# Evaluation of a Potential Mining Method in the Jamalganj Coal Deposit, Jaipurhat District, Western Bangladesh

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**Abstract**

In coal mines, evaluating a potential mining method is critical, especially for deeper coal mine areas. This paper investigates the possible mining method of the Jamalganj coal deposit in Bangladesh, which was discovered below the surface at depths of 640 to 1,150m in 1962. This study provides an outline of the numerous issues that influence longwall and room and pillar mining. The layout is made up of the basic geometry of nearby geological strata. The excavated area's stress distribution and failure behavior are studied using numerical modeling using the boundary element method (BEM). From the result of numerical modeling, I found that both room and pillar mining and longwall mining are possible in the Jamalganj coal deposit. However, in the room and pillar mining method, the low extraction rate and ventilation problem may cause more problems than the longwall mining method. Furthermore, low extraction rates may cause cost-effective issues in both situations. Generally, the production rate in the underground mining process does not reach 40%.



**Keywords**

Longwall mining, room and pillar mining, boundary element method, stress distribution.

**Introduction**

The Jamalganj coalfield is located in the Jaipurhat district, near the town of Jamalganj and west of the north-south railway line. The coalfield was identified in 1962 by the geological survey as part of the UN-sponsored coal exploration program at depths ranging from 640 to 1,150 meters below ground level. In the Jamalganj-Paharpur area of Jamalganj district, ten wells were drilled as part of the operation. Coal seams were discovered in 9 wells in Permian Gondwana rocks at depths ranging from 640 to 1158 meters below the surface. The 9 bore holes that pierced the coal seams are spread across an area measuring 12.5 kilometers east-west and 4.8 kilometers north-south. The extent of the coal deposit examined by the 9 boreholes was estimated to be around 37 square kilometers (Rahman and Zaher 1980). The field's total coal reserve is projected to be 1,053 million tons, making it Bangladesh's largest coalfield to date (Imam et al., 2002).

Several international experts were invited to perform a feasibility study of mine after discovering the coalfield. Fried Krupp Rohstoff(1966), Powell Doffryn Technical Services (1969), and Robertson Research International (1976) are among others. For trial purposes, Krupp recommended three mining methods: (i) Room and pillar, (ii) Auger, and (iii) Longwall mining without stowing. Powell Duffryn Technical Services Ltd, on the other hand, disagreed with Krupp's Room and Pillar method, stating that "the great depth of the coal seams presents a special problem because the dead weight of the overlying strata is greater than the coal's uniaxial compressive strength when split into pillars." It is impossible to conduct a trial without digging the shaft and installing much of the equipment and apparatus. It is also impossible to recreate the conditions in the laboratory." The Powell Duffryn's remarks were too much for Krupp to bear." ( Rahman and Zaher, 1980).

In the case of Jamalganj, it is at least known that coal is there and can be mined. The challenges that will arise will not be insurmountable, which may increase the project's cost, and this element may be a factor that makes the project unattractive to potential investors. However, the growth of the Jamalganj Coal Mine should be evaluated in the context of the entire national interest, not only profit.

