type of mining machinery to be deployed, the type of excavation to be selected, and the direction of the mining to be selected. So, it has a huge impact on the presence and orientation of the geological discontinuity. So, along with the ore body modeling and related models, we also include the feature maps and the feature characteristics of the geological discontinuities, and that is playing a very important role. So, the 3D modeling methods, so different authors have used 3D models, and we have discussed that in the last lesson its importance in visualizing the ore body in its entirety in the in-situ conditions in the underground okay, and this gives us a precise idea of its surface and subsurface geology and its different geology that basically relates and nearby which kind of rock basically hosts this ore body, the structure of the host rock, its orientations, its deep strike orientation, and the deep strike amount, this helps a lot with this 3D model. So, this particular case study used the 3D GeoModeller software to basically study this. So, let me brief you in a few lines about the 3D GeoModeller. This is a very popular software developed by the BRGM and the Geophysicist, about developing the 3D reconstruction of the ore body and the geological bodies and geological structures. So, it's a very widely used software model mathematical framework used to represent the variability, the spatial extent, and the elevations. So, this is very popular software, and it has a lot of features based on the data that you collect. There are uncertainty-based models that show, with this percent of certainty, that there would be some kind of variation. So, this is a probabilistic approach. Another way this latest GeoModeller software has the add-on is that it can also add electromagnetic surveying data to its software and portal so that it can further update the 3D shape of the geology, which can greatly help the mining process. So, unlike other 3D solid modeling approaches, these 3D GeoModeller tools utilize a potential field formulation where geological boundaries are iso-potential surfaces and their dips are represented by gradients of the potential. So, this is a very important step forward for getting very good accuracy using the GeoModeller. So, this model is built into a georeferenced system and incorporates a digital elevation model, simplified geological maps, sections, plans, and information on fracture faults measured within different units. So, these fracture fault dikes and joints basically represent the geological discontinuity. So, these software's have the add-on that it can adjust, and it can take that information and appropriately model the ore body and the geology. So, this is a representation of how these software's basically build DEM models. So, here you can see the 1, 2, and 3 numbers of DEMs created using the data.

So, the first step is the incorporation of the DEM into the ArcGIS software. This is in ASCII format to model the topographic surface and acquire, compile, and standardize the geological information and borehole data. This is the first step so, here we have the borehole database and the different logs, lithological logs of the borehole, and also the lab-level data based on the samples we have collected and analyzed in the lab, and then we have a re-logging and unifying of the lithology and assay of the 3000 boreholes. Then we are building and creating the digital elevation model. Based on that, we have the



geological data, geological maps, foliation, and bedding plans. So, separately, one by one, we are building the maps, superimposing them upon one another, and finally seeing what they look like in their interrelations and in their contact with different geological formations. So, based on that, we have to select which kind of methods and which kind of attacking methods we will choose to approach this ore body and mine it efficiently and economically.

