International Journal of Coal, Geology and Mining Research
Vol.7, No.1, pp.49-63, 2025
Website: https://www.eajournals.org/
Published by European Centre for Research Training and Development UK

Thar Block Ii Lignite Resource Estimation Based on 3D Block & Gridded Seam Modelling Techniques

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Citation: Zaman H.M.T. and Iqtidar A. (2025) Thar Block Ii Lignite Resource Estimation Based on 3D Block & Gridded Seam Modelling Techniques, *International Journal of Coal, Geology and Mining Research*, Vol.7, No.1, pp.49-63

Abstract: *Pakistan holds 7th largest lignite resources in the world with about 200 billion tons of coal, mainly discovered in Thar region. Purpose of this study is to estimate total lignite resources of Thar Block II by comparing two different resource modelling techniques i.e., 3D block model (3DBM) and gridded seam model (GSM) for lignite resource of Thar Block II and discuss their benefits and limitations. In this study, drill hole data base with fixed stratigraphic information has been used to develop structural model of all layers within block boundary by using 3DMine. Resource models are developed in MineSight 3D software by using both 3DBM and GSM technique. Both models represent negligible difference in seam wise lignite volumes, tonnages, and overall quality. Lignite quality compositing criteria in both models are different i.e., GSM deals with seam constraints compositing but 3DBM offers fixed length compositing. Due to the different quality compositing techniques used in both the models, GSM generally calculates single composite value of each quality parameter for each seam within every individual borehole whereas Block model divides the composited quality values vertically using fixed lengths within each borehole. Therefore, based on quality compositing criteria, 3DBM offers more precise and detailed quality for small block outs. However, GSM provides a composite average quality of specific seam which is also considered as most reliable method for lignite coal seams (layer type deposit) with simple geometry.*

Keywords: Thar Block Ii Lignite Resource, Estimation Based, 3D Block, Gridded Seam Modelling, Techniques

INTRODUCTION

Pakistan hold the 7th largest lignite resources in the world with about 200 billion tonnes of coal, mainly discovered in Thar region with about 176 billion tonnes of lignite resource. The Thar desert of Pakistan is portion of a much larger desert extending to north and east to India (Fassett and Durrani, 1994) . Thar coal field is located in the south-eastern part of Sindh. The extension of entire lignite bearing area in Thar is about 9100 Km² (Masih, 2018). Thar Block-II covers an area of about 95.5 sq. km. Purpose of this study is to illustrate the methodology that can be applied to develop structural and resource model of coal resource. Mining has higher risks than any other business. The main source of the related mining risks is the error made in resource estimation. Accurate estimation of the location, size, shape and properties of ore deposit and interbed rock to be extracted during operation is the basics for reliable economical, technical and financial planning. This can be provided through geological modeling of the ore deposit as 3D shape and properties of materials present in the deposit (Erdem and Güyagüler, 2017). This study emphasizes comparison of two different resource modelling techniques. Now a days due to technology advancement, application of computer software packages for resource modelling has significantly strengthened the economic evaluation and confidence in geological and resource modelling (Adeshina and Muili, 2020). The ultimate objective of resource estimation is a numerical values that can nearly predict the tonnages and grades that can be exploited during a mining operations (Rossi and Deutsch, 2014).

This study focused on the resource estimation of Thar Block-II region by using 3D block modeling (3BDM) and gridded seam modeling (GSM) techniques and discuss their merits and limitations.

LOCATION OF STUDY AREA

The Thar desert of Pakistan is portion of a much larger desert extending to north and east to India (Fassett and Durrani, 1994). Thar coal field is located in the south-eastern part of Sindh, where about 176 billion tonnes of lignite resource has been explored (Rehman et al., 1993). The coal sequence in Thar coal is field is bounded by thick aquifer bodies (Kazmi, 1985). Today, 13 blocks have been demarcated in Thar from which Thar Block-II covers an area of about 95.5 sq. km. (Figure 1) with coal resource of 2.4 billion tonnes (Turner, 2017).

GENERAL GEOLOGY OF THE STUDY AREA

The Thar Coal Field lies within the Lower Indus Platform Basin. The basement consists of predominantly granitic rocks of Precambrian age that were exposed and eroded in Mesozoic times (Fassett and Durrani, 1994). The erosion cycle was followed by the deposition of the fluvial-deltaic Bara Formation during Palaeocene and Early Eocene, in a period with environmental conditions suitable for the formation of coal. Subsequently the region remained stable, resulting neither in the deposition of younger rocks nor in the erosion of the relatively thin Palaeocene-Early Eocene unit. The Thar coals occur in Bara Formation of middle Palaeocene to early Eocene age, which is in turn unconformably overlain by sub Recent alluvial deposits (Ahmad et, al., 2014). During the Neogene, the area subsided and was traversed by the Indus river system, which deposited the Pliocene alluvial sediments with an average thickness of 60-75 m. The Recent succession is composed of dune sand with a thickness of 60-90 m (Fasset and Durrani, 1994).

The lignite-bearing Bara Formation varies between 80 m and 120 m of thickness and is mainly composed of fluvial sandstones at the base grading upward into carbonaceous claystones with intercalated coal seams in the middle and upper parts. Thar coals are brownish black, greyish black and black in colour and poorly cleated to well cleated and compact. The Bara coals contain scattered resin globules of coal seams up to 30 cm thick and patches of fine-grained pyrite (Khan et al. 1996). Warwick and Thomas (1995) suggest that the Bara Formation was deposited in near-shore mires that formed in a subsiding basin during a relative low stand. The stratigraphic contacts of the Bara Formation are marked by unconformities with the Precambrian basement at the base and Pliocene alluvial deposits at the top (Table 1).