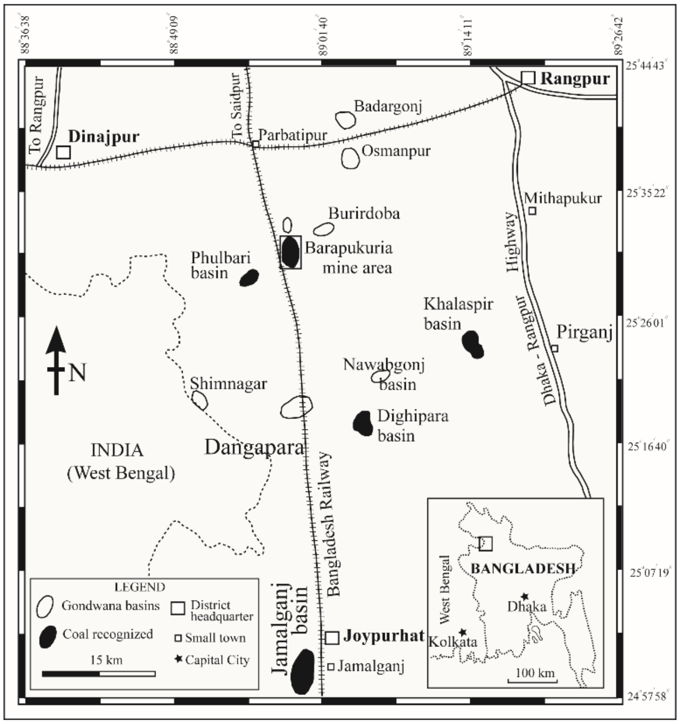



Figure 1: Location of Jamalganj coal deposit (Islam and Hayashi 2008)

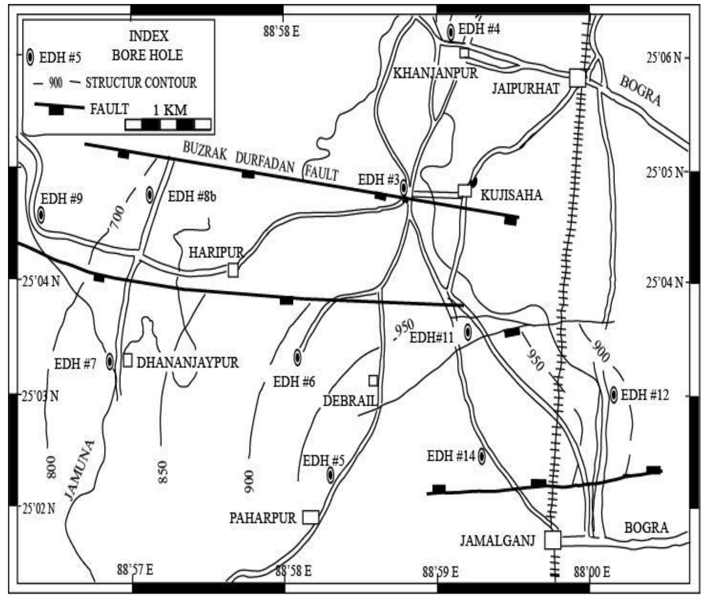



Figure 2: Geologic structure of Jamalganj coal field (after Imam et al., 2002)

#### Geological structure of the basin

The Jamalganj coalfield is located on the tectonically stable Precambrian platform's Bogra shelf unit. The coal deposit's structural information is based on seismic and borehole data (Halloway and Baily 1995). Within the Archaean basement, coal can be found in a typical half-graben basin. The Jamalganj coal basin is bordered to the north by the Buzrak–Durgadah boundary fault, which runs east–west. Between wells EDH-9 and EDH-11, another east–west down to the south fault can be found further south. At this time, the western, eastern, and southern borders of the Jamalganj coal deposit are unknown.

However, the coal measure is projected to continue to the east and possibly to the west of the drilled area, given on regional geology. The coal seams are almost certainly deeper and extend further south. Several faults have impacted the coal deposit, however there is no sign of folding. The Gondwana rocks drop 5–10 degrees on average, but dips of up to 15 degrees have been documented in some spots. Boreholes EDH-10 and EDH-11 have more mild dips of 2–5 degrees. The rock horizons have a regional south-east dip, according to seismic reflection data. Figure 2 depicts the general contour of the depth to top of coal seam III. It's been argued that the basin's original size was substantially larger. A portion of the sedimentary succession, including coal beds, has been eroded, but the portion within the fault-bounded basin has been retained ( Imam et al., 2002; Rahman and Zaher, 1980; Halloway and Baily, 1995; Rahman and Zaher, 1980).

