

# Geological modelling of a deposit and application using Surpac

*With the help of a mine planning and design software Surpac, a geological database was created into which the coordinates and alignment of the borehole points and their constituents along with their individual grades were fed into. The deposit which has been studied is a bauxite ore. From this database, the boreholes were displayed graphically in the software GUI. Further, surface generation using the points was done that facilitated for the manual task of sectioning of individual borehole row sets. After sectioning all the hole sets, a solid model representation of the ore deposit was generated, validated and its volume and tonnage were determined with the input of its specific gravity which is known as reserve estimation. Moreover, the borehole data was composited using downhole compositing method and statistical trends of individual constituents of bauxite were studied. Block modelling was done with the help of downhole composite and the volume of the total block model was also calculated. The anomalies in the volumes between solid model and block model was discussed. The grades of individual constituents of bauxite, i.e.  $Al_2O_3$ ,  $Fe_2O_3$ ,  $SiO_2$  and  $TiO_2$  were determined for a particular block using Inverse Square Distance method (ISDM) and were found out to be 44%, 28.28%, 2.21% and 2.02% respectively. For the same block, the grade of  $Al_2O_3$  was determined using three different grade measurement techniques, i.e. Nearest Neighbour, ISDM and Ordinary Kriging and were found out to be 41.4%, 44% and 41.37% respectively. The grades were compared to proper reasoning and concluded accordingly.*

**Keywords:** Geological database, solid model, block model, Surpac software, reserve estimation, grade measurement.

## 1. Introduction

In the mining industry, there are two aspects which are highly essential to monitor and optimize apart from environment- money and time. Equivalently in a mining industry, time is money; one has to extract much resources in

a limited period of time to earn profits. This necessitates proper planning on where to extract and how to extract resources and timely execution of the planning prospects.

Planning for opencast mines is done by assessing the total reserve and the average grade of the deposit. From this data, scheduling is done time to time based on where to extract the ore at a particular point of time. Sometimes the mine management may ask for rich grades of ore while sometimes it may ask for normal grades and ore blending.

Opencast mine planning is done by first generating a representative model of the ore deposit, then dividing the ore body into smaller blocks and sub-blocks which is basically referred to as block modelling. From the stage of block modelling, a suitable depth is selected from which the pit is to be designed. While designing the pit, it should be kept in mind that the stripping ratio should be economical in order to minimize losses.

For the process of geological modelling and opencast mine planning, several softwares have come into use with the application of information technology in mining industry. Among them, Surpac is one having multiple high end functions of mine modelling. The software has been developed by Gemcom International. It is a complete software of mine planning and designing.

Several works have been done by various researchers in the field of mine planning and designing using this software. Geological databases have been established for a multi-metal mine with the purpose of grade measurements, analysis of faults, crevices and geological discontinuities for underground excavation (Zhou et al., 2007). In another research work, reserve estimation of a high phosphorus stockpile has been done for an iron mine using geostatistical modelling (Kasmaee et al., 2010). Designing modelling tools have also been applied for oil shale mining in Estonia (Karu et al., 2008). In one of his books "Mineral Exploration: Principles and Applications", Dr. S. K. Haldar has emphasized application of geostatistics to resolve the problems of grade-tonnage mismatch and wider grade variations of estimated blocks (Haldar, 2013). Other works have also been done with respect to orebody modelling and comparison of various reserve estimation techniques (Moharaj and Wangmo, 2014)

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TABLE 1: COLLAR TABLE AND ASSOCIATED FIELDS

Field	Description
1. BHID	Tells about the borehole ID. Unique for each borehole
2. Y	Northing
3. X	Easting
4. Z	Elevation or reduced level
5. Max_depth	Tells about the drill path length
6. Holepath	Tells if a borehole is drilled vertical or inclined
7. No. of samples	Tells how many ore samples have been examined from a borehole

TABLE 2: SURVEY TABLE AND ASSOCIATED FIELDS

Field	Description
1. BHID	Tells about the borehole ID. Unique for each borehole
2. Depth	Tells about the vertical distance traversed by a borehole
3. Dip	Tells about the angle of inclination of a borehole w.r.t vertical
4. Azimuth	Tells about the direction of inclination

