 ISSN: 2521-2293

Application of geological data analysis and assessment techniques for coal resource evaluation

Nonduduzo B. Mamba
Department of Mining and Geological Engineering
BIUST
Palapye, Botswana
nonduduzo.mamba@studentmail.biust.ac.bw

Bonny B. Matshediso
Department of Mining and Geological Engineering
BIUST
Palapye, Botswana
matshedisob@biust.ac.bw

Rahul Verma
Department of Mining and Geological Engineering
BIUST
Palapye, Botswana
vermar@biust.ac.bw

***Abstract*—Coal mine development relies on the availability of accurate geological data, its analysis and the application of geological data to coal mine design. The collection, analysis and official use of drillhole and coal quality data are crucial for deriving meaningful resource estimates. This study presents a step-by-step approach for geological data analysis for an area that was extensively explored by Shell Coal Botswana between 1974 and 1982, where significant coal resources were identified. While much exploratory data is available, computer-aided geological modeling and data analysis has not been carried out as the resource estimation was carried out using the traditional resource estimation and modeling methods.The methodology for determining coal resources has been refined, taking advantage of improvements in geologic and mining model computer software. This study, therefore, helps in understanding the applicability of geological data analysis for the purposes of determining coal Seams boundaries, generation of 3D solid coal seam models of the deposit, which is evaluated to determine in-place coal resources. Following this methodology, three coal seams were identified and evaluated. These seams covered a total area of 52,492,911 m^2, occupying a total volume 560,030,268 m^3 at various depths.The estimated tonnage of the coal mineralization for the three coal Seams was 728 039 348.4 tonnes of mineable coal.**

Keywords*—Geological data analysis; coal seam modeling

I. INTRODUCTION

Geological data and interpretations form the basis for the coal resource evaluation process by delineating the mineralization, estimating the resource and providing information for mine design [1]. Botswana Government has embarked on a journey since independence which focused on an aggressive nationwide geological and geophysical mapping which resulted in 90% of the land area covered in high resolution aeromagnetic and relatively high-resolution gravity survey in the northern part, central part and the Molopo farms areas [2]. The current total geological mapping has covered 48% of the country. The purpose of exploration work is to provide information on the coal seam thickness, coal quantity, structure and mechanical properties of the rock associated with the coal deposit, and the distribution and quality of groundwater.

Geological data is obtained through exploration drilling programs, often augmented by down hole geophysical logging and the analysis and testing of core samples. This geological data is then assimilated using computer database and modeling systems: this is then used to develop a 3-dimensional (3D) illustration of the deposit which is used in mine planning as a basis for the evaluation of the in-situ, recoverable and marketable coal resource. The data obtained is processed, interpreted and computerized: a database is created and managed to ensure retrieval of data when needed. A software that has come into use with the application of information technology in the mining industry is GEOVIA Surpac, having multiple high-end functions of mine modeling [3]. It is a complete software of geological data analysis, coal seam modeling, and mine planning and designing. Use of these techniques and data collected assist in the design and operation of effective systems of coal mining, coal preparation and utilization.

II. RESEARCH OBJECTIVES

The main objective is to develop a step-by step approach for geological data analysis and interpretation. This study also helps in understanding the applicability of geological data analysis for the purposes of determining mine boundaries, generation of 3D solid coal seam models of the deposit, which is evaluated to determine in-place coal resources

III. STUDY AREA

The geological data of a limited area (142 km^2) that was extensively explored by Shell Coal Botswana between 1974 and 1982, was provided for the purpose of this analysis and modeling. A total of 201 boreholes had been drilled in the lease area by 1984, at an average density of one borehole per 0.97km2 (Fig. 1). NQ wire-line equipment was used to core most of the boreholes. Core for geotechnical testing was sourced from thirteen individual boreholes, three clusters of 10 large diameter boreholes, and a further 3 single large diameter bores, each providing 150mm core which was used for bulk core sampling. Of the 201 boreholes drilled in the area, data for 15 drill holes was utilised for demonstration of this analysis.