The Bara Formation is structurally simple with minor faulting and strata dipping gently at around 2° to the west-northwest. The Thar deposit limit to the south is the Rann of Kutch Fault with E-W orientation. To the north the coal thins abruptly at approx. 26°10' of latitude. To the east the boundary is either the paleo-coastline or an erosional limit due to uplifting in post-Eocene times (Figure 1).

Stratigraphy of study area is nearly horizontal and no large scale faulting has been identified. The coal-bearing Bara Formation is intersected between 130m and 250m depth. The coal bearing layers of Bara Formation are named as CL1-1, CL1-2, CL2-1, CL2-2, CL2-3, CL2-4, CL2-7, CL2-8, CL3-1, CL3-2 and CL3-3 which are divided into 02 main groups i.e. mineable and non-mineable seams (Figure 2).

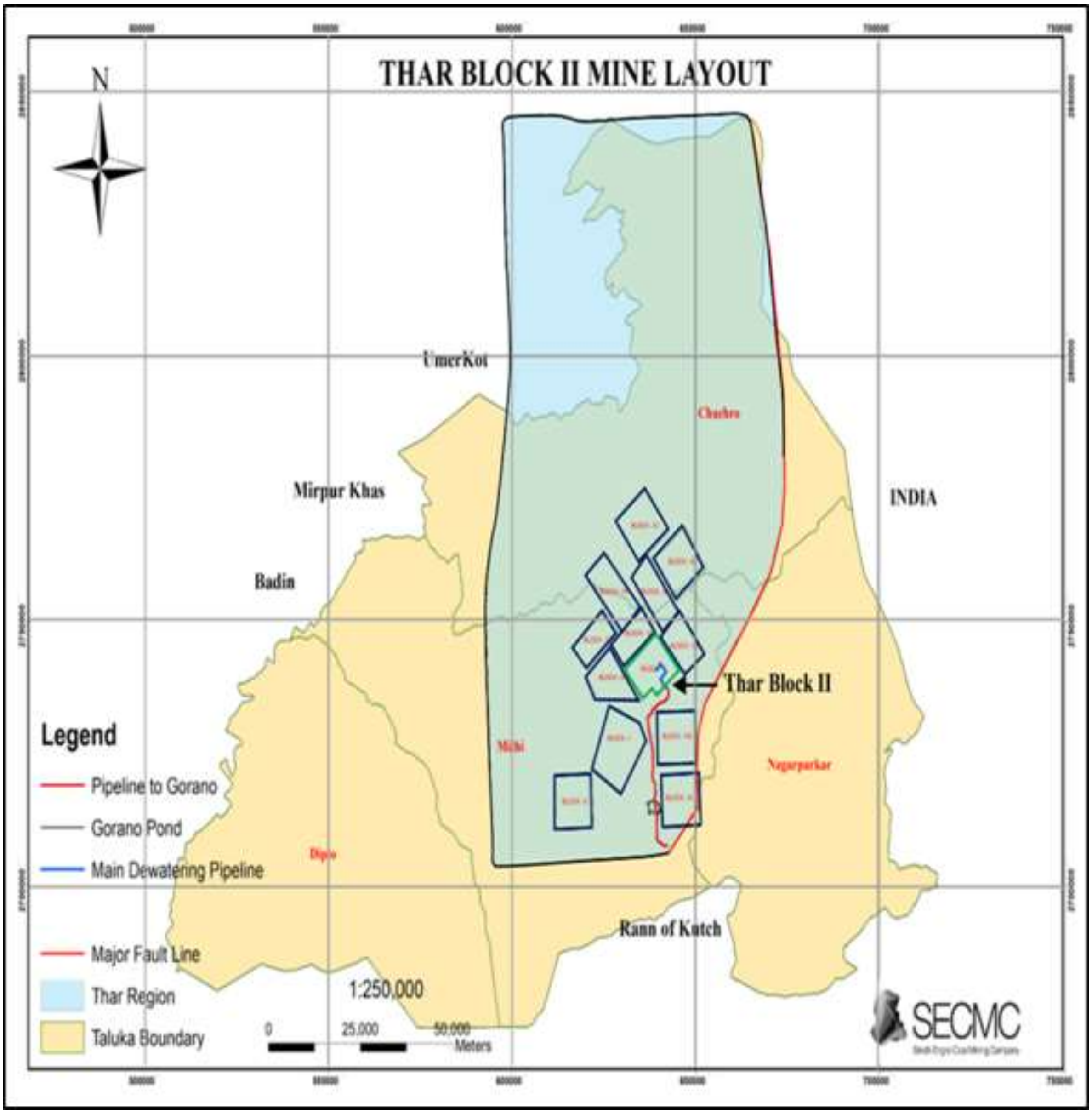

Figure 1: Location map of study area, Thar Block-II, Sindh.

Vol.7, No.1, pp.49-63, 2025

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Considering the limited thickness pinch outs and high strip ratio, CL1-1, CL3-1, CL3-2 and CL3-3 are classified as non-mineable seams and not included in resource model.