TABLE 3: ASSAY TABLE AND ASSOCIATED FIELDS

Field	Description
1. BH_name	Same as the borehole ID
2. Sample_id	Assigns a number identity to a sample extracted from borehole
3. From_SMPL	From what depth the sample has started
4. TO_SMPL	From what depth the sample has ended
5. Al <sub>2</sub> O <sub>3</sub> %	Percentage assay of Al <sub>2</sub> O <sub>3</sub>
6. Fe <sub>2</sub> O <sub>3</sub> %	Percentage assay of Fe <sub>2</sub> O <sub>3</sub>
7. TiO <sub>2</sub> %	Percentage assay of TiO <sub>2</sub>
8. SiO <sub>2</sub> %	Percentage assay of SiO <sub>2</sub>

and opencast mine modelling (Agarwal, 2012).

This paper deals with the process of ore reserve modelling, estimation of its reserve and determination of its grade using some of the popular estimation techniques and comparison in their values.

## 2. Area of study

The area of study is an opencast bauxite mine which is located in Odisha, India. The mine is owned by a company which is administered by Ministry of Mines, Government of India. The company has a production of 6.8 million tonnes of bauxite and 1.6 million tonnes of overburden. The overburden is composed of hard ferruginous laterite extending in thickness from 0-3.5 m and bauxite layer extending in an irregular form from 10-35 m having an average thickness of 14 m. The bauxite deposits are of Precambrian age where the ore has been formed through a process of weathering and lateralization of the parent rock, i.e. khondalite.

The bauxite mine is the largest single bauxite deposit in Asia having a reserve of 310 million tonnes of bauxite deposit. It is a part of east coast bauxite deposit having a total reserve of 3000 million tonnes from which 2000 million tonnes of deposit is distributed in Odisha and 1000 million tonnes in Andhra Pradesh.

The deposit lies on a flat to gently rolling plateau top extending over a length of 21 km in NE-SW direction and having an average width of 800 m. The area of the deposit is approximately 17 sq. km. The deposit is divided into three blocks - north block, central block and south block.

The geological data of a limited area (around 5-6 ha) has been provided for the purpose of geological modelling.

## 3. Objective

The main objective here is to develop a graphical representation of the ore deposit from borehole data, compute its reserve and estimate its grade with the purpose of better mineral resource evaluation. Furthermore, emphasis has also been given on making comparisons between different grade estimation techniques for the same deposit and figuring out the reasons behind the differences in grades, if any.

## 4. Methodology

### 4.1. CREATION OF A GEOLOGICAL DATABASE

For the process of geological modelling, the first step is to create a geological database. Geological database is basically done from the raw data acquired from the boreholes or equivalently drillholes so that the software understands the type of information fed into its system and can compute the results or display any graphical form according to the user's requirements. For feeding into a Surpac database or basically any geological database two mandatory tables are required – collar and survey. For obtaining information related to grade, types of rocks present near the orebody and the presence of any geological features or discontinuities, other optional tables are used such as assay, litho, geology, etc. The software system uses two tables intrinsically as a part of system tables – translation and styles which deals with the graphical display formats. For the provided geological data, only collar, survey and assay tables are required (Tables 1, 2 and 3).

During the process of data importing, data is taken from the csv files (the given data files) to the newly created Surpac database through the software wizard. Data can be imported from access and various versions of paradox database files. It has to be made sure that the correct csv file should be selected for the tables and the column number of Surpac database parameters and the field number of the parameters mentioned in csv files should match each other.

