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# 3-Dimensional Modeling and Analysis of Mineable Seam of Khalashpir Coal Field, Rangpur, Bangladesh

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***Abstract*—Khalashpir is one of the six discovered coal fields situated in Pirganj Upazila, Rangpur District, Bangladesh. With a 3 Dimensional modeling it is possible to evaluate the distribution of sedimentary rocks; orientation, continuity, structural thickness and elevation of the coal and thus a mineable seam can be selected both throughtime and space. In the Khalashpir basin, the coal bearing sequence is divided into 8 zoneswith an average composite thickness of about 37.21 meters,containing numerous coal beds. The seam I, II, and IV constitute the major part of the resources with average thickness of 8.303 m, 9.778 m and 11.43 m respectively. Among these, Seam IV might be very potential for mining because it is situated below the probable seams and contains major part of coal reserves, which is about 145.63 million tons (almost 31% of total reserve) and also with good quality and better position in the basin. This study targets a better understanding for Khalashpir coal basin through 3-D modeling and analysis.**

***Keywords*—Khalashpir coal field, 3-D geological modeling, coal bed, mineable seam, coal reserve.**

## I. Introduction

The Khalashpir coal basin is located almost in the western part of Pirganj Upazila, Rangpur District, Bangladesh. It is situated at a probable distance of 290 km north from Dhaka and 48 km south from Rangpur District. The coal field was delineated and defined by the Geological Survey of Bangladesh (GSB) in 1989 on the basis of 4 borehole GDH-45, GDH-46, GDH-47, and GDH-48. Afterwards, a Chinese Company consortium with Hosaf International Ltd. and Senwine Mining Group Co. Ltd. further carried out a feasibility study and drilled 14 more boreholes, which are GTB-1, GTB-2, GTB-3, GTB-4, GTB-6, GTB-8, GTB-9, GTB-10, GTB-12, GTB-16, GTB-18, GTB-19, GTB-20 and GTB- 21 (2004-2006) to explore geological extent and other commercial aspects of the basin at the Khalashpir Coalfield.

2-D seismic survey was done in order to find out the boundary of the coal bed deposits, basic structural shape, and the fault which is around 20 meters.Later on,3-D seismic survey was carried out in mining area to have a clear picture of the fault.Within the structural limits of the basin,there are 8 coal seams that ranges at a depth from 239 to 485 m below the surface with an average composite thickness is 37.21 meters. The most vital and potential reserves are found within seam IV, with a variable thickness of 11.43 m. However, the Borehole data available in case of Khalashpir coal field at that time, were not adequate to execute the three dimensional modelling. It is to be mentioned that the Grodner (2002) used 1190 borehole logs collected from three mining companies, which were used to prepare 3-D modelanalysis of the Permian Witbank coalfield of South Africa. So far no detail investigation or research work have been conducted over Khalashpir coal basin.

Literatures on the three dimensional modeling of coal basin in Bangladesh are rare, though a few work weredone on hydrogeological and aquifer modeling in 3-D (Haque, 2006, Mostafa, 2005, Rahman, 2005). The authors of this research work took the initiative with a limited data of boreholes to prepare a 3-D modeling to evaluate the distribution of rocks, and orientation of coal seam both through space and time.

## II. Tectonic Structure Of The Deposit

The Khalashpir coal deposit lies in an asymmetric synclinal basin with an axial NW-SE strike. In 2005, 2D and 3D seismic surveys were conducted and therefore major tectonic structures were discovered.Though data were acquired in general, sequence stratigraphy of the coal seam is variable. The western limit of the deposit is formed by the successive sub-crop of the seams beneath the overlying Miocene / Pliocene Surma Formation.

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Based on China Jinan Mining Development corporations report, seven normal faults have been identified by the seismic survey, trending generally sub parallel to the NW-SE synclinal axis. The three largest faults in the FS are interpreted with maximum vertical displacements with 50 m of extent. These major fault discontinuities effectively subdivide the prospect into four discrete blocks and resource estimation as well as preparation for a conceptual mine could be done with the division.