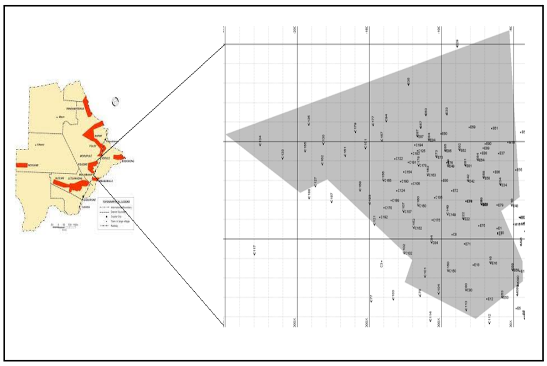

Fig. 1. Location of drill holes

IV. METHODOLOGY

Study was carried out based on borehole information sourced from the coal mine database. Information such as the property history and regional and property geology was sourced from a previous technical report which was revised and updated as required. This paper illustrates the development of a graphical representation of the coal deposit from borehole data, computing of coal reserves and estimation of coal grade suitable for coal mine design.

A. Drill hole data management

Data used was based on information obtained from drilling, lithological logging, core sampling, and the descriptions of stratigraphic sections measured in the field. This data also included collar information of drill holes coordinates; drill holes angles (dip and azimuth); coal seam intercepts; coal grades information; and geological and sampling data such as: lithology of samples taken from drill holes, calorific value, ash content, and moisture content. Data was presented in Microsoft Excel Comma Separated Values format so that the GEOVIA Surpac software understood the type of information that was fed into its system and results could be computed and displayed in graphical form. For the geological data provided, the collar, survey, lithology and assay tables were required (Tables I, II,III and IV).

TABLE I. Collar table and associated fields

Drill hole ID	y	x	z	Max depth
Unique code for each borehole	Northing	Easting	Elevation	Drill hole path length

TABLE II. Survey table and associated fields

Drill hole ID	Max depth	Dip	Azimuth
Unique code for each borehole	Drill hole path length	Angle of inclination of a drill hole w.r.t vertical	Direction of inclination

TABLE III. Sample table and associated fields

Drill hole ID	Sample ID	Depth from	Depth to	Calorific value	Other coal qualities
Unique code for each borehole	A number identity assigned to a sample extracted from the drill hole	From what depth the sample started	From what depth the sample ended	Coal calorific value from the sample in MJ/kg	Percentage of other coal qualities i.e ash, moisture, volatiles, sulphur, and carbon

TABLE IV. Geology table and associated fields

Drill hole ID	Depth from	Depth to	Lithology
Unique code for each borehole	From what depth the sample started	From what depth the sample ended	Description of the different lithologies using rock codes obtained from the sample

B. Creation of geological database

Geological database is created from raw data acquired from drill holes presented in Microsoft Excel CSV files 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. The data in the Microsoft Excel CSV files is imported into GEOVIA Surpac version 2022 (x64) software The importing of data is mandatory for the processing of the database, as well as data validation to eliminate inconsistencies between the input data and the database descriptions made during database creation.

C. Generation of string files

A string file from the given borehole set, indicates the depths in the boreholes which can be considered as ore for the creation of sections. Firstly, the drill holes are displayed, and color constrained in terms of the geology and calorific value selecting the parameters of cut-off grade.The boreholes are then sectioned in the North South direction at 400m interval and digitized by selecting only the grades within and above the cut off value inside the digitized region using the section method to form ore strings which are further connected in a series to cover the entire deposit . The creation of sections is done for all the drill holes row sets using import data from the geology file.

D. Compositing

Once the ore strings are created, they are composited to; find basic statistics of the deposit enabling the proper solid modeling, create a block model, ensure proper resource evaluation and determine the resource estimate using estimation techniques. The process of compositing entails combining the assay values of adjacent samples from the drill

ISSN: 2521-2293

holes in order to determine the assay values of longer drill holes intervals. Compositing is performed on samples contained within the drill hole with respect to the intercepted contacts rather than the entire hole. 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 1.5 m composite length, with minimum percentage of samples to be included as 75% and no zone selection method.