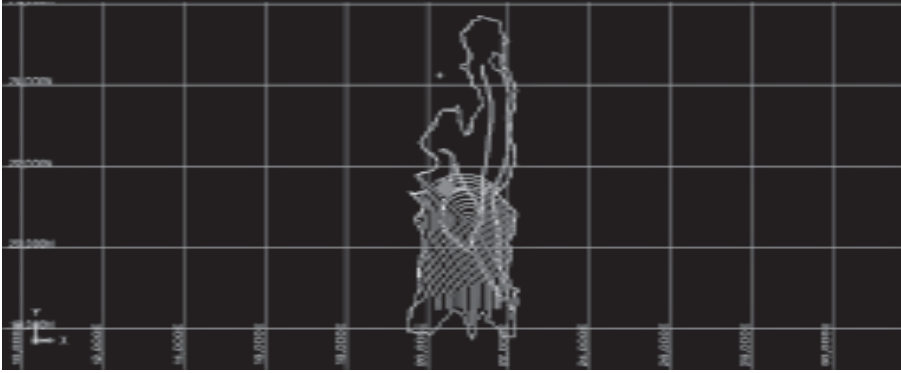


Fig.1 Location of drillholes in the mine plan

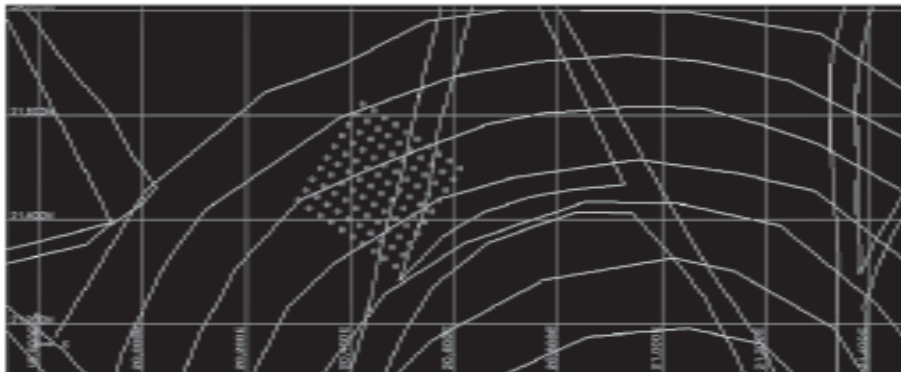


Fig.2 Magnified view of the drillholes and the plan

the string file is generated (Fig.3). Then the surface string file is saved and from this file, the surface DTM is generated (Fig.4).

Next, the drillholes are displayed, and colour constrained in terms of geology and labels selecting the parameter of cut-off grade % of  $Al_2O_3$ , i.e. 42% (Fig.5). Then the set of drillhole rows are digitized selecting only the grades within and above the cut-off value inside the digitized region using the section mode. The creation of sections is done for all the drillhole row sets (Fig.7). The figures for explaining the procedure has been illustrated in Figs.5, 6 and 7.

Then, using the function of triangulation inside a segment and triangulation between segments for the extreme two section strings, the 3-D model of the ore is generated (Fig.8). The solid model is then validated for any invalid edges or repetitions of edges, etc. Then the volume of the solid model is calculated (Table 4).

#### 4.2. DISPLAY OF BOREHOLES

The mine plan was imported into the Surpac graphics in the form of string file, i.e. str format. Then the mine plan was corrected for its scale and orientation by using the 'Move string constrained by - transformation' function. The map was rotated to an angle of  $+72^\circ$  and its scale was increased to a magnitude of 13.6. Simultaneously the map was also subjected to translation till it reached its desired coordinates. With this configuration, the drill holes were displayed in the plan (Figs.1 and 2).

#### 4.3. 3-D MODELLING

Prior to 3-D modelling, some of the other functions to be carried out include generation of surface DTM from a given borehole set, indicating the depths in the boreholes which can be considered as ore and creation of sections for different drillhole sets.