## III. Stratigraphy And Coal Seam Correlation

The stratigraphy of the coal field area was juxtaposed on the basis of these drill holes data. Permian Gondwana Group is the oldest rock unitcovered by Barind clay residuum and Alluvium sediments. The stratigraphic sequences are identified as Gondwana Group of Permian age, Barind clay residuum of Pleistocene age and Alluvium of Holocene age.However, detailed correlation of the coal seams remains problematic. The original GSB exploration proposed a succession of coal seam horizons within the Permian Gondwana sequence in descending order and designated eight seams as No. I to No. VIII. GTB generation of explorationwas inspired by the correlation, although the graphic logs presented in the FS, clearly demonstrate that the correlation is not conducive to the simple sequence of eight seams due to rapid seam splits and unions within all groups of seams across the entire prospect, resulting in rapid coal and interburden thickness variation.

Hence, the dearth of analytical data daunts further investigation to correlate from chemical and physical properties.

**TABLE-I**
**STRATIGRAPHIC SUCCESSION OF KHALASHPIR COAL FIELD**

| Age | Group/ Formation | Lithology | Max. Thickness (m) |
|---|---|---|---|
| Holocene | Alluvium | Grey sand and silty clay. | 4.26 |
| Pleistocene | Barind clay residium | Yellowish gray silty clay. | 6.10 |
| Pliocene | Dupi Tila Formation | Grey to yellowish gray sandstone with uncommon mudstone. | 162.12 |
| Miocene | Surma Group | Grey to dark gray mudstone, sandstone and pebbly sandstone. | 184.14 |
| Permian | Gondwana Group | Felspathic sandstone, carbonaceous sandstone carbonaceous shale, siltstone, mudstone, coal and conglomerate. Base not seen | 814.93 + |

*Coal Quality*

Core samples from the initial GSB boreholes were analyzed. The horizons of ~~the~~ each sample are identified in the FS report, although they have been averaged over the whole seam. But it lacks detailed sub section analysis which could help to correlate the seams.

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Interestingly, metallurgical cocking properties are diagnosed in some samples. IMC recommends that this possibility is explored further with a number of isolated samples taken from new cores or re-sampling the existing cores, if the origin of the samples can be unquestionably verified.

Average analytical results of the coal of Khalashpir coal field (GSB) show that it has moisture (6-5%), Fixed carbon (32-66%), Volatile matter (6-29%), Ash (7-50%), and Sulphur (less than 1%).The coal is bituminous. The maceral analysis shows more than 70% vitrinite in 6 samples. Samples have small Fusinite and pyrite is present as vein lets or nodular pore fillings. Coal seam I&II has relatively high inertinite contents with low volatile matter. The upper 6 meters of coal seam II contains about 100% inertinite which can be mined as special cut for blending with high vitrinite coal to increase the cooking strength. Samples from several beds show good cocking properties.

*Objectives of the study*

The rationale behind the work is to identify the mineable coal seam with 3-D modelling, in Khalashpir coal field. The objectives can be pointed briefly as follow:

1. Lithological,stratigraphic and 3-D coal reserve modeling based on digital data by rock ware software.
2. To get the 3-D cross sectional view of the reserve by rock ware software.
3. To determine the potential zone for quality coal extraction from Khalashpir coal field.
4. To select the potential mineable coal seam with good quality and better position in the basin.
5. To identify the Structural thickness andmineable seam elevation.

## IV. Methodology And Modeling

*Contour map*

Contour map was drawn by collecting all the data and converting them to digital format, and finally with an interpretation in a spread sheet of MS Excel.All 14 borehole data were interpreted into Rockware software with following parameters- proper longitude/latitude, Easting/Northing, Elevation, Total depth, Symbol and colour.Below, the image of the Rockware with borehole data represents all borehole locations in the map.