METHODOLOGY

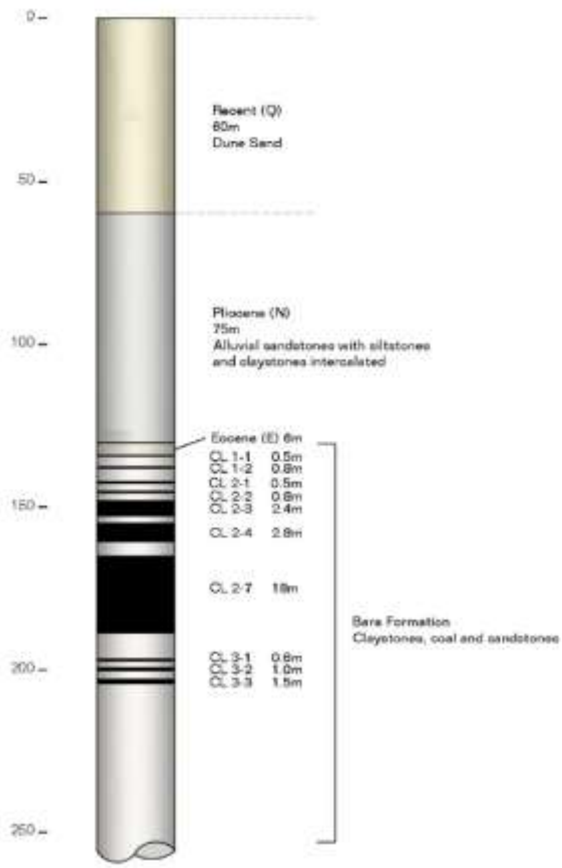

Figure 2: Typical stratigraphic column of study area, Thar Block-II, Sindh (modified after Ahmad et al., 2014)

Exploration and Drill Hole Data

After the first coal intersections in 1980 during drilling of water bores in the Thar desert, a test drilling programme of 4 boreholes was conducted in 1992 by GSP and USGS with HQ & NQ diamond bits. The exploration results confirmed the presence of thick coal beds near the village of Thare-Jo-Tar with a cumulative coal thickness of approximately 30 m. In 1992-1993 the GSP and USGS drilled 21 boreholes in order to define the horizontal extent of the lignite deposit. In 1993 another 10 boreholes were drilled by GSP in association with the United States Agency for International Development ('USAID') through John T. Boyd for first mining investigations, followed by 3 additional boreholes in 1994. Among the 38 boreholes drilled between 1992 and 1994, only 2 of them (TP3 and SPT3) were drilled in the Block II area with HQ & NQ diamond bits.

Table 1: Stratigraphy of Thar Block-II, Sindh, Pakistan (modified after Ahmad et al., 2014)

Age	Stratigraphic Unit	Description
Recent	Dune Sand	Medium to fine grain sand
Pliocene	Sub Recent	Semi-consolidated to consolidated sandstones with gravelly intervals toward the base. The middle part consists of siltstones and claystones with frequent limonite nodule and ferruginous oxide. The upper part contains partly cemented sandstones.
Paleocene-Eocene	Bara Formation	Grey-white sandstones at the base grading into carbonaceous claystones with intercalated coal seams in the middle and upper intervals.
Paleozoic	Basement	Predominantly granite with amounts of rhyolite and metamorphic rocks.

In 1995-1996, a total number of 43 boreholes (SB and SBNC series) were drilled in Block II, with 26 cored holes by GSP and 17 non-cored holes by a private contractor. A total of 570 samples were collected and all holes were geophysically logged with a minimum wireline suite of gamma ray, density and caliper. Coal core samples taken by GSP were split in half. One half was packed into a plastic bag and then placed in PVC pipe, sealed and sent to GSP laboratory for analysis. The other half was placed in core boxes for record purpose. Sampling lengths ranged from 0.3 m to more than 3.0 m. The 26 SB cored holes provided 300 samples available for this resource estimate.

In 2002, a detailed exploration programme and resource evaluation was undertaken by NECB. This drilling programme consisted of 111 boreholes (C series). All boreholes were logged for gamma ray, density, resistivity, spontaneous potential, caliper and verticality. In all NECB drill holes, collar coordinates were determined by GPS with an instrument precision error of less than 1 mm. Core samples were packed in four high-strength plastic bags and put into sealed transport boxes before being transported by air to Shenyang, China for analyses. Sampling lengths ranged from 0.9 m to 3.0 m. A total number of 1,215 core samples (926 of coal) were taken from 85 drill holes which are available for this resource estimate. Since 2009, SECMC has lead the resource evaluation and feasibility studies of Thar Block II. SECMC completed a total of 17 hydrogeological drill holes, including 02 core holes (G2 and C1) which provided 30 core samples available for this resource estimate. In 2014 and 2015, 6 cored holes (PP1 and ZK series) were drilled in the initial mining box cut area for geotechnical and coal quality assessment.

Between 2016 and 2017, SECMC completed 58 cored holes distributed across the Block II area, 44 of them located in the initial mining area. All holes were surveyed and geophysically logged using gamma ray, density, resistivity, spontaneous potential, caliper and verticality. Core samples were recovered using 1.5 m core barrel. The core samples were washed using raw water and placed in plastic sleeves packed with scotch tape. Then the sleeved core was wrapped with cotton bandage and packed with plastic tape. Finally, the packed samples were stored in PVC pipe and labelled before being transported in vehicle to the testing laboratory. total number of 562 samples from SGH holes were analyzed for coal quality and used in this resource estimate.

Drill holes were drilled using reverse rotary drilling rigs and wire-line core barrels with HQ (63.5mm core diameter) and NQ (47.6 mm core diameter) diamond bits for coring. The drilling medium used was bentonite and CMC polymer mud, occasionally supplemented by locally purchased additives. Non-core drilling was done using tricone roller bit.

Data Verification

Data verification includes; drill hole coordinates and comparison of drill hole collar elevation with existing topography data, sedimentary logs verification which includes lithologies, seam name and depths, geophysical logs used to calibrate the seam depths and core samples with depths and laboratory test results.

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Structural Model

The coal seam structure has been modelled within modelled boundary (Figure 3) by using 3D mine software based on the drill hole intersections and supported by the geological field data and geophysical logs. The coal succession comprises a total number of fifteen coal intervals which occur over a sequence of approximately 120 m thick, with the top seam intersected at 120-130 m of depth and the bottom seam at 220-230 m.

The coal seam CL1-1, CL3-1, 3-2 and 3-3 shows frequent thickness variation of the coal and interburden due to this their inconsistency these seams are not included in the resource.