The surface string is generated using the 'import data from one file' function. The collar file is selected and

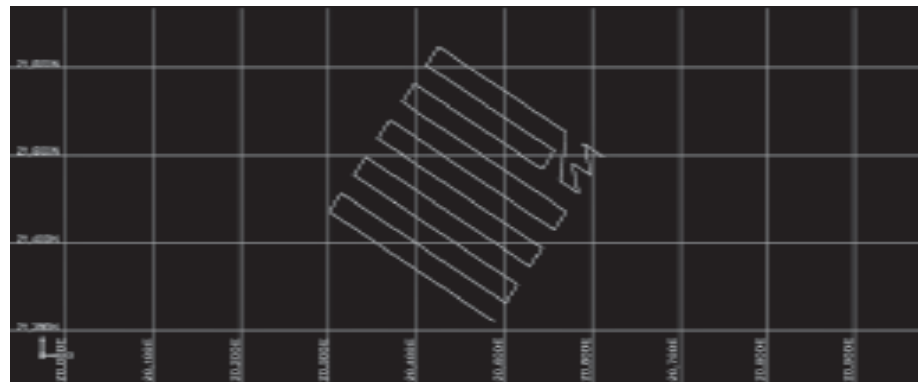


Fig.3 Generation of surface string file

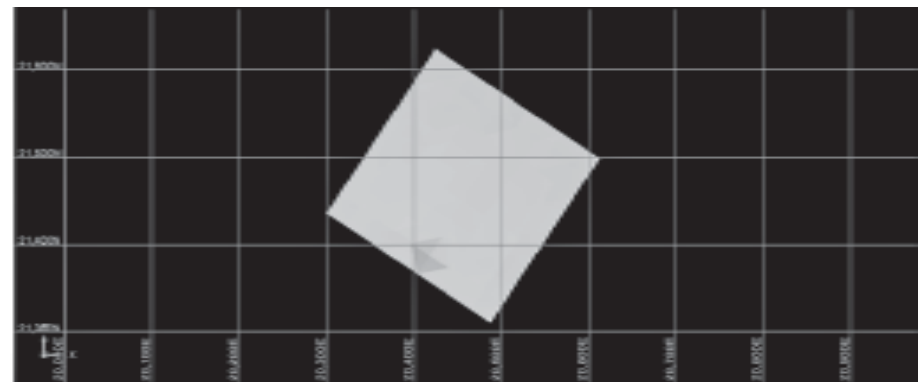


Fig.4 Generation of surface DTM file

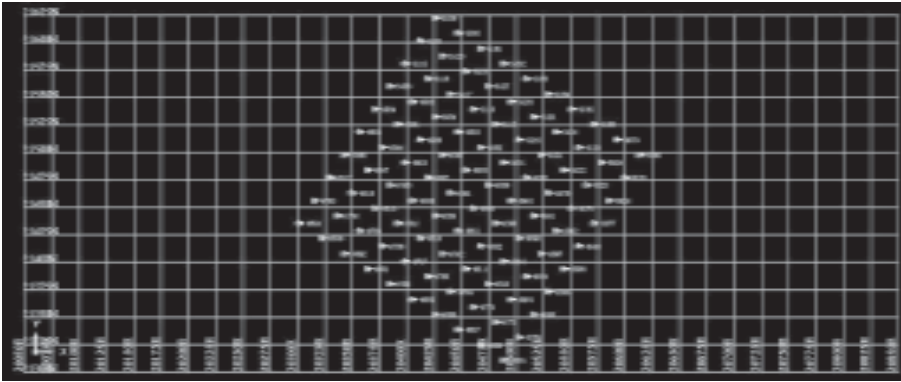


Fig.5 Drillhole display

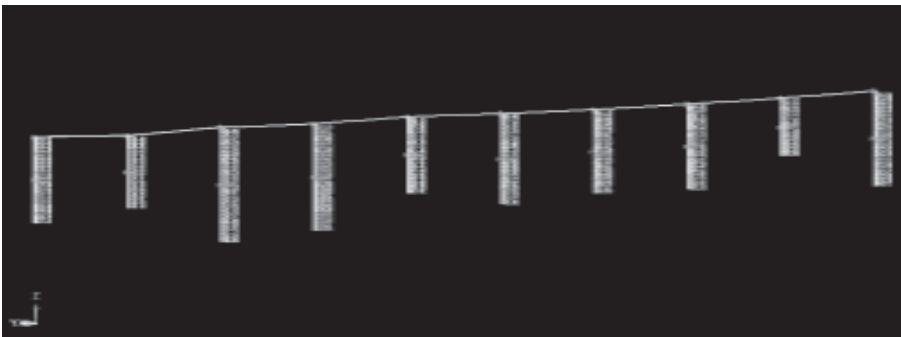


Fig.6 Colour constraining of drillhole row set and entering into the section mode