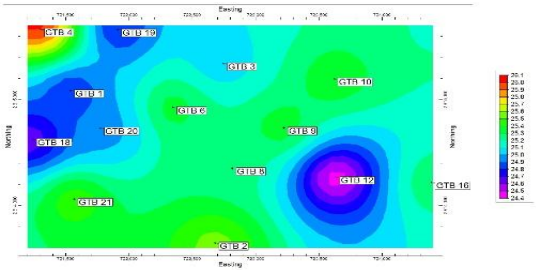


**Figure-1: Contour map indicates all boreholes in Khalashpir coal field.**

*Data and Software*

The drill and record of the datasets from 14 borehole logs were done by Hosaf International limited and Shangdong Ludi 2006 (figure 2(a)-no stretching). Such borehole logs are converted to a common data format and spatial information are converted to planner earth projection UTM (Universal Transverse Mercator) for better area and volume calculation as well as 3-D analysis (Figure 2 (b)-with stretching). Coal seam volume calculation was done with various surface mapping & computing software and 3-D analysis was done with Rockware Version 15(Rockware Inc. Golden, CO,USA). The specific log is indicated by left sided coloredlithologic symbols.

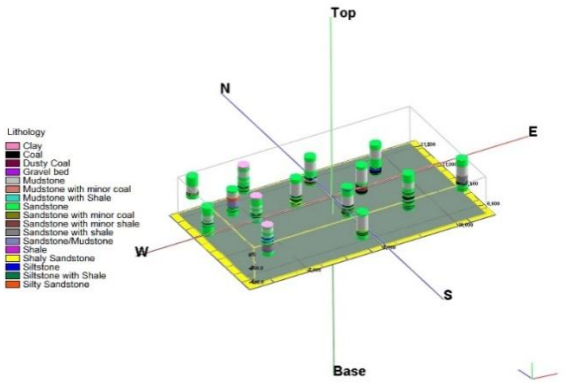


**Figure-2 (a): All 14 logs are shown in a 3-D orientation without stretching.**

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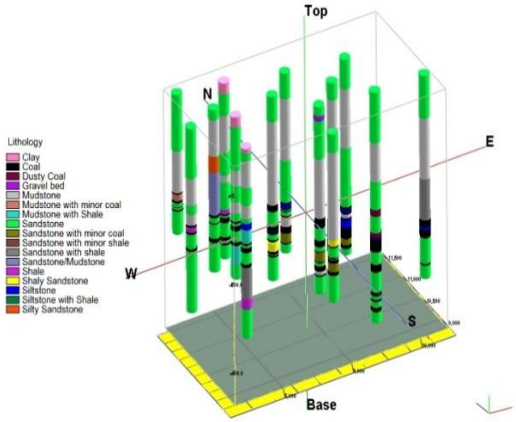


**Figure-2 (b): All 14 logs are shown in a 3-D orientation with stretching.**

*Lithologic bed and lithostratigraphy*

The lithological sequences are not same spatially and vertically as these are composed of clay, sandstone, mudstone, shale, coal, sandstone with minor coal, mudstone with minor coal, siltstone. Coal seams are buried ranging from 257 m to 480 m beneath the surface. Lithological modeling shows the distribution of all lithology in 3-D. Some of the lithological units are also patchy. Clay and sandstone are teemed in the surface and the grans become coarser gradually with depth. The formation thickness increases proportionally as it approaches to the northern part. The modeled basin shows coarser or finer grained lithologic strata in 3-D fence pattern(figure 3 a) & mixed lithology in 3-D fence diagram( Figure 3 b) The 3-D fence diagram represents the dominance of the coal seam in the southwestern part and also their discontinuity through the basin.