For better structural modelling purpose, some coal seams are locally split in Upper and Lower seams in the model. i.e. CL2-3 is divided in CL2-3U and CL2-3L, CL2-4 in CL2-4U, 2-4L, CL2-7 in 2-7U and 2-7L and CL2-8 in 2-8U and 2-8L.

All drill holes have been modelled as vertical. All seams were set to be conformable with the seam stratigraphically below, and all seams were allowed to pinch out where not present in a drill hole. The model Schema is set up to allow for the coal seams to have associated upper and lower plies (e.g. CL2-3U and CL2-3L) where splitting occurs with a minimum separation of 0.5 m. All partings less than 0.5 m thick were sampled either individually or together with the coal, providing quality values for the seam composite and thus modelled as part of the seam. The structural model uses the inverse square distance method with a search radius of 1,000 m. The higher interpolation order given to surface allows the seams to follow the general structural trend beyond the data points in areas where few drill holes exist. All other parameters of structural model are mentioned in Table 2 and 3. Structurally modelled layers have been exported in *.dwg format so that it can be utilized in Minesight 3D for block or gridded seam modelling.

Table 2: Structural or geological and quality modelling units.

Unit	Formations	Compound/Plies	Description
Recent (Dune Sand)	Q	DS1	Recent dune sand above compacted layer
		DSC	Compacted Sandstone
		DS2	Recent Dune sand below compacted layer
Sub-Recent (Pliocene Alluvial Sediments)	N	ST	Siltstone
		SC1	Silty Claystone 1
		CS1	Clayey Siltstone 1
		SC2	Silty Claystone 2
		CS2	Clayey Siltstone 2
		SC3	Silty Claystone 3
		A2	2nd Aquifer
Eocene – Pliocene (Bara - Coal Bearing)	E	IB11	IB 1-1 Interburden
		CL11	CL 1-1 Coal Seam
		IB12	IB 1-2 Interburden
		CL12	CL 1-2 Coal Seam
		IB21	IB 2-1 Interburden
		CL21	CL 2-1 Coal Seam
		IB22	IB 2-2 Interburden
		CL22	CL 2-2 Coal Seam
		IB23U	IB 2-3 Interburden Upper Split
		CL23U	CL 2-3 Coal Seam Upper Split
		IB23L	IB 2-3 Interburden Lower Split
		CL23L	CL 2-3 Coal Seam Lower Split
		IB24U	IB 2-4 Interburden Upper Split
		CL24U	CL 2-4 Coal Seam Upper Split
		IB24L	IB 2-4 Interburden Lower Split
		CL24L	CL 2-4 Coal Seam Lower Split
		IB27U	IB 2-7 Interburden Upper Split
		CL27U	CL 2-7 Coal Seam Upper Split
		IB27L	IB 2-7 Interburden Lower Split
		CL27L	CL 2-7 Coal Seam Lower Split
		IB28U	IB 2-8 Interburden Upper Split
		CL28U	CL 2-8 Coal Seam Upper Split
		IB28L	IB 2-8 Interburden Lower Split
		CL28L	CL 2-8 Coal Seam Lower Split
		IB31	IB 3-1 Interburden
		A3	3rd Aquifer Sub-burden

3D Block Modelling and Parameter

3D block model describe 3-dimensional volumes with small sized parallelepipeds. 3DBM are useful tool for resource estimation, mine planning and evaluation. Mainly majority of mineral resource estimates are obtained using block models. For each of these grid or area, an estimated grade is taken by weighted average along the specified dimensions of the area and an assumed density which can be used to estimate the tonnages and grade of each section or gird (Stone and Dunn 1996). Characteristics of geological deposits and features will drive the geometry of block model. For deposits with simple geometry i.e. Thar Coal regular single size blocks are generally used (Rossi and Deutsch, 2014). 3D block modeling technique is appropriate for vein, massive and disseminated type deposits. This technique can also be applied to steeply dipping strata to very thick coal seams (Erdem and Guyaguler, 2017)

3D Block Modelling and Parameter

Table 3: Structural modelling parameters.

Modelled Quality Items	Description
MO	Total Moisture (%_ar)
MI	Inherent Moisture (%_ar)
AS	Ash (%_ar)
ASD	Ash (%_d)
VM	Volatile Matter (%_ar)
VMD	Volatile Matter (%_d)
QG	Gross Calorific Value (MJ/Kg_ar)
QGD	Gross Calorific Value (MJ/Kg_d)
QN	Net Calorific Value (MJ/Kg_ar)
QND	Net Calorific Value (MJ/Kg_d)
TS	Total Sulphur (%_ar)
TSD	Total Sulphur (%_d)
FC	Fixed Carbon (%_ar)
FCD	Fixed Carbon (%_d)
ISD	Insitu Density (gm/cm^3)
SI	Ash Analysis – SiO2
AL	Ash Analysis – Al2O3
FE	Ash Analysis – Fe2O3
CA	Ash Analysis – CaO
MG	Ash Analysis – MgO
SO	Ash Analysis – SO3
TI	Ash Analysis – TiO2
K	Ash Analysis – K2O
NA	Ash Analysis – Na2O

Modelled Element	Description
Drill holes Used	222
Stratigraphic Elements	10 overburden units, 12 coal intervals
Overburden Sequence	Conformable
Seam Sequence	Conformable
Min. Separation Thickness for Seam Splitting	>0.5 m
Seam Continuity	Continuous
Unconformity	2
Overburden Structure Software Used	3D Mine (Grid interval: 20m)
Seam & Interburden Structure Software Used	3D Mine (Grid interval: 20m)
Search Radius	1000 m
Easting	Min: 638130.00 ; Max: 642290.00
Northing	Min: 2738650.00 ; Max: 2742830.00
Elevation	Min:160 ; Max: 140
Datum and Projection System	WGS-84 UTM Grid

Table 4: 3D block modelled parameters.