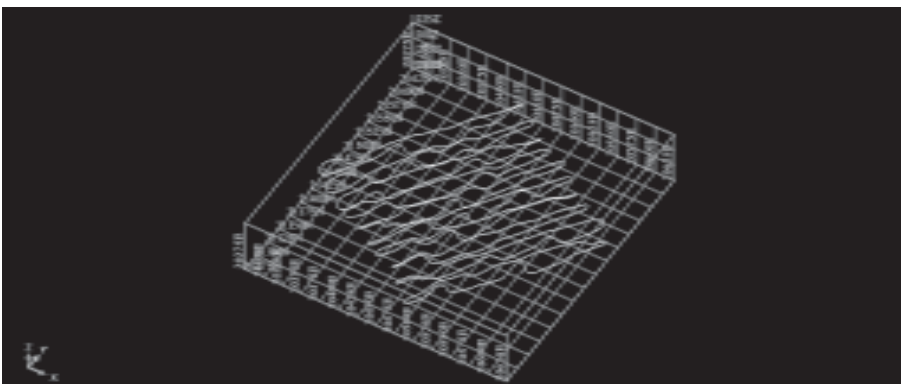


Fig.7 Creation of sections for all drillhole sets

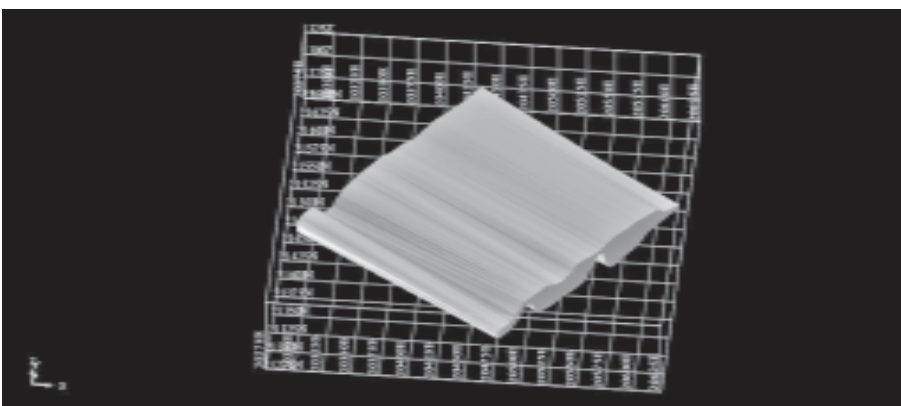


Fig.8 3-D model or solid model of the ore deposit

#### 4.4. BLOCK MODELLING

Before starting block modelling, compositing of drillholes is done for proper resource evaluation. In the process of compositing, the assay values of the adjacent samples from the drillholes are combined in order to determine the assay values of longer drillhole intervals. Basically, there are six types of compositing methods used in Surpac software- downhole, bench elevation, by grade constraints, by geological constraints, from end of hole and from multiple elements.

Downhole drill compositing has been done with a fixed length of 5 m composite length, with minimum percentage of samples to be included as 75% and no zone selection method. Compositing has been done with the parameter of grade % of  $Al_2O_3$  (Fig.9). The compositing string data and the statistics of the raw data, i.e. the statistical trends of grades vs number of samples for  $Al_2O_3$ ,  $Fe_2O_3$ ,  $SiO_2$  and  $TiO_2$  have been illustrated as below (Fig.10).

Next comes the process of block modelling in which the solid ore model is divided into smaller regular block units of customized size for better resource evaluation which means determining the volume of the entire ore deposit from the block model and comparing with the volume of the solid model and second, to estimate the grade of a particular block using different grade estimation techniques with the aid of compositing.