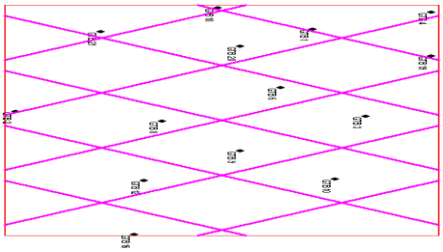

**Figure-3 (a): Fence diagram pattern based on lithologic modelling-used Rockworks 15 with Inverse Distance (ID)**

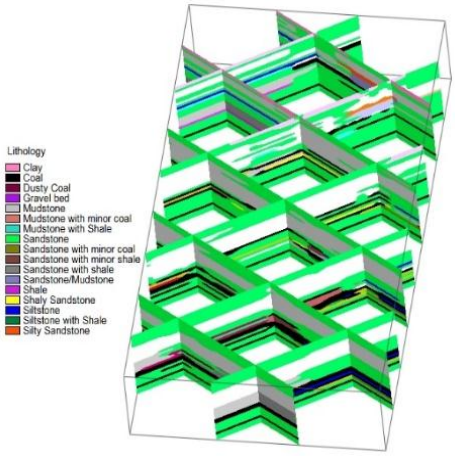


**Figure-3 (b): Fence diagram based on lithologic modelling-used Rockworks 15 with Inverse Distance (ID**

*3-D characteristics of the coal sequences*

By using a 3-D model it is possible to evaluate the distribution of subsurface formation, both through space and time. By this modeling one can interpret the depositional environment condition at the time of sediment deposition. The Khalashpir basin is more or less an elongated one with the largest axis directed to NE-SE. The gravity map shows it as a fault bounded one both in northeast and southeast sides. Drilling data reveal the existence of a prominent fault in the north-northeast side (near GDH 46) with NNW-SSE alignment. This fault may be one of the major faults in the Gondwana basin that controls the basin characteristics. The throw of the fault could not be calculated properly due to lack of data .But from the correlation of conglomerate beds in between drill holes GDH-47 and 48, it appears to be 150m. The deepest part of the basin as well as the thickest sedimentary succession is accumulated near the drill hole GTB-16. The stratigraphic model indicates, upper alluvium, Dupitila formation, Surma Group, Gondwana group specifically. Folding with coal connected stratum is a single syncline .The 3-D survey assumes greater coal deposits in the SE side of the surveyed area (figure-4-a, b).

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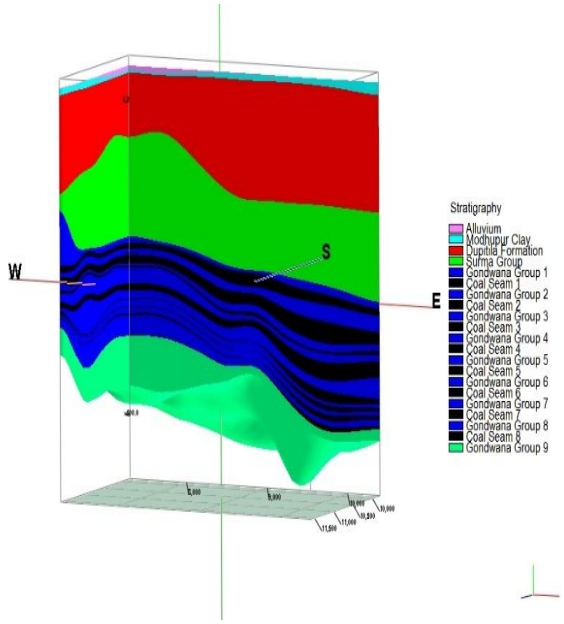


**Figure-4 (a):3-Dimensional Stratigraphic model (SW side) of khalashpir coal field**

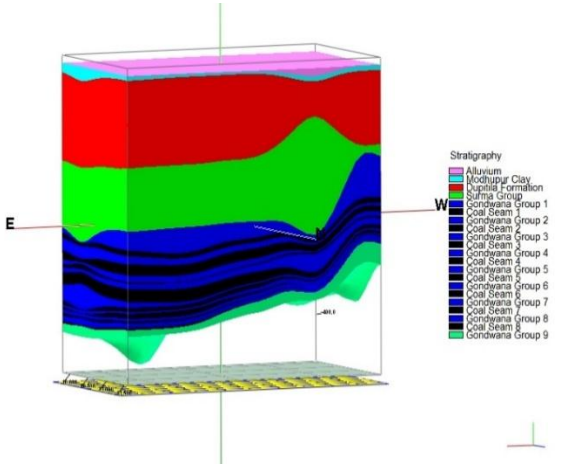


**Figure-4 (b):3-Dimensional Stratigraphic model (NE side) of khalashpir coal field**.

*Coal Seam Continuity*

The seam continuity is determined from the drillhole, seismic data and 3-dimensional analysis (figure-5, 6, 7, 8) of Khalashpir coal mine. Eight seismic sections along with drillhole data are studied and interpreted for the continuity of the coal seam.