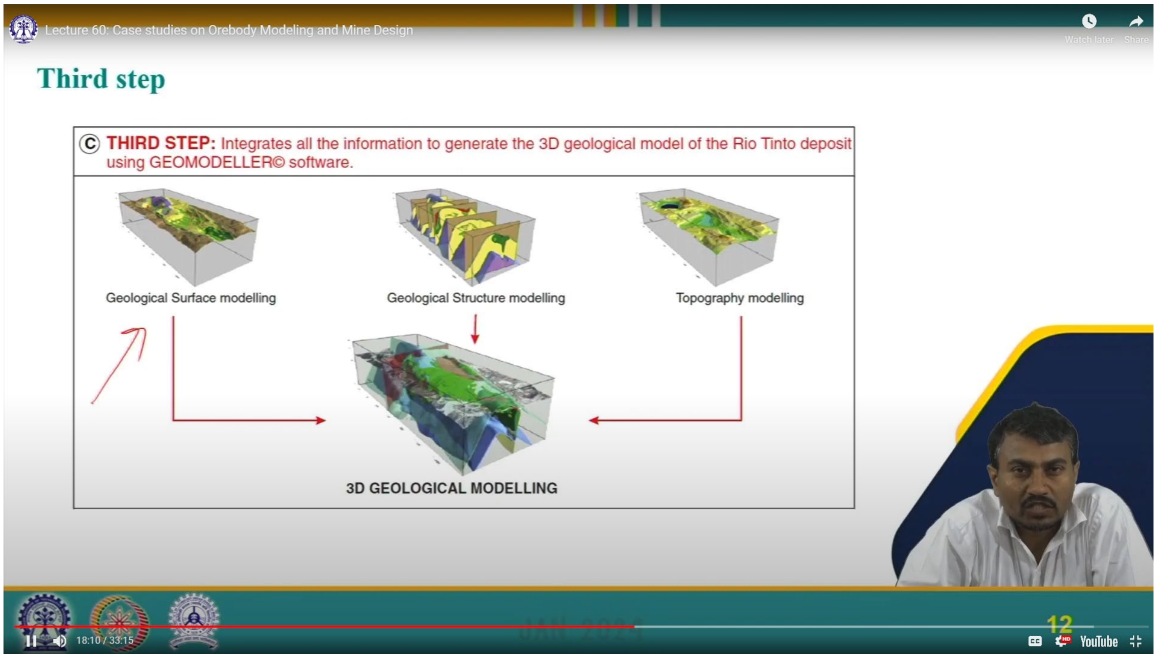
Step number two is basically the manual process and the digitization. So, here we have the 93 vertical sections at 50-meter spacing and different kinds of contours. Now we digitize this model using the data and its attributes its basically neighbors, its quality, and its different features and we have six horizontal sections with 50-meter spacing. Again, we digitize these geological contacts and faults in the horizontal sections. Then we have this XYZ point data set, and we have the point data set of the orientation data because the geological discontinuity is a structural feature. So, in principle, all these structural features have an orientation, a direction. So, this direction is measured by the strike and the dip. So, strike and dip, there are different kinds of representation. Stereonet is one kind of representation that we commonly use in rock mechanics and mining engineering and that is that is also used by geologists. This kind of map represents all these geological structures on one map. So, to understand their concentration, their contours, and their



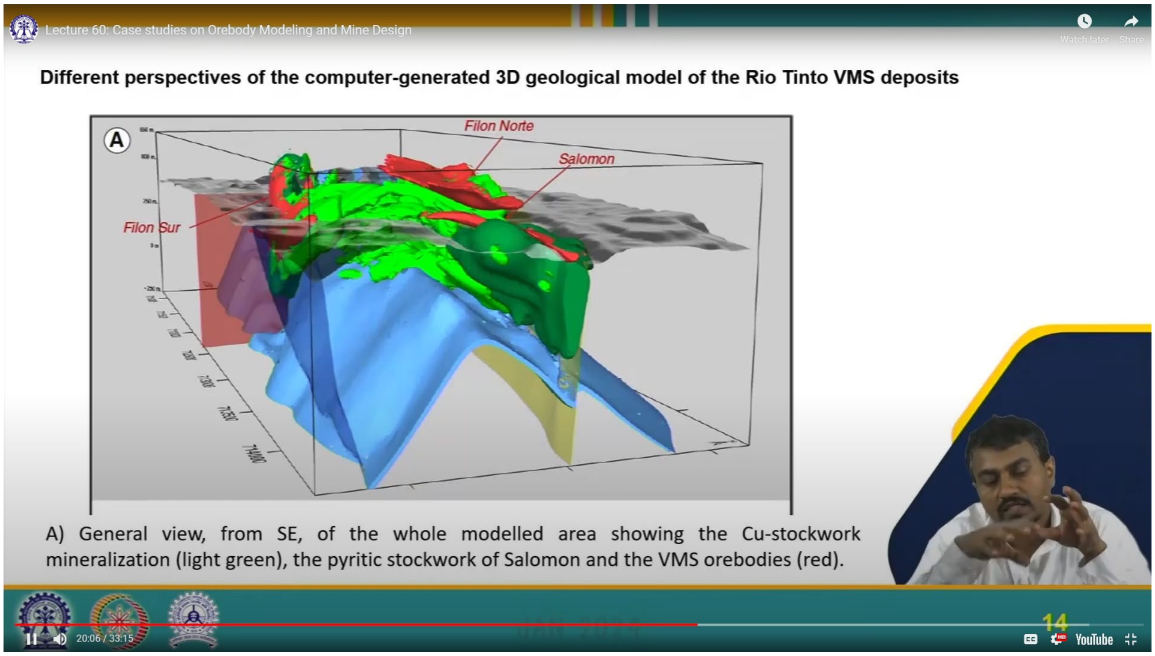
poles, where it is concentrated, based on that in the hilly terrain, we can basically align our roads so that we can avoid potential hazards or landslides because this is basically related to the landslides. So, more geological features are represented in a particular area, we should avoid those kinds of public roads because public road safety is very important for the country. So, there are different usages. Also, in mining, we have different usages for which kind of mining method to select. Then, specially, we merge, we synchronize all this data, and we get the spatial geodatabase merging all together. This is the second step.