Modelled Element	Description
Grid Type	Block Model
Grid Area	95.5 Km^2
Grid Cell Size	20 * 20 * 2
Grid Compositing	Fixed Length
Interpolation Method	Inverse Distance Squared
Search Radius - Seams	1,000 m
Assumed Density	CL2-7 & CL2-8 : 1.19g/cc
	Other seams : 1.275 g/cc
	Partings (<0.5m thickness) : 1.93 g/cc

Table 5: Gridded seam modelled parameters.

Modelled Element	Description
Grid Type	Gridded Seam Model
Grid Area	95.5 Km^2
Grid Cell Size	20 * 20 * Seam thickness
Grid Compositing	Seam constraint
Interpolation Method	Inverse Distance Squared
Search Radius - Seams	1,000 m
Assumed Density	CL2-7 & CL2-8 : 1.19g/cc
	Other seams : 1.275 g/cc
	Partings (<0.5m thickness) : 1.93 g/cc

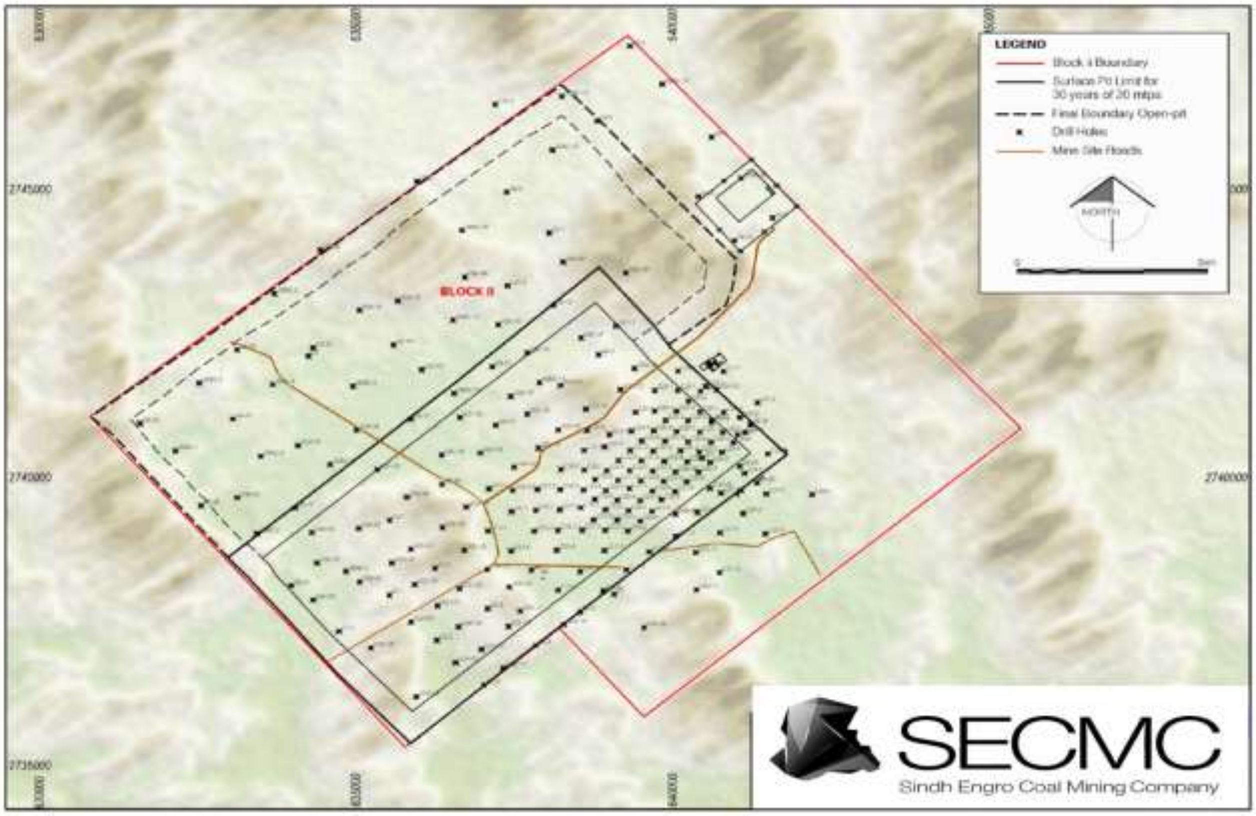

Figure 3: Modelled boundary of study area.

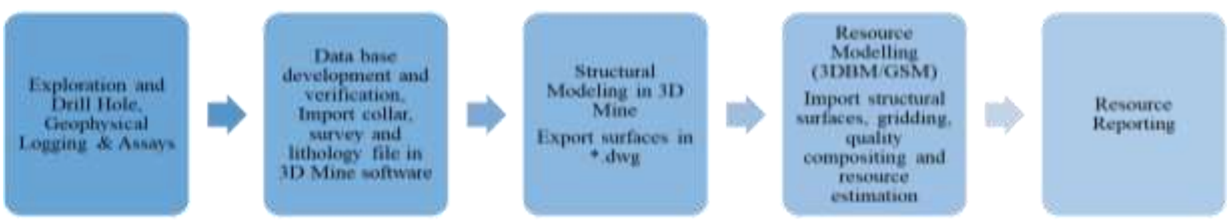

Figure 4: Generic workflow of resource modeling and estimation.

In addition to the structural models of the seams, it is necessary to model various coal quality parameters such as ash content, sulfur, total moisture, calorific value and density. As the original analyses on the drillholes do not necessarily follow the correlated and fixed stratigraphy, it is necessary to composite these values to receive a single value for each parameter per correlated seam before modelling the parameter in two or three dimensions as a grid model (Kapageridis, et.al., 2018).

3DBM parameters are mentioned in Table 4 and complete workflow from data collection to modelling is shown in Figure 4.