Block modelling has been done with block size of 10 m \* 10 m \* 4 m and sub-block size of 5 m \* 5 m \* 2 m. Then the block model is constrained according to the extent of the ore deposit and the volume of the block model is calculated (Fig.11 and Table-6). Grade estimation of  $Al_2O_3$  for a particular block has been done using the techniques of Nearest Neighbour, Inverse Distance and Kriging (Table 5). The values have been compared as shown in Table 5.



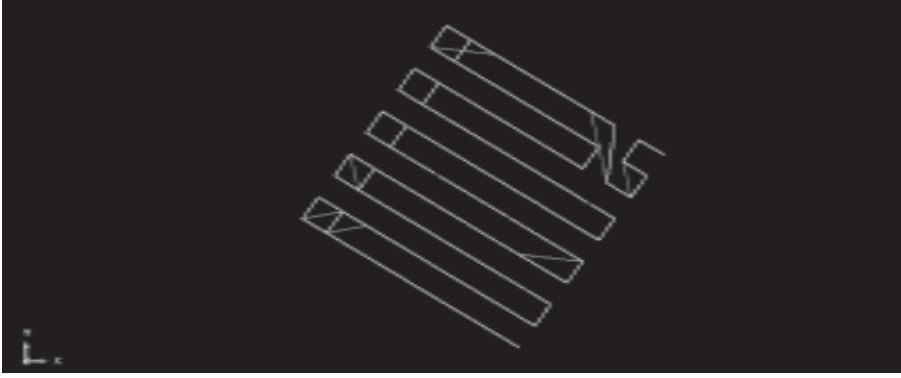


Fig.9 Downhole compositing

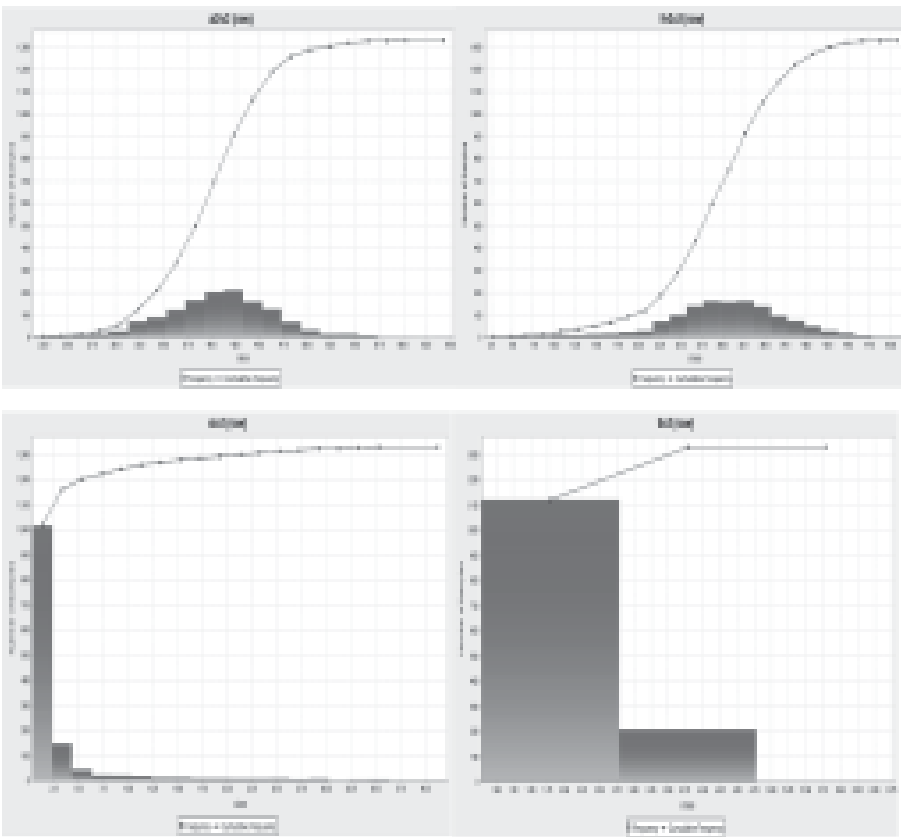


Fig.10 Statistical analysis of various constituents of bauxite

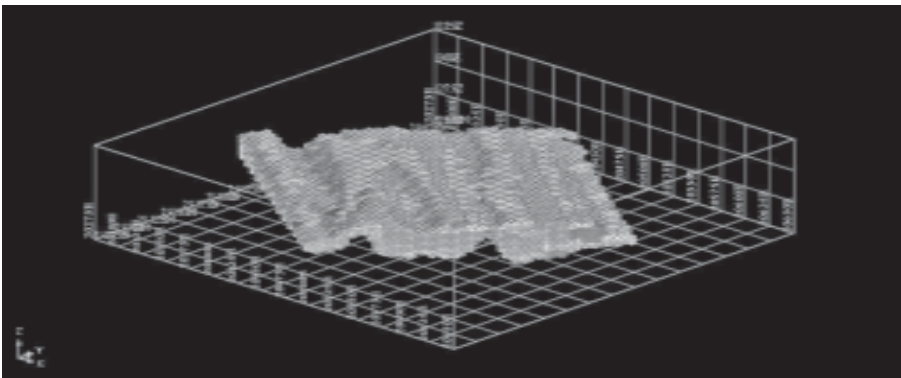


Fig.11 Block model of the deposit showing grades through inverse square distance method

## 5. Results and conclusion

1. The total ore reserve volume for the 3-D model is 996117.53 m<sup>3</sup>, while the total ore reserve volume for the block model is 998950 m<sup>3</sup>. The difference in their volumes comes out to be around 2832.47 m<sup>3</sup> which is 0.284% or approximately 0.3% of the total ore reserve volume for the solid model. This implies that the volume of the block model is 0.3% greater than the volume of the solid model. This anomaly is occurring because the 3-D model has been formed from the process of triangulation, leading to smooth surfaces and softer edges, but the block model is composed only of larger blocks and smaller sub-blocks and the pointed edges of the blocks/sub-blocks cannot negotiate with the surface that has been formed from a solid model, thereby overestimating the volume of the ore body.