The sample database used contained a total of 138 assay samples representing 386.11m of core. To minimize dilution and over smoothing due to compositing, a composite length of 1.5m was selected as an appropriate composite length for resource estimation based on the average sample length. Using the downhole compositing method; compositing resulted in a total of 307 composite samples. Of the total assay population, approximately 25% are 1.1 meters or less with approximately 75% of the samples from 1.2 to 1.5 meters in length. Each composite sample was assigned a rock code corresponding with the mineralized solid in which it occurred, and each composite was used for grades interpolation onto the block within the individual solid by only placing additional constraints on the model.

E. Statistical analysis

Statistical analysis investigates the presence of high-grade outliers and a binomial distribution (two non-adjacent peaks) on the composite data presented in histograms. The reason for checking for outliers is that extreme grades (whether low or high) can bias the calculation of averages towards the extreme value especially in cases where there are few samples. This effect is even greater when the distribution is positively skewed. Histogram plots and cumulative probability plots of the composite data are also used to understand the degree of skewness and the need to apply top cut if the coefficient of variation is greater than 1.2.

The compositing string data and the statistics of the raw data were plotted, i.e. the statistical trends of grades vs number of samples for the sample data. Fig. 2 illustrates an example of a histogram plot for the coal calorific value sample data. The histogram has no outliers and no binomial distributions meaning the sampling data is representative with a normal distribution.

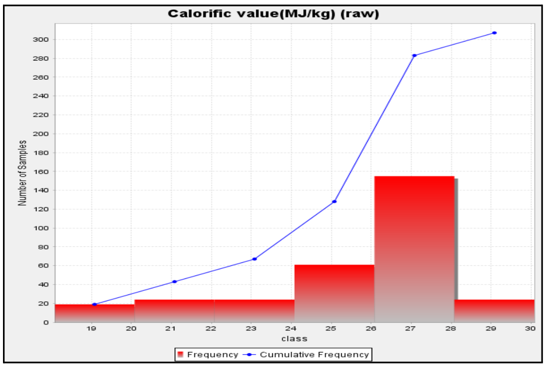

Fig. 2. Statistical analysis of coal calorific value

F. Spatial analysis

Spatial analysis shows how data values change over distance and direction. Variograms are used to illustrate the sample differences (variance) against distance (lag) for the various coal qualities. Several directional variograms are drawn to ascertain the direction of anisotropy of the deposit. Firstly, an experimental variogram is created from the population data (represented by the black data points), then afterwards fitted with a variogram model represented by the red curve. The variograms were drawn at 0° dip, 0° azimuth with 90° spread. Based on the composited data files, the following variogram was obtained for the coal calorific value sample data (Fig. 3).

The variograms modeled, indicated a strong negative spatial correlation as most of the variogram points were above the sill. Worth considering also is that if the nugget value is larger relative to the sill indicates that there is not enough correlation between the data points. In the variogram model for the calorific value, the nugget value was less than the sill value, meaning the correlation between the data points was adequate.

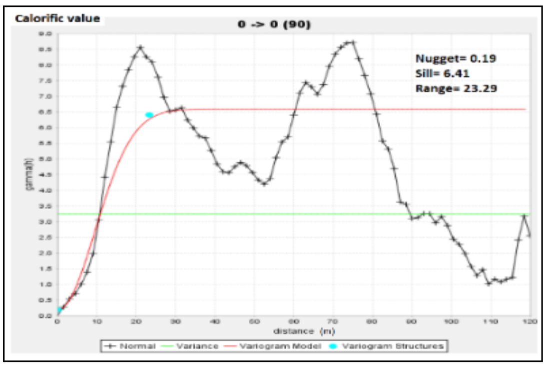

Fig. 3. Spatial analysis of coal calorific value

ISSN: 2521-2293

G. Creation of a solid 3-D coal seam model

A 3-D coal seam model in the form of a surface digital terrain model (DTM) is generated from the previously created ore string files. The ore strings are oriented in the clockwise direction (applicable if strings were digitizing anti-clockwise). Then, using the function of triangulation inside a segment and triangulation between segments for the extreme two sections, ore strings are oriented in clockwise direction and triangulated by connecting them to form a wireframe model of the deposit. After triangulation, the wireframe model is validated to check for the presence of invalid edges, triangles, repetition of edges, etc. Once validation is completed and accepted, the wireframe model is set to solid Fig. 4. The reported surface area and volume of the coal seams for the given sample data are given in Table V.