Step number three, so we have now the vertical cross-sections and six horizontal sections, and we have seen at the 50-meter level, 50-meter intervals, and these drawn are from the 450- and 200-meter levels with a scale of 1 to 2,000. So, now this methodology employs the conventional geological practices commonly used in mineral exploration and mining. So, the section and plans have been geo-referenced and digitized to obtain the XYZ coordinates for each contact between geological units, the mineralized bodies identified in step 1, and the geological structures. So, all digitized information has been stored in a geodatabase created in ArcGIS. So, this topological relationship between the digitized elements has been checked for accuracy.

Step number three: here we merge all the data together and form the 3D geological models. The first is the geological surface model, the same as a digital elevation model;

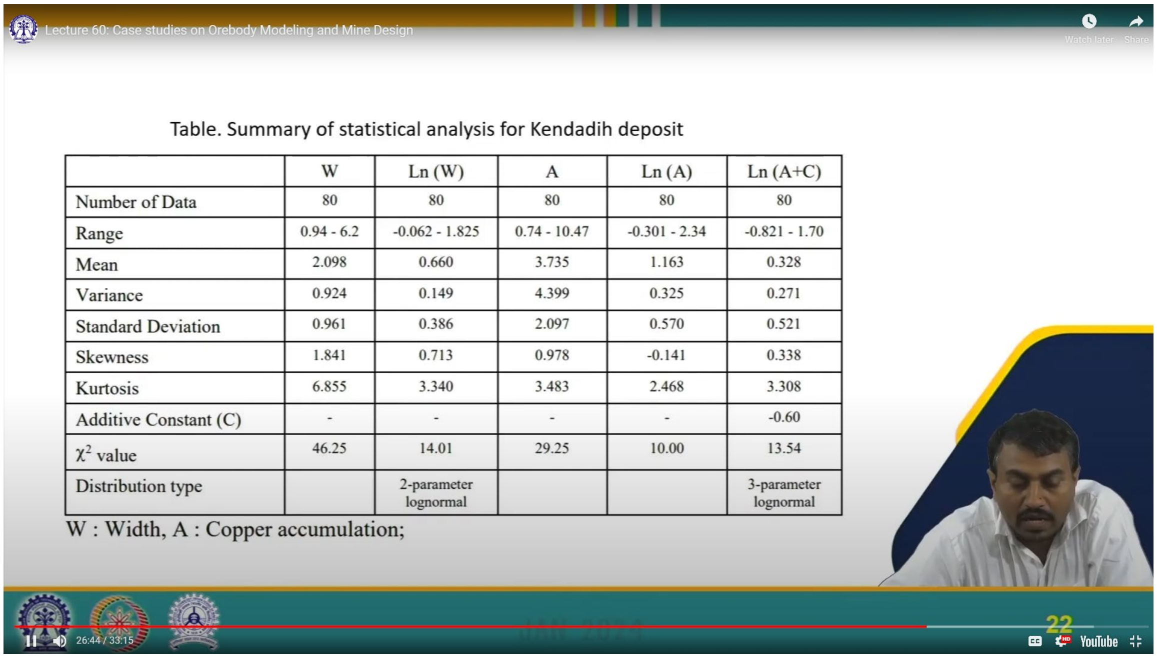


the second is the geological structure model; and the third is the topography model. When we combine all three together, we get the 3D geological models. So, this is not only the ore body; we are now extending our idea; we are now extending the application of this idea to get a broader view of the geology, a broader view of the geological formation that may influence the mining process chain. So, now we are getting a better and more different insight into the geology, and this gives us more confidence about the certainty and uncertainty of the geology and its structures. So, importing all geological contacts, fault intersections, and digital elevation models from the data and to the GeoModeller. So, the construction of the geological surface model using contact and deep vectors obtained from the vertical section and the DEM data. So, the validation of geological subsurface objects using extensive borehole data at depth ensures the accuracy and reliability of these geological models. So, from the different perspective of the computer-generated 3D geological models of the Rio Tinto deposit, this looks like this. This is the whole deposit. Now, the red represents the VMS ore body, and the light green represents the copper mineralization. So, based on that, we have to choose which area to excavate and which are the points of the open pit location so that there would be less overburden to be removed to extract these ores because removing the ore body means overburden is a huge cost, and handling, dumping, and maintaining for a lifetime until the mine closes is a huge investment. So, the selection of the appropriate location where, from the start the mine, the stripping ratio is important. Based on these data, we can design that.



So, this is another deep insight here are the existing mine open pit mines, and the blue lines indicate the intermediate units of the faults, while the light blue indicates the transition series of these and decline boundaries. So, based on that, we basically orient, manage, and drive our mining operations. So, another representation of this includes the positions where the mining has already been done and different mineralization’s. You can see the light greens where the copper mineralized mining is being exploited and other different units and their