2. There is also the occurrence of anomalies in the trisolation extents of solid model and those of the block model due to their methods of formation.
3. The overall surface area for the block model is definitely greater than the surface area of the solid model, i.e. 136505.15 m<sup>2</sup>.
4. In the statistical trends for various constituents of bauxite, the average grade of Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub> and TiO<sub>2</sub> are found out to be 40.53%, 30.36%, 3.13% and 2.26% respectively.
5. Comparing the grades of Al<sub>2</sub>O<sub>3</sub> for the mentioned block using the three different grade estimation techniques, we find that the grades by Natural Neighbour, Inverse Square Distance and Kriging methods come out to be 43.1394%, 43.99% and 41.37% or approximately 43.14%, 44% and 41.37% respectively. If we compare the Nearest Neighbour and Inverse Square Distance methods, we notice a slight difference in the

TABLE 4: SOLID MODELLING OBJECT REPORT

Layer name: section2.dtm
Object: 1
Trisolation: 1
Validated = true
Status = solid
Trisolation extents
X minimum: 20289.046      X maximum: 20619.962
Y minimum: 21294.427      Y maximum: 21632.713
Z minimum: 1260.898      Z maximum: 1303.550
Surface area: 136505.15
Volume : 996117.53

TABLE 5: COMPARISON OF  $Al_2O_3$ % GRADE FOR A PARTICULAR BLOCK

Parameter	Value
Y-coordinate	21391.927
X-coordinate	20361.546
Z-coordinate	1297.898
Block size	5*5*2
$Al_2O_3$ % (nearest neighbour)	43.1394
$Al_2O_3$ % (inverse distance)	43.99
$Al_2O_3$ % (ordinary kriging)	41.37