Gridded Seam Modelling and Parameter

Working principle of GSM working is similar to a standard block model, with two exclusions. One is that, GSM may have variable height of each block, unlike block model. Therefore, the blocks in a layer describe the thickness and extent of a deposit such as a lignite coal seam. Second one is that GSM supports sparse model concept. In this concept, only the layers of interest are modeled. Layers between the seams (interburden) are excluded from the resource. The input data must be split into litho, survey and collar files, where each file contains the assay data corresponding to a particular seam. This method allows interpolation to proceed for each seam and interburden without having the connecting seams affect the final resource estimate (Erdem and Guyaguler, 2017). This is the major advantage of the GSM. For example, the thickness of ore deposit can be estimated by subtracting the lowest structure from the top structure. The other important advantage of GSM needs lower disk space because after defining the reference point, locations of the others can be calculated easily by the software. In other words, there is no need to store all easting and northing coordinates. In addition, drawing contour lines and volumetric calculations of map modifications are much faster using gridded seam model (Erdem and Guyaguler, 2017). GSM parameters are mentioned in Table 5 and complete workflow from data collection to modelling is shown in Figure 4.

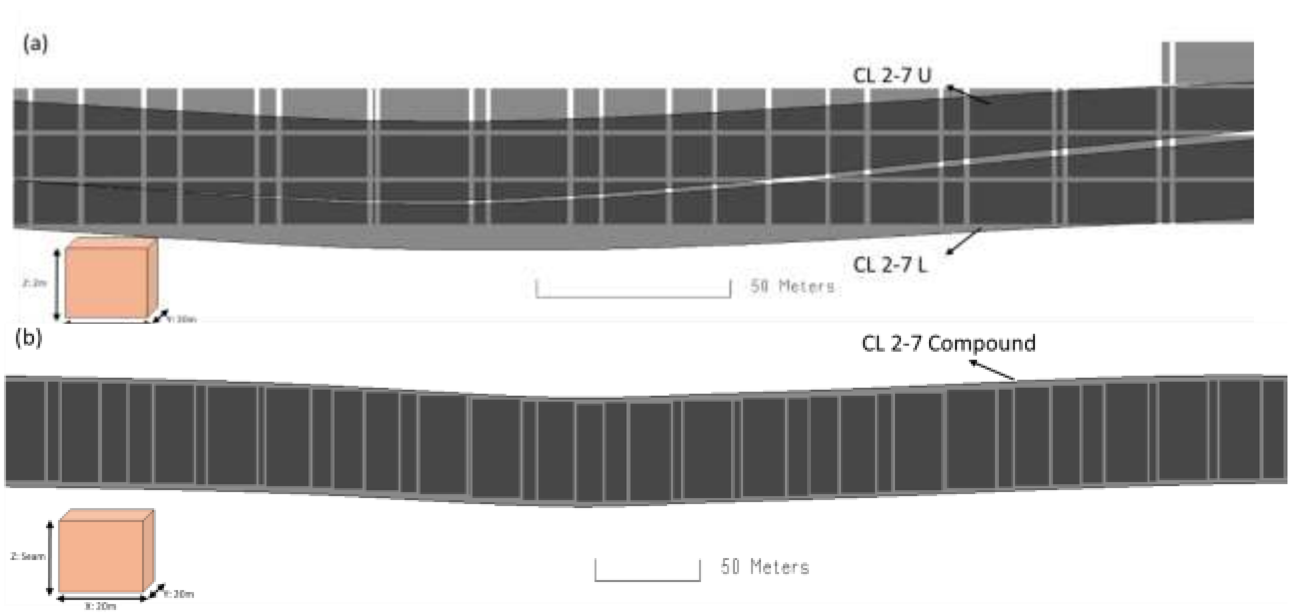

Figure 5: (a) Cross-section showing 3D block modelling in which blocks with vertical z-elevation as fixed length (b) Cross-section showing gridded seam modelling in which blocks with vertical z-elevation as seam thickness

RESULTS AND DISCUSSION

Coal Quality Compositing – 3DBM vs GSM

Compositing of quality parameters such ash, volatile matter, heating value etc. is the major requirement of any type of resource or quality model, however quality compositing may vary in accordance with the modelling techniques. For instance, if we use GSM compositing technique for quality compositing then it will be honoring the seam top and bottom and assigned an interpolated quality value to the whole seam as shown in Figure

5(b) and Figure 6. In contrast, in 3D block model compositing, z-interval is fixed for quality compositing. In this case we consider 2m z-interval for quality compositing as shown in figure 5(a) and 7.

Total moisture (%), Ash_ar (%), Net calorific value_ar (MJ/Kg) and Total sulfur_ar (%) were modelled by using both techniques i.e. GSM and 3DBM, results of both models have been reported in accordance with similar mine designs. During this comparison, it is evident that there is not much deviation is observed in mentioned parameters, such as only 0.05% difference in total moisture, 0.07% variation is observed in Ash_ar, 0.08 MJ/kg difference is observed in net calorific value and so on. In short, in quality parameter no major deviation is observed in quality modeling of coal seams (Table 6).