#### Stratigraphic succession

Figure 3 depicts the geologic history of the Jamalganj coal basin, which shows a Gondwana group succession overlain by a Tertiary sequence with a significant unconformity in the middle. The Gondwana Group, where the coal is found. No well has ever reached the Archaean basement beneath the Gondwana sequence. As a result, there is no way of knowing the total thickness of Gondwana rocks in the Jamalganj coal basin. In the EDH-6 well, a total of 577 meters of Gondwana rocks were drilled. The Gondwana Group is primarily composed of hard, compacted, low-permeability arkosic coarse to medium-grained sandstones with coal layers and a few shales and conglomerate. The group is divided into two parts, i.e., Lower Gondwana and Upper Gondwana. (Rahman and Zaher, 1980).

A 305-meter-thick sequence of feldspatic sandstones, with a few coal seams and small carbonaceous shales and siltstones, represents the Lower Gondwana of Permian age. The sandstones are kaolinitic, hard, and compact. The Raniganj Formation (Permian) of eastern Indian coalfields has been tentatively linked to this unit. However, Robertson Research International Ltd. believes this unit is equal to the Barakar Formation (Permian), based on the thickness of the coal seams in the Jamalganj coalfield, which are substantially thicker than those in India's Raniganj Formation. The Lower Gondwana series contains seven large coal seams with a cumulative thickness of 64 meters. Individual coal seams vary in thickness from well to well, and they are found at depths ranging from 640 to 1158 meters below the surface. The Lower Triassic Upper Gondwana unit is made up of around 250 meters of medium to coarse-grained feldspatic sandstone interbedded with microbrecciated conglomerate and small siltstones ( Rahman and Zaher, 1980).

The Jurassic volcanic Rajmahal Trap Formation encountered in the Kuchma coal basin is absent in the Jamalganj coalfield. The Paleocene–Eocene Jaintia Group overlain the Gondwana Group with a large unconformity (185m). From the base upward, the Jaintia Group is divided into the Cherra Formation (104m), which consists primarily of sandstones with subordinate shale, the Sylhet Limestone Formation (38m), which mainly consists of fossiliferous limestone, and the Kopili Formation (42 m), which consists primarily of shale lithologies. (Rahman and Zaher, 1980). The Oligocene–Miocene Jamalganj Formation is overlain by the Jaintia Group and consists of around 400 meters of alternating sandstone, shale, and siltstone. The Pliocene DupiTila Formation consists of poorly consolidated medium to coarse grained sandstone with modest shale–clay lithofacies, is followed by roughly 270m of Pliocene DupiTila Formation. Recent alluvium comprising sand, silt, and clay lies on top of the above. (Rahman and Zaher, 1980).

The massive Gondwana system sediments were accumulated between the Late Carboniferous and the Late Jurassic or Early Cretaceous. None of the holes in the Jamalganj area were dug all the way to the bottom of the Gondwana formation. Gondwana most likely sits on top of the Carboniferous Talchir Boulder Bed, which sits awkwardly on top of the Precambrian basement (Rahman and Zaher, 1980).

#### Thickness of coal seam

The thickness of the coal seams varies from less than 2 meters to more than 46 meters. Individual coal seams have large lateral thickness differences, as measured from well to well (Table 1). The average cumulative coal thickness is 64 meters. In terms of thickness, lateral continuity, and reserves, coal seams III and VII are the two most important coal strata. Seam IV, the third seam, likewise records great thickness and lateral continuity. In the eastern portion of the field, coal seam III has a thickness of 46.82 m in well EDH-11 and 40.82 m in well EDH-10, and a reduced thickness of just 4.26 m in well EDH-6 in the middle area. Seam III meets seam IV in the eastern half of the coalfield. Imam and colleagues (Imam et al., 2002).