The coal seams are present in three major blocks created by faults (Hosaf International and its Consortium). In most cases the coal seams in the side blocks are truncated with the surma group and the disturbed points are eroded. But the middle block doesn't exhibit the property that much as some of its edges are eroded due to asymmetric nature. After analyzing all the parameters it is inferred that four coal seams (I, II, III, IV) are continuous within the Khalashpir basin.

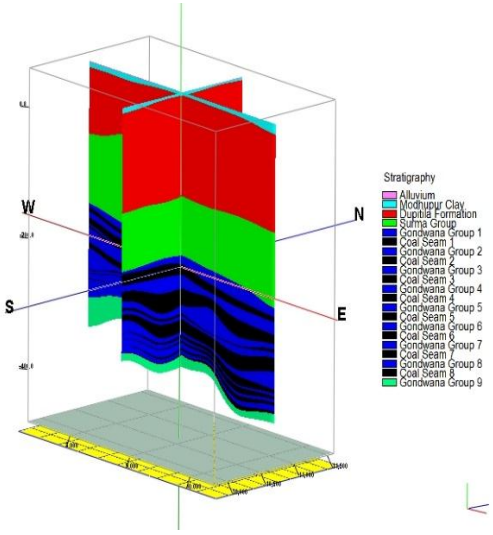


**Figure-5: The fence diagram, view of coal basin section as diagonally.**

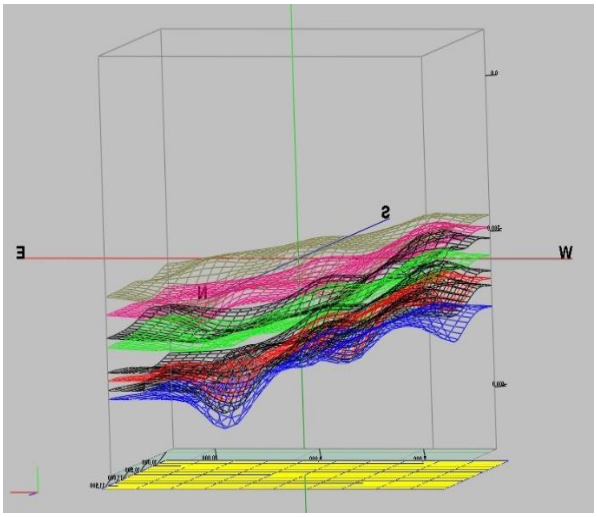


**Figure-6: 3-Dimensional structural elevation of all 8 coal seam.**

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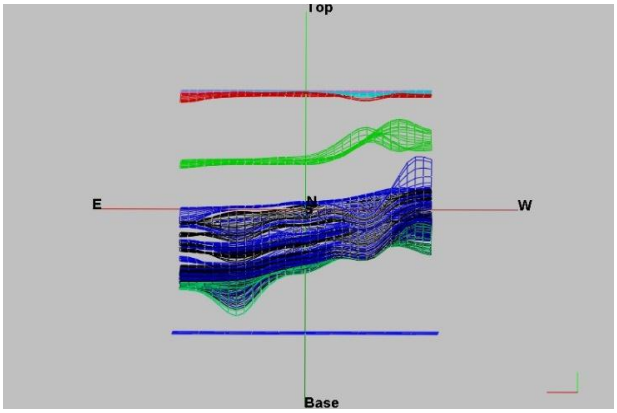