Due to the different quality compositing techniques used in both the models, GSM generally calculates single composite value of each quality parameter for each seams within every individual borehole whereas Block model divides the composited quality values vertically using fixed lengths within each borehole, however GSM is more suitable for resource estimation in seam or tabular type deposits. As GSM is based on the set of 02 dimensional grids and third one is thickness of seam itself and each grid represents a surface or a value, these surfaces

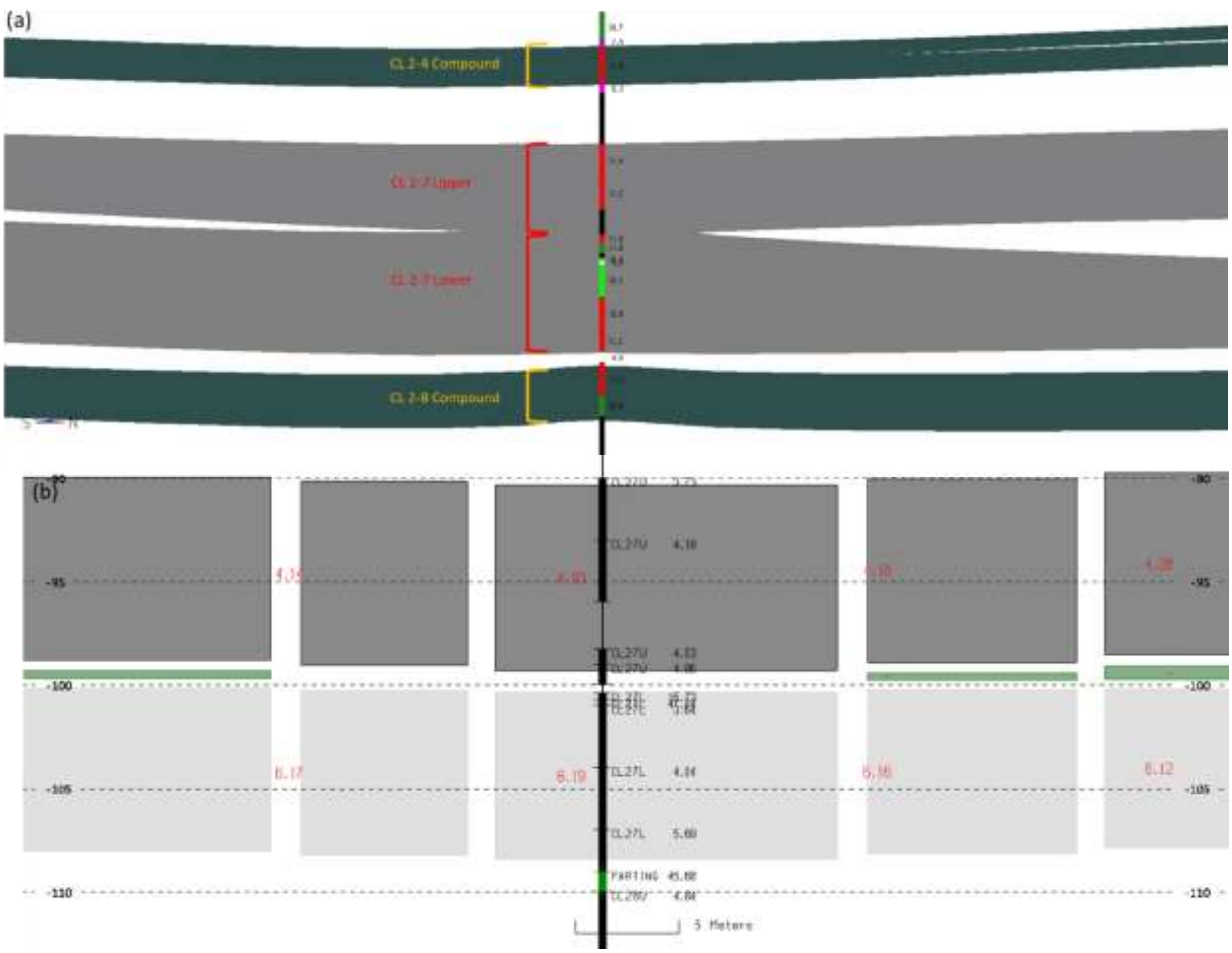

Figure 6: (a) Cross-section showing quality compositing of heating value in MJ/Kg (b) quality compositing of Ash % in coal seams by using GSM technique

or values are estimated by interpolation using a set of irregularity spaced data to a fixed dimension grid. GSM is widely used to develop resource model of multiple seams and other layer type mineral deposits, because interpolation of data is very handy by using the developed grids (Erdem and Guyaguler, 2017)

Seam Wise Resource Comparison – 3DBM vs GSM

Resource model has been developed by using modelled structural surfaces in accordance with both techniques i.e. GSM and 3DBM. As mentioned above, 3DBM used x, y and z for modelling purpose and z-elevation is fixed in each 3D block model however in GSM z-elevation is the function of seam thickness. To compare the performance of both modeling techniques in lignite coal deposit of Thar Block-II, both resource models volumes and tonnages have been reported on same mine design to get the apple to apple comparison. During comparison it is evident that negligible difference is observed in terms of tonnages or volumes (Table 7). Therefore, due to negligible difference in both volumes or tonnages so we may conclude that GSM and 3DBM both are reliable for resource modeling of lignite seams, however due to the convenience of splitting of coal seams and interburden, calculation of seam thickness and software handling, GSM may be referred as best fit technique for resource modelling of coal / lignite seams (layer type deposit) with simple geometry.