cross-section according to the GeoModeller output and the visualizations. The result is that we are constructing this result using 300 bore holes with 93 cross-sections based on a 50-meter interval. Now the resolution is that we are getting an approximate 3-meter resolution, so this gives us a very detailed insight into the ore body and the host rock that is present in the surrounding area, and that gives us more confidence about the mining process. An inclusion of the mineralization in the model encompasses the exploited mineralization above the present topographical profile as well as the distribution of the VMS and the stockwork mineralization yet to be mined. So, this gives us an enhanced understanding of the geology and gives us a fresh perspective on this mine and which direction it should go so that we can mine it economically sustainably for a longer period of time.

Now let's focus on Case Study 2. So, this is about the copper deposit of the Singhbhum copper built in Kendadih, Jharkhand, and the geology and mineralization are predominantly localized in quartz, chloride, biotite, and cyst, and the sulfites are found in several parallel conformable loads as dissemination over a wide zone within which some portions are richer due to the development of massive veins. Altogether, there are six parallel loads with a strike length of about 600 meters and a width of about 1.5 meters to 2 meters, some of which merge with each other at depth. So, in the database, we have 80 surface drill hole data. We also have exploration data, and this database contains information on drill hole identification, collar coordinates xyz from azimuth inclination, true width of mineralization, percentage of copper, and metal accumulation value, which is the width of the X assay. This initial input data was then transferred into an assay database that considers mineralized intersections. So, what are the variations and how do you use the geostatistical tool here? So, the width and copper accumulation values have been considered for statistical and geostatistical modeling of the Kendadih copper deposit, and the copper assay value is mostly in the range of 0.5 to 2 percent, but the width of the ore body changes significantly throughout the deposit. The deposit being a vein type shows a positive correlation between grades and width, and hence the grade value at any location is calculated by dividing the copper accumulation value by the width of the ore body. In the statistical modeling, we have the frequency histogram probability plot analysis that reveals a single population for both width and copper accumulation values, with width confirming the two-parameter log normal distribution and copper accumulation value confirming the three-parameter log normal distribution. So, the three-parameter log normal distribution is nothing but the extension of the two-parameter log normal, provided that X value is a natural logarithmic value that follows the normal distribution. So, the result indicates an average of 1.41 meters of width and 2.401 percent of copper accumulation value. The average grade for the copper assay value is 1.7 percent. The respective central 90 percent confidence limits for the average copper grade are 1.06 to 2.54 percent.