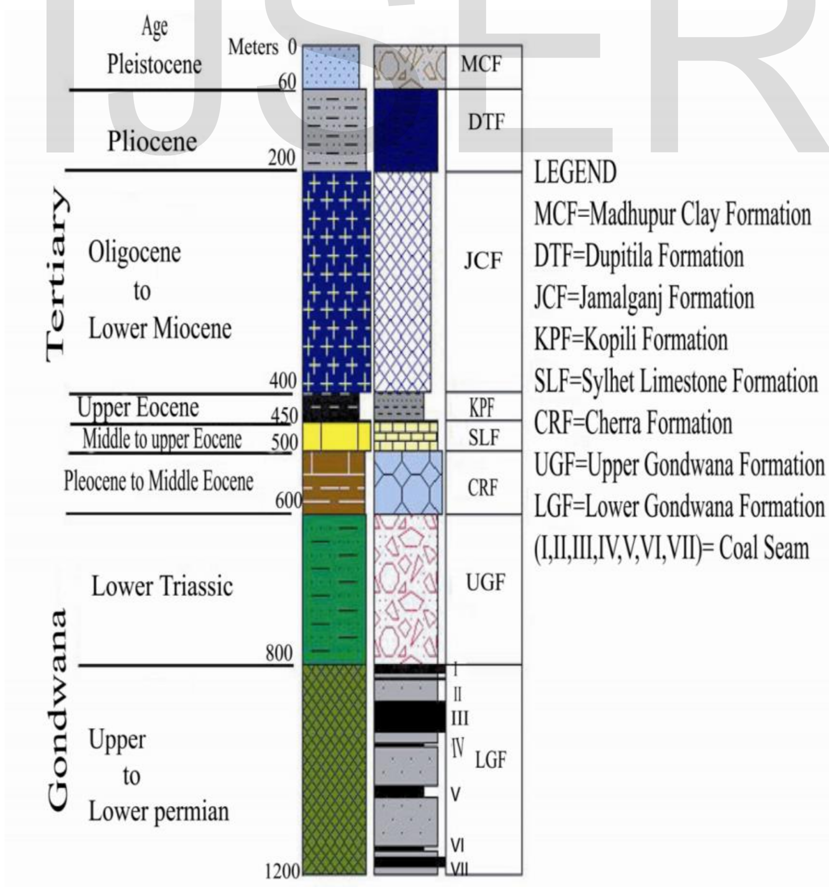



Figure 3: Stratigraphic succession of Jamalganj coal field (After Imam et al., 2002)

Table 1: Thickness of Coal Seams of Jamalganj Coalfield in Different Wells (Source: Rahman and Zaher, 1980)

| Coal | Western part | | | | | Eastern Part | |
|---|---|---|---|---|---|---|---|
| | EDH-5 | EDH-6 | EDH-7 | EDH-8 | EDH-9 | EDH-10 | EDH-11 |
| Seam I | 1.52 | - | - | - | - | 12.68 | - |
| Seam II | 4.56 | 12.46 | 4.26 | 7.9 | 5.17 | 2.56 | 3.19 |
| Seam III | 19.41 | 4.26 | 20.37 | 20.67 | 8.87 | 40.76 | 46.82 |
| Seam IV | 20.22 | 7.9 | 10.34 | 24.78 | 4.55 | 5.22 | 8.97 |
| Seam V | 2.36 | 5.17 | 13.68 | 20.98 | - | 16.42 | 16.42 |
| Seam VI | - | 2.56 | 7.6 | 10.99 | - | 6.04 | 6.04 |
| Seam VII | - | 3.19 | 15.05 | - | - | 15.81 | 15.81 |

### Depth of coal seam

The depth of the coal seam varies from 641 to 1126 meters below ground level and from 119 to 512 meters below the Tertiary unconformity's base. Seam (III) is the thickest and well-developed coal seam, with depths ranging from 659m (EDH-9) to 1032m (EDH-14) below the surface. The deepest coal seam VII has a recorded depth of 1013 m (EDH-7) to 1124 m (EDH-10) below the surface. (Imam et al., 2002)