TABLE 6: BLOCK MODEL REPORT

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Block model report
Constraints used
a. Inside 3DM section 2
Keep blocks partially in the constraint: False
Volume 998950
1/1

grade values which occur because the Nearest Neighbour method uses the concept of Voronoi polygon in which the distance of all the corners (other sample points) from the concerned point remains the same, but in Inverse Square Distance method, the weightage (grade values) between two sample points are taken into consideration. Both Nearest Neighbour and Inverse Square Distance methods take only two points for consideration. But in the Kriging method, the weightage (grade values) of multiple points are taken into consideration and calculation is done using a tedious formula, thereby giving a smaller average value. This clearly implies that the Nearest Neighbour method over estimates the alumina percentage. It also under estimates the volume of the reserve. Inverse Square Distance method overestimates both attributes in comparison to ordinary Kriging.

### References

1. Agarwal, H. (2012): Modelling of Opencast Mines using Surpac and its Optimization. E-Thesis (2012). National Institute of Technology, Rourkela.
2. Dagdelen, K. (2001): Open pit optimization- Strategies for improving economics of mining projects through mine planning. International Mining Congress and Exhibition of Turkey- IMCET 2001. Pages: 117-121.
3. Haldar, S. K. (2013): Mineral Exploration- Principles and Practices. Elsevier Publications. Pages: 157-182.
4. Huang, Ping, Yang, Peng, Chen, Yizhou and Chenjun, Liu (2011): "Three Dimensional model of Cangshang Gold Mine based on Surpac." *International Journal of Advancements in Computing Technology*. Dec 2011, Vol-3 Issue 11. Pages: 299-306 (8p).
5. Jiang, Xue-liang, Yang, Hui and Wen, Chang-ping (2013): "Excavation Simulation of Opencut Mining Slope Containing Goaf Based On Refined Three-Dimensional Geological Model With Surpac and FLAC 3D." *EJGE* Vol. 18 (2013), *Bund. B*. Pages: 345-364.
6. Karu, V., Vastrik, A. and Valgma, I. (2008): Application of Modelling Tools in Estonian Oil Shale Mining Area. Oil Shale, 2008, Vol 25, No. 2 Special, Estonian Academy Publishers. Pp 135-144.
7. Kasmaee, Sara, Gholamnejad, Javad, Yarahmadi, Alireza and Mojtahedzadeh, Hosein (2010): Reserve Estimation of the high phosphorous stockpile at the Choghart iron mine of Iran using geostatistical modelling. *Mining Science and Technology* 20 (2010), Elsevier Publications. Pages: 855-860.
8. Moharaj, M. C. and Wangmo, Y. (2014): Ore Body Modelling and Comparison of Different Reserve Estimation Techniques. E-Thesis (2014). National Institute of Technology, Rourkela.
9. Roy, Indranil and Sarker, B. C.: Ore body Modelling: An Integrated Geological-Geostatistical, Approach, Department of Applied Geology, Indian School of Mines, Dhanbad.
10. Xiao-ming, Liu, Zhou-quan, Luo, Qing-fa, Chen, Xun-fang, Zhang and Qing-ling, Zhu (2009): "3D dynamic monitoring of collapse area based on CMS-Surpac." *IEEE Journal*. Pages: 637-641.
11. Zhi-yong, Zhou, Jiang-hong, Chen and Ke-ping, Zhou (2004): "Application of Surpac Vision software in establishing model of ore body." *Modern Mining* 04-2004.
12. Zhouquan, Luo, Xiaoming, Liu, Jiahong, Su, Yabin, Wu and Wangping, Liu (2006): "Building of Three Dimensional Models of Deposit based on Surpac." *Metal Mine* (04-2006).
13. Zhou-quan, Luo, Xiao-ming, Liu, Zhang, Bao, Hao, Lu and Chang, Li (2008): Cavity 3D modelling and correlative techniques based on cavity monitoring. *Journal of Central South University of Technology* (2008) Vol 15, Springer Publications. Pp 639-644.
14. Zhou-quan, Luo, Xiao-ming, Liu, Jia-hong, Su, Ya-bin, Wu and Wang-ping, Liu (2007): Deposit 3D modelling and application. Springer publications. Pages: 225-229.