**Figure-7: 3-Dimensional structural elevation of all surfaces.**

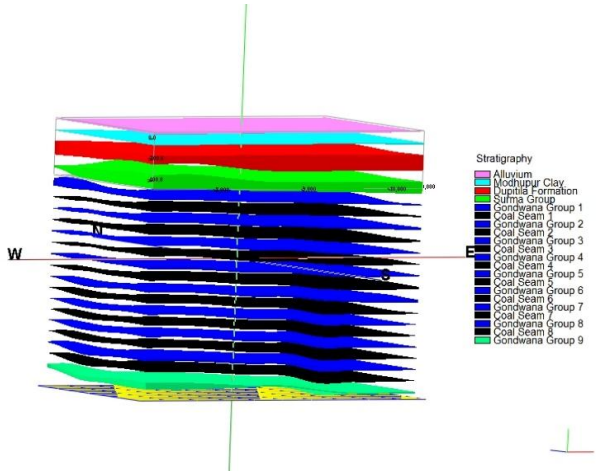


**Figure-8: Explode diagram of 3-Dimensional stratigraphic model.**

## V. Selection Of Mineable Seam

The mineable coal seam selection of the Khalashpir Coal Field was carried out on the basis of the orientation, thickness mineable reserves and quality of the coal. In the Khalashpir basin, the coal bearing sequence is divided into 8 zones (figure-9-a, b, c) containing numerous coal beds. The seam I, II, and IV constitute the major part of the resources at the Khalashpir coal basin with average thickness 8.303 m, 9.778 m and 11.43 m respectively. That's why coal seam I, II, and IV are considered for mining with priority and the rest could be done later if the milieu remains workable. The in situ mineable reserves of seam I, II, and IV is almost 145.63 Million tons as deduced and potential for underground mining. The cross section indicates that the thick coal layer is dominated more in theeastern portion than western. The coal seams might have single or multiple beds with good quality, bright (vitrain), and dull (durain) coals containing fussains spots.

The coal shows banded layers exposed as dull and bright. Geotechnical and hydro-geotechnical hazards are the main limitations here and entire reserves base cannot be recovered by mining. Different mining methods in different geological, geotechnical and hydro geological settings result in a wide range of recovery rates. For the underground mines the recoverable reserves would be almost 30% to 35% of the mineable reserve base.

Seam IV might be significantly potential for mining as it has the highest reserves and lies below the Dupitila formation. Further exploration could estimate the reserve with more accuracy. Stratigraphic thickness of coal seam IV indicatesit's comparatively larger eastern side than western (figure-10-a, b, c, d). The units are sandy and sand part increases in thickness towards NW-SE direction.