Table 2: Coal Seams: Depth in Meters below Ground Level, Jamalganj. (Source: Rahman and Zaher, 1980, Friederich 1992)

| Well number | Western part | | | | | Eastern Part | |
|---|---|---|---|---|---|---|---|
| | EDH-5 | EDH-6 | EDH-7 | EDH-8B | EDH-9 | EDH-10 | EDH-11 |
| Seam I | 913 | Missing | missing | missing | Missing | 867 | Missing |
| Seam II | 940 | Missing | 786 | 699 | 614 | 876 | 892 |
| Seam III | 1000 | 930 | 838 | 725 | 659 | 909 | 977 |
| Seam IV | 1037 | 995 | 882 | 807 | 679 | 967 | 1005 |
| Seam V | 1070 | 1018 | 942 | 866 | hole terminated earlier | 1024 | 1036 |
| Seam VI | 1126 | 1102 | 981 | 902 | | 1109 | 1093 |
| Seam VII | united with seam VI | | 1014 | missing | | 1124 | 1101 |

### Reserves

Fried Krupp (1966) estimates that the Jamalganj coalfield has a total coal reserve of 1054 million tons. According to this reserve estimate, the thickness of coal seams detected in EDH-10 represents average values, and the coal has an average specific gravity of 1.49 g/cm. Because of its poor development, seam I was left out of this reserve estimate. It is evident from the below table 3 that coal seam III contains about 50 % of the total reserve, while seam VII includes 35 % of the entire reserve in the Jamalganj coalfield. (Imam et al., 2002)

Table 3: Coal seams and coal reserve of Jamalganj coal field (Source: Rahman and Zaher, 1980, Friederich 1992)

| Coal seam number | Range of thickness(m) | Coal reserves (million tons) |
|---|---|---|
| I | 1.5 m to 2.6 m | Ignored |
| II | 2.5 m to 12.4 m | 39.5 |
| III | 4.2 m to 46.8 m | 526.8 |
| IV | 4.5 m to 24.7 m | 32.4 |
| V | 2.6 m to 20.9 m | 30.0 |
| VI | 2.6 m to 10.9 m | 50.8 |
| VII | 3.1 m to 15.8 m | 374.4 |
| TOTAL RESERVE = | | 1053.9 |

#### Methodology

Boundary Element method (BEM) is mainly used to investigate the stress characteristics and deformation, know the concentration of shear and tensile stresses, analyze the deformation failure, and evaluate the potential mining method in the Jamalganj coal deposit. The 3d lithological model of several bore holes is evaluated using Rock Work software.

#### Boundary element method

The boundary element method (BEM) is a numerical computing approach for solving linear partial differential equations in boundary integral form that have been specified as integral equations. Fluid mechanics, fracture mechanics, and solid mechanics are just a few of the fields in which it can be used. The governing partial differential equation's integral equation can be viewed as an exact solution. The boundary element approach tries to fit boundary values into the integral equation using the specified boundary conditions rather than values throughout the space represented by a partial differential equation. The integral equation can then be employed in the post-processing stage to calculate numerically the solution directly at any chosen position in the interior of the solution domain. (Ilievsk , 2006).

#### Numerical modeling

Mining-induced stratum deformation and stress-dependent characteristics were predicted using the boundary element method (BEM). The Examine 2D software package was used to create models based on plane strain condition, and the findings were presented. Numerical modeling was used to show the distribution and amplitude of various stress and strain characteristics. In different drill holes, seam III is located between 850 and 1000 meters below the surface. At a depth of 1000m below the surface level, numerical modeling was used in the Coal seam III.