Then the data that we have found is the width of the assay value, their log normal value, so the copper accumulations, so we have the statistical data, its range mean variance, skewness, kurtosis, and the size square value, chi square value. Now using the geostatistical modeling, we have the 3D experimental semi-variogram, which was computed along four principal directions, namely 0 degrees, 45 degrees, 90 degrees, and 135 degrees, with an angle of regularization of 11.25 degrees for both the width and the copper accumulation value, and plotting these experimental semi-variograms did not reveal any major anisotropy in either case. So, the semi-variogram is basically a representation that it indicates, and it relies on the data that is closer and closer, and based on that, it interpolates and its variations okay, and this is a very useful method by the geologists as well as the people that are working with the dust-related issues modeling the dust concentration, so this is basically a useful statistical tool. So, here the mean isotropic 3D experimental variogram was constructed and the spherical model was fitted by the point-krigging cross-validation technique. So, these are the data of the steel variance nugget variance and the range of influence, so the range of influence we have in the width of 128 meters at the accumulation of 132 meters. Mineral inventory and grade tonnage relationship-So, in geostatistical modeling, the individual slices are krigged block by block using the model semi-variogram parameters to produce a krigged estimate and krigging variance for each block. A total of 377 blocks were distributed regularly on a 100-meter reduced level, with 9 meters into 2 meters into 2 meters of block dimension over cracked. The overall mean creaked estimate and the creaking variation for the copper grade at 90 per 900-meter reduced level are 1.72% and 3.32%, respectively, and the computed central 90% geostatistical confidence limit around the mean is 1.34 and 2.31%. The tonnage of each block was computed by multiplying the block volume with an average specific gravity of 2.9, and the level-wise reserve was obtained by multiplying the tonnage factor volume with a specific gravity with a total number of blocks in that level. The 100-meter level possesses a total of 53,568 kilo tons of ore. So, the ore body modeling is a reflection of the geological and geometrical reality of an ore deposit. So, geologists and mining engineers can benefit from such an integrated modeling approach by honoring deposit geology, understanding statistical distribution, and emphasizing these spatial continuity studies. The model can act as a principal guide for the development of mineral inventory models and grade tonnage curves, which ultimately can lead to a value model in terms of economic extraction of the ore body.

So, these are the references. Let me summarize in a few sentences what we have covered. So, we have covered a case study of the Rio Tinto for the volcanogenic massive sulfide VMS deposit of the Iberian pyrite belt of Spain and how the 3D GeoModeller is used to model not only the ore body but also the host rock and the geological discontinuity. Then we investigated the geostatistical approach for the copper belt of Singhbhum and how it was beneficial for the mining and how it was giving accurate information with a percentage of certainty about the grade and the tonnage of the ore that we have discussed. So, this is the last part of our lecture on mine automation and data analytics. So, we have traveled across different avenues of mine automation, different sensing technologies adopted in the mine automation strategy, and different models that basically make the industry successful. In the second stage of this course, we have concentrated on the different statistical methods to be used to handle this data, analyze it, and find patterns. In the third stage, we have applied the advent of machine learning to get more insight, insight and behaviors from the data. So, these are an interesting journey and we hope the future of Indian mining scenario is basically going to take the full potential of this automation strategy, the different modeling technique and different AI technique and machine learning technique to advance the mining and operate the mining sustainably and make less footprint on the environment. So, with this kind of mining automation strategy and with the help of the data analytics tool, future mining will be greener, more sustainable, and more accommodating in relation to society. Thank you.