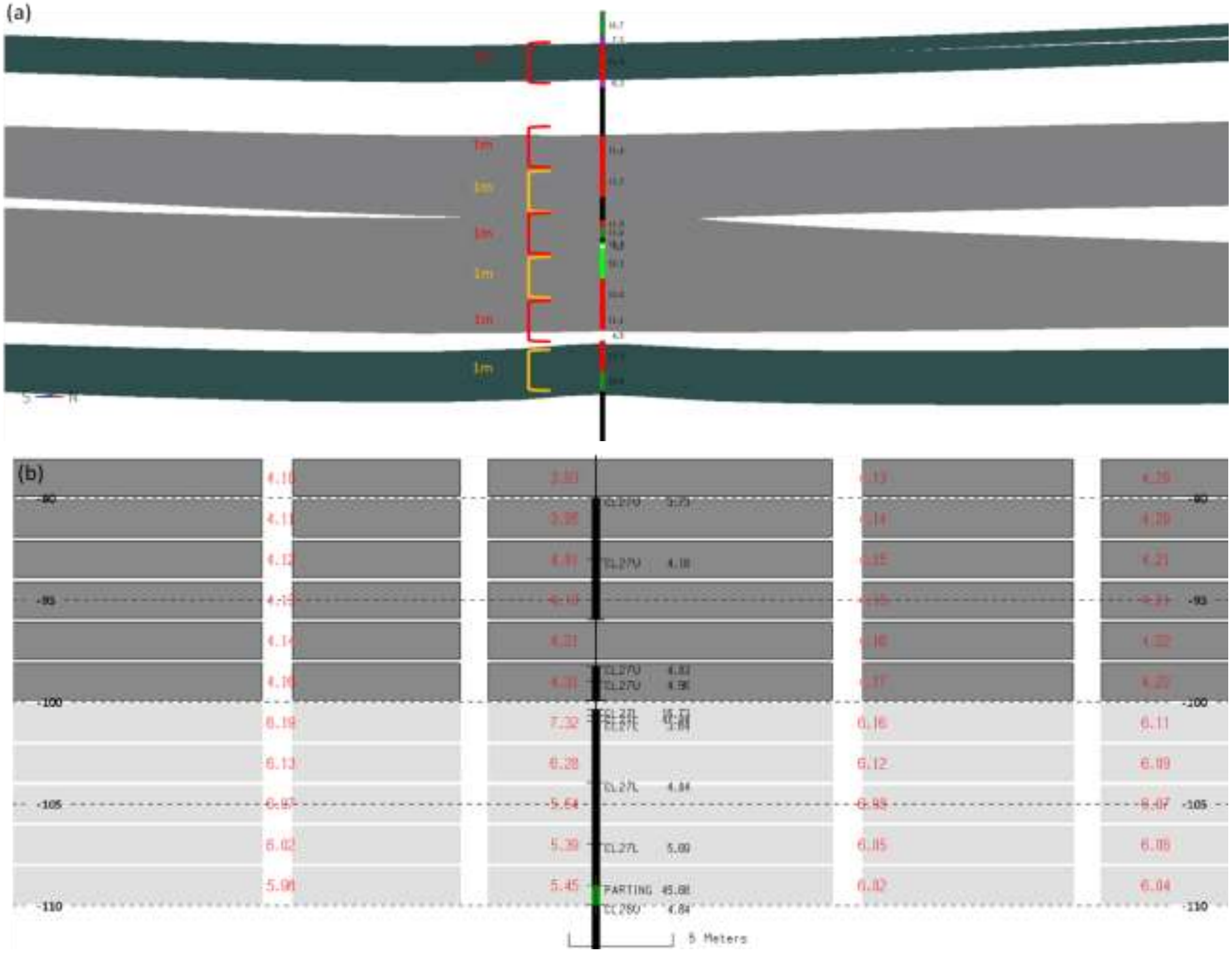

Figure 7: (a) Cross-section showing quality compositing of heating value in MJ/Kg (b) quality compositing of Ash % in coal seams by using 3DBM technique

Table 6: Showing comparison of coal quality of GSM and 3D block models resource.

Seam	Insitu Total Moisture_ar (%)		Insitu Ash_ar (%)		Insitu Qnet_ar (MJ/Kg)		Insitu Total Sulphur_ar (%)	
	Gridded Seam	Block Model	Gridded Seam	Block Model	Gridded Seam	Block Model	Gridded Seam	Block Model
CL 1-2	45.44	46.64	11.02	10.82	11.28	10.77	3.63	2.98
CL 2-2	47.12	47.12	12.30	12.28	9.95	9.95	2.55	2.53
CL 2-3 Upper	48.65	48.64	9.16	9.01	10.42	10.47	1.76	1.78
CL 2-3 Lower	48.83	48.66	9.23	9.16	10.40	10.41	1.90	1.83
CL 2-4 Upper	46.71	46.61	11.11	11.49	10.37	10.28	1.10	1.15
CL 2-4 Lower	46.74	46.22	12.69	13.47	10.08	9.96	1.25	1.27
CL 2-7 Upper	49.43	49.63	6.09	6.10	11.30	11.25	1.01	1.04
Average	**47.80**	**47.85**	**9.92**	**9.99**	**10.55**	**10.47**	**1.83**	**1.77**
ar=as received								

Table 7: Showing comparison of coal tonnages of GSM and 3D block models resource.

Seam	Insitu Tonnages (Mt)	
	Gridded Seam Model	Block Model
CL 1-2	64.30	64.36
CL 2-1	5.90	5.91
CL 2-2	54.45	54.57
CL 2-3	218.50	218.53
CL 2-4	287.50	288.54
CL 2-7	1,577.50	1,575.80
CL 2-8	191.50	191.10
Total	**2,400**	**2,399**

SUMMARY AND CONCLUSION

Resource model of Thar coal Block-II has been developed by using exiting borehole data in accordance with 02 different modelling techniques such as 3D Block Modelling (3DBM) and Gridded Seam Modelling (GSM). After detailed comparison of both techniques in terms of volumes, tonnages and quality modelling following points are concluded:

- GSM deals with seam constraints compositing but 3DBM offers fixed length compositing
- Based on quality compositing criteria, 3DBM offers more precise and detailed quality for small block outs. However, GSM provides a composite average quality of specific seam
- GSM is more reliable and convenient for resource and quality estimation in lignite coal seam or tabular type deposits.

ACKNOWLEDGEMENT

We would like to thank Sindh Engro Coal Mining Company (SECMC) management; especially Muhammad Azhar Malik [Vice President - Site Operations] and Faisal Shafiq [General Manager – Mine Operations] for his support and allowing the publication of this paper.

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