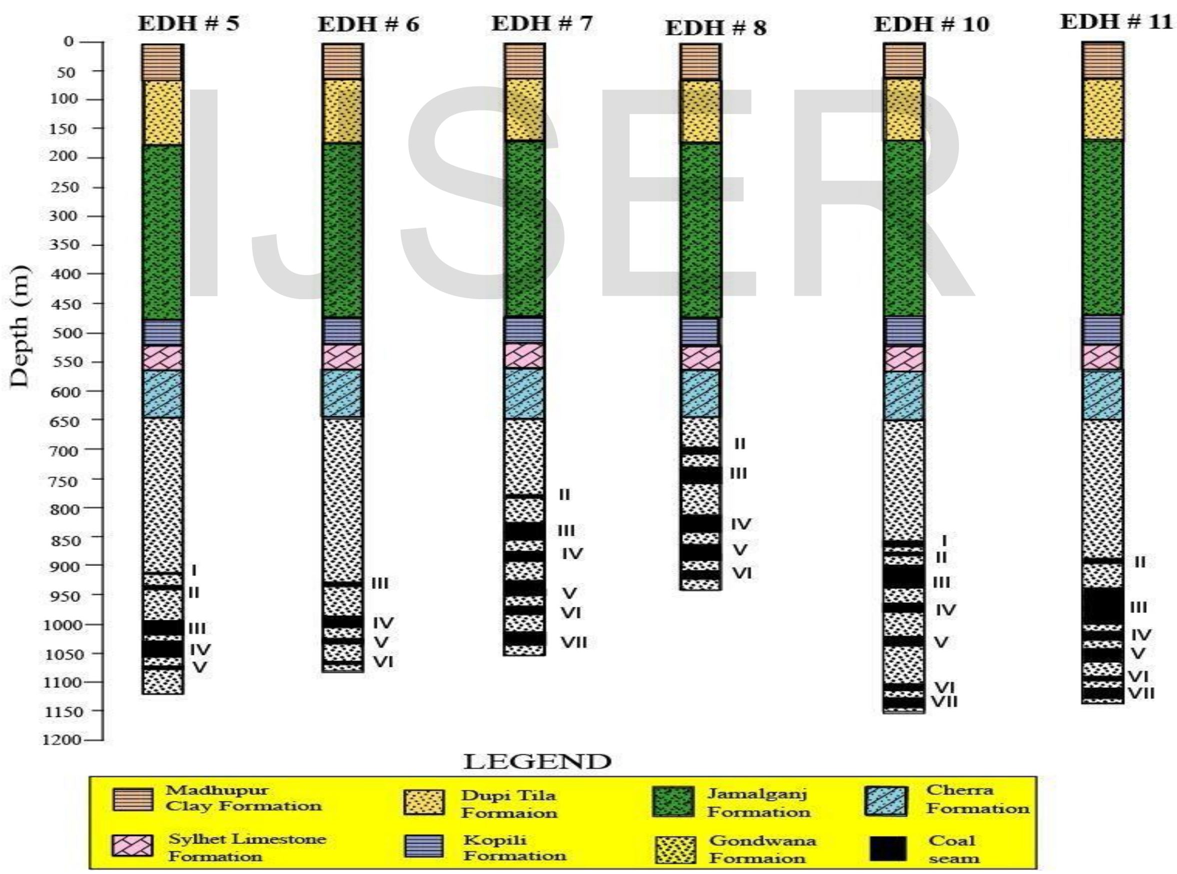



Figure 4: Stratigraphy and coal seams sequences in EDH #5 to EDH #11 of the Jamalganj Coal Basin, Jaipurhat Bangladesh