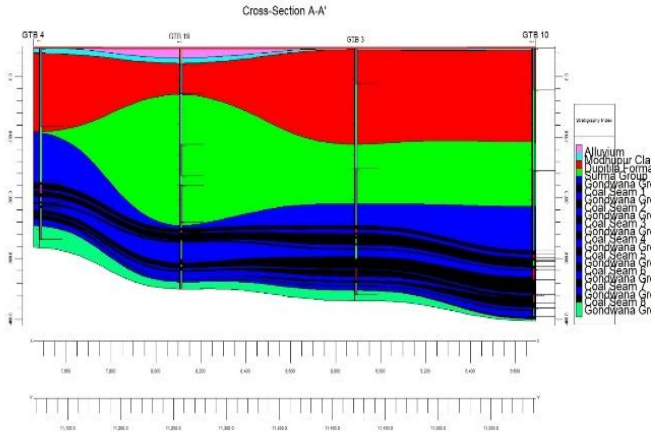


**Figure-9 (a): Stratigraphic cross section along 4 boreholes (GTB 4, GTB 19, GTB 3, GTB 10) of khalashpir coal field**

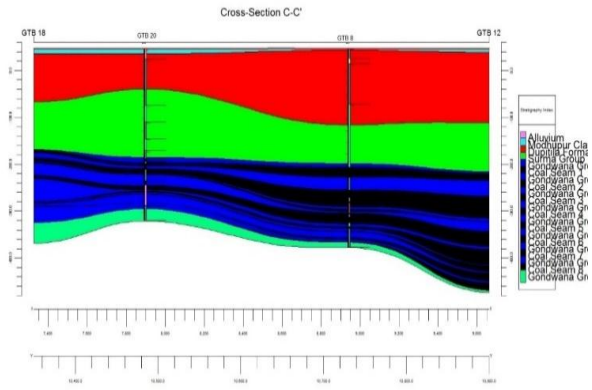


**Figure-9 (b): Stratigraphic cross section along 4 boreholes (GTB 18, GTB 20, GTB 8, GTB 12) of khalashpir coal field**

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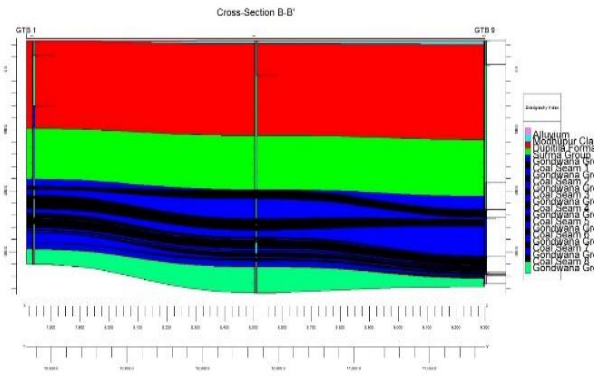


**Figure-9 (c): Stratigraphic cross section along 3 boreholes (GTB 1, GTB 6, GTB 9) of khalashpir coal field**

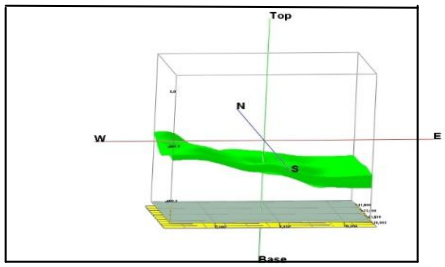


**Figure-10 (a): Stratigraphic thickness of seam IV view from north.**

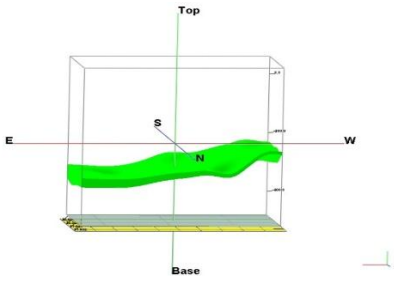


**Figure-10 (b): Structural elevation of seam IV, view from south.**

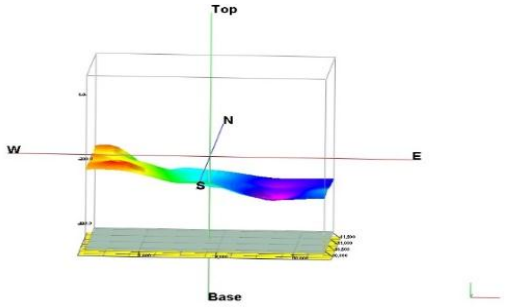


**Figure-11 (a): Structural elevation of seam IV, view from south.**

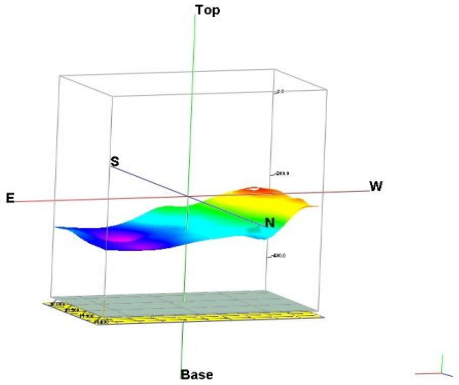


**Figure-11 (b): Structural elevation of seam IV, view from north.**

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**TABLE-II**
**THICKNESS AND DEPTH OF ALL COAL SEAM IN KHALASHPIR COAL FIELD**