TABLE V. Coal Seams Surface Area and Volume

	Surface area (m^2)	Volume(m^3)
Coal Seam1	15 501 637	135 142 695
Coal Seam2	18 632 260	199 188 878
Cola Seam3	18 359 014	225 698 695
Total	52,492,911	560,030,268

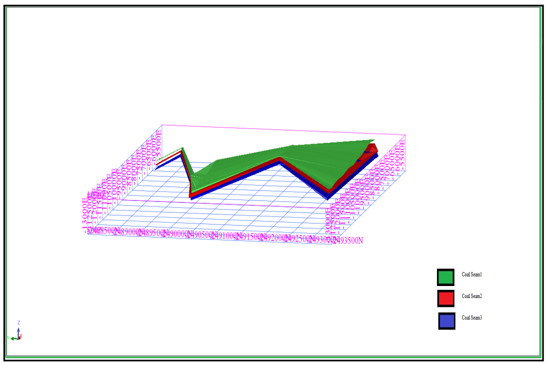

Fig. 4. 3-D model of the coal seams

H. Block model

Wireframes are used to constrain composite values chosen for grade interpolation and the coal blocks reported in the Mineral Resource estimate. The block size is chosen based partially on the average spacing between drill holes (borehole spacing), composite assay length, the tentative starting mining method, as well as the estimated minimum bench height achievable on the coal mine area. A block model of size 20m x 20m x 20 m was created to encompass the known areas of coal resources. At the scale of the sample deposit, this provided a block size reasonable for discerning grade distribution, but still big enough not to mislead when considering a higher cut-off grade distribution within the model. The extents of the model were a factor of the concession boundaries and the geometry of the mineralized solid (Table 6).

TABLE VI. Block model report

Parameter	Value
y- coordinate	2493200
x- coordinate	12765.781
z- coordinate	696.822
Block size	20x20x20
Total blocks	58 303

I. Adding constraints to block model

Constraints are added to the empty block model to control the blocks from which interpolations were made i.e., restricting influence from surrounding samples through interpolating grades according to solid precedence. By incorporating the solid model to the overall block model, the extra blocks available in the area which fall outside the ore deposit are removed for a better estimation of the coal resource. The block model is also intersected with an overburden model and a surface topography model in order to exclude blocks that extend above the bedrock surface. The solid model generated was incorporated in the block model to form a constraint model.

J. Cut-off grade selection

Coal prices, reasonably assumed mining costs, metal recoveries and grades (used for comparable deposits in the region), are some of the several factors considered in determining the appropriate cut-off grade. Table 6 lists the price and recovery percentage used for coal equivalent calculations and cut-off grade determination. Based on the coal price of US$80 and recovery of 78%, a cut-off grade of 22MJ/kg was applicable to mineable blocks.

K. Filling constraint block model with attribute values

Interpolation of coal grades (calorific values) onto the block model is completed using the nearest neighbour estimation technique. The block model is filled with attribute values, these are, the coal qualities values (calorific value, ash content, carbon content and Sulphur content), specific gravity, air, waste and rock type. The block model is further intersected with an overburden model and surface topography to exclude blocks or portions of blocks that extend above the bedrock surface (air).

Coal grades are assigned to all blocks with a percent greater than zero, also flagged with a lithology code. Blocks within the model with a grade value less than the cut-off are considered waste (i.e blocks where no parts of a mineralized solid are captured, and no grades assigned) whilst those with values above the cut-off grade are considered as ore. The constraint block model modeled with assigned attributes as per the cut-off grade of 22MJ/kg thus obtained is shown in Fig. 5. The estimated tonnage of the coal mineralization for the three coal Seams was 728 039 348.4 tonnes.