| Borehole No. | Thickness and depth of all coal seams | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Coal Seam-I | Coal Seam-II | Coal Seam-III | Coal Seam-IV | Coal Seam-V | Coal Seam-VI | Coal Seam-VII | Coal Seam-VIII |
| GTB 1 | 5.45 | 8.42 | 0.68 | 9.98 | 0.4 | 0.55 | 0.35 | 0.15 |
| GTB 2 | 6.03 | 11.22 | 2.01 | 7.00 | 0 | 0 | 0 | 0 |
| GTB 3 | 5.51 | 7.07 | 2.16 | 15.64 | 3.06 | 3.18 | 0.54 | 0.31 |
| GTB 4 | 5.8 | 5.13 | 2.02 | 3.95 | 1.75 | 0.94 | 1.20 | 1.20 |
| GTB 6 | 15.00 | 16.53 | 3.64 | 4.01 | 1.16 | 6.88 | 4.35 | 0.88 |
| GTB 8 | 22.28 | 19.07 | 1.46 | 13.86 | 3.66 | 0.64 | 1.13 | 0.36 |
| GTB 9 | 13.04 | 2.35 | 0.20 | 29.10 | 0 | 0 | 0 | 0 |
| GTB 10 | 5.62 | 7.61 | 0.88 | 24.43 | 1.22 | 9.97 | 1.43 | 1.20 |
| GTB 12 | 14.60 | 36.52 | 0.50 | 15.89 | 11 | 4.83 | 11.82 | 6.85 |
| GTB 16 | 4.36 | 3.7 | 7.22 | 15.23 | 0 | 0 | 0 | 0 |
| GTB 18 | 4.32 | 4.35 | 1.91 | 4.82 | 0 | 0 | 0 | 0 |
| GTB 19 | 5.26 | 4.26 | 1.80 | 2.92 | 0 | 0 | 0 | 0 |
| GTB 20 | 4.5 | 5.66 | 1.45 | 6.75 | 0 | 0 | 0 | 0 |
| GTB 21 | 4.48 | 5.00 | 2.08 | 5.13 | 0 | 0 | 0 | 0 |
| **Average thickness(m)** | **8.304** | **9.778** | **2.00** | **11.34** | **1.59** | **1.93** | **1.49** | **0.78** |
| **Average depth (m)** | **261.26** | **283.89** | **308.28** | **325.01** | **358.84** | **370.18** | **382.56** | **394.02** |

## VI. Result And Discussion

By using a 3-D model it is possible to evaluate the distribution of sedimentary rocks, exact orientation, continuity, thickness of coal seam, both through space and time. The geometry of basin has a typical extensional structure. So, it is more or less elongated basin which increases in thickness in deposition towards the west to east direction. The mineable coal seam selection of the Khalashpir Coal Field was carried out on the basis of the orientation of the coal seam in the basin, thickness coal seam, mineable reserves and quality of the coal. The seam I, II, and IV constitute the major part of the resource at the Khalashpir coal basin containing average thickness 8.303 m, 9.778 m and 11.43 m. The in-situ reserves of seam I, II and IV are considered potential for underground mining.

The main limitation is the Geotechnical and hydro-geotechnical hazard. The in situ mineable reserves base of seams I, II, and IV is 145.63 million tons (about 79%of total reserve).Stratigraphic thickness of coal seam IV indicates, the seam are large amount or more dominated in Eastern direction compared to Western side. On the basis of all characteristics of coal seam the seam-IV is the most vital, because it contains major part of coal reserves about 56.13 million tons (about 31% of total reserve), good quality and better position in the basin.

## VII. Conclusion

By using a 3-D model it is possible to evaluate the distribution of sedimentary rocks, exact orientation, continuity, thickness of coal seam, both through space and time. At the time of sediment deposition, one can interpret the depositional environment condition by this modeling. 3-D figures have been used for understanding the variability of the structure and thickness of coal beds as well as surface maps. A better visualization of the regarding area in our article is done with the results of the conducted three dimensional surveys. In case of Khalishpir basin, it is finally concluded that the eastern part in far more potential and seam IV is the greatest prospective due to location, bigger reserve and the appreciable quality.

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