ISSN: 2521-2293

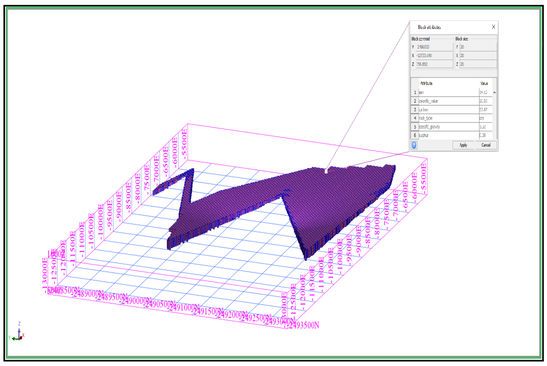

Fig. 5.Block model of the deposit showing grades through nearest neighbour method

V. RESULTS

The summarized methodology for geological data analysis and assessment as well as determining coal resources estimate is illustrated in Fig. 7.The coal mineralization in the study area was found to be widely distributed with even grade. Following this methodology, three coal seams were identified and evaluated. These seams covered a total area of 52,492,911 m^2, occupying a total volume 560,030,268 m^3 of at various depths.

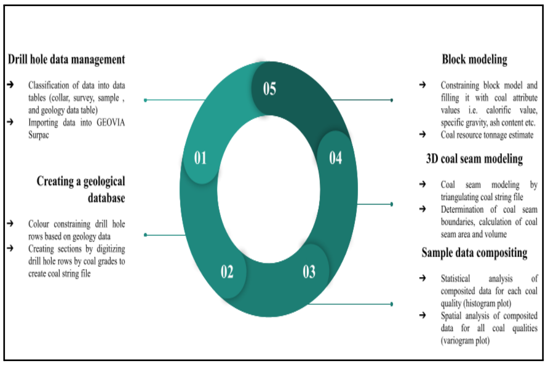

Fig. 7. Summarized methodology for geological data analysis

VI. CONCLUSION

In order to complete an updated Mineral Resource estimate for the coal seam block, with the help of a mine planning and design software Surpac, a geological database consisting of a series of comma limited spreadsheets was created into which the coordinates and alignment of the borehole points and their constituents along with their individual grades were fed into. The database included drill hole location information, specific gravity data, survey data, assay data and lithology data which were imported to GEOVIA Surpac. The borehole data was composited using downhole compositing method and statistical and spatial trends of individual constituents of coal.

Three-dimensional grade-controlled models were built by visually interpreting mineralized intercepts from cross sections using coal calorific values. Polygons of mineral intersections, snapped to drill holes, were made on each cross section and were wire framed together to create continuous resource wire frame models, the volume of the total block model was calculated, and the tonnage estimated. Mine models can then be formulated based on the resource estimates.

For the chosen study area, following the formulated methodology, coal seam boundaries were determined, a 3D solid model of coal Seams generated, and in-place coal resources evaluated. Following this methodology, three coal seams were identified and evaluated. These seams covered a total area of 52,492,911 m^3, occupying a total volume 560,030,268 m^3 at various depths.The estimated tonnage of the coal mineralization for the three coal Seams was 728 039 348.4 tonnes of mineable coal.

VII. REFERENCES

[1] Rupprecht, S., (2004). Establishing the feasibility of your proposed mining venture. In Proceedings of the International Platinum Conference 'Platinum Adding Value'. The South African Institute of Mining and Metallurgy. pp. 243-247.

[2] Sefemo, M.D., (2021). The 2018/19 Botswana mineral accounts technical report. Retrieved from The 2018-19 Botswana Mineral Accounts Technical Report.pdf (bgi.org.bw)

[3] Sahoo, M. M., & Pal, B. (2017). Geological modelling of a deposit and application using Surpac. J Mines Metals Fuels, 417.