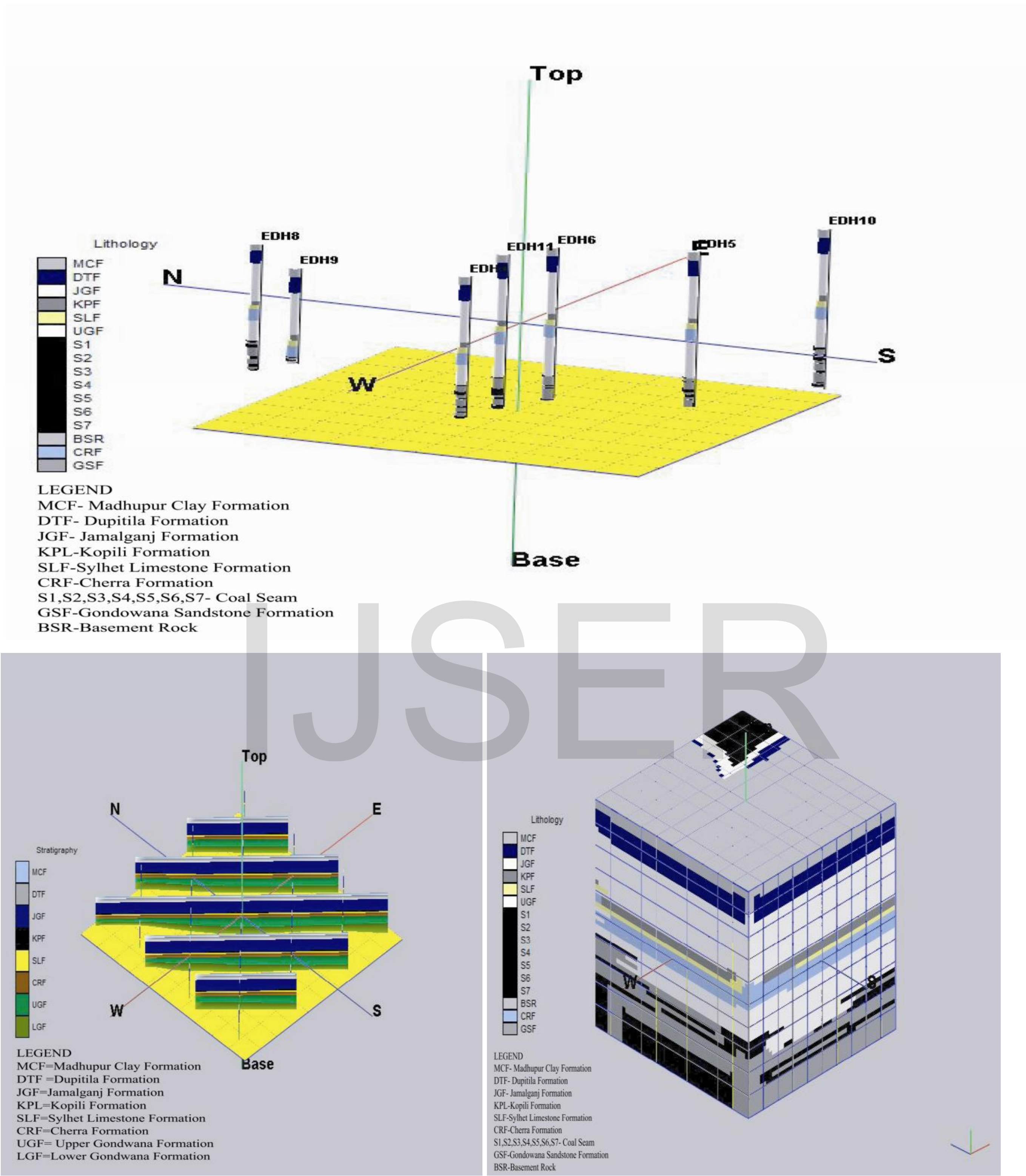





Figure 5: 3D location of multiple logs, 3D Stratigraphical model of different boreholes, and 3D Lithological model of different boreholes in Jamalganj coal deposit

**Section of room and pillar and long wall mining method**

Figure 6 shows the section of room and pillar and long wall mining method for numerical analysis. Width of room and pillar is 5m and height is 3.75m. Extraction starts from 1000m in the coal seam III. For long wall panel width is 200m and extraction height is 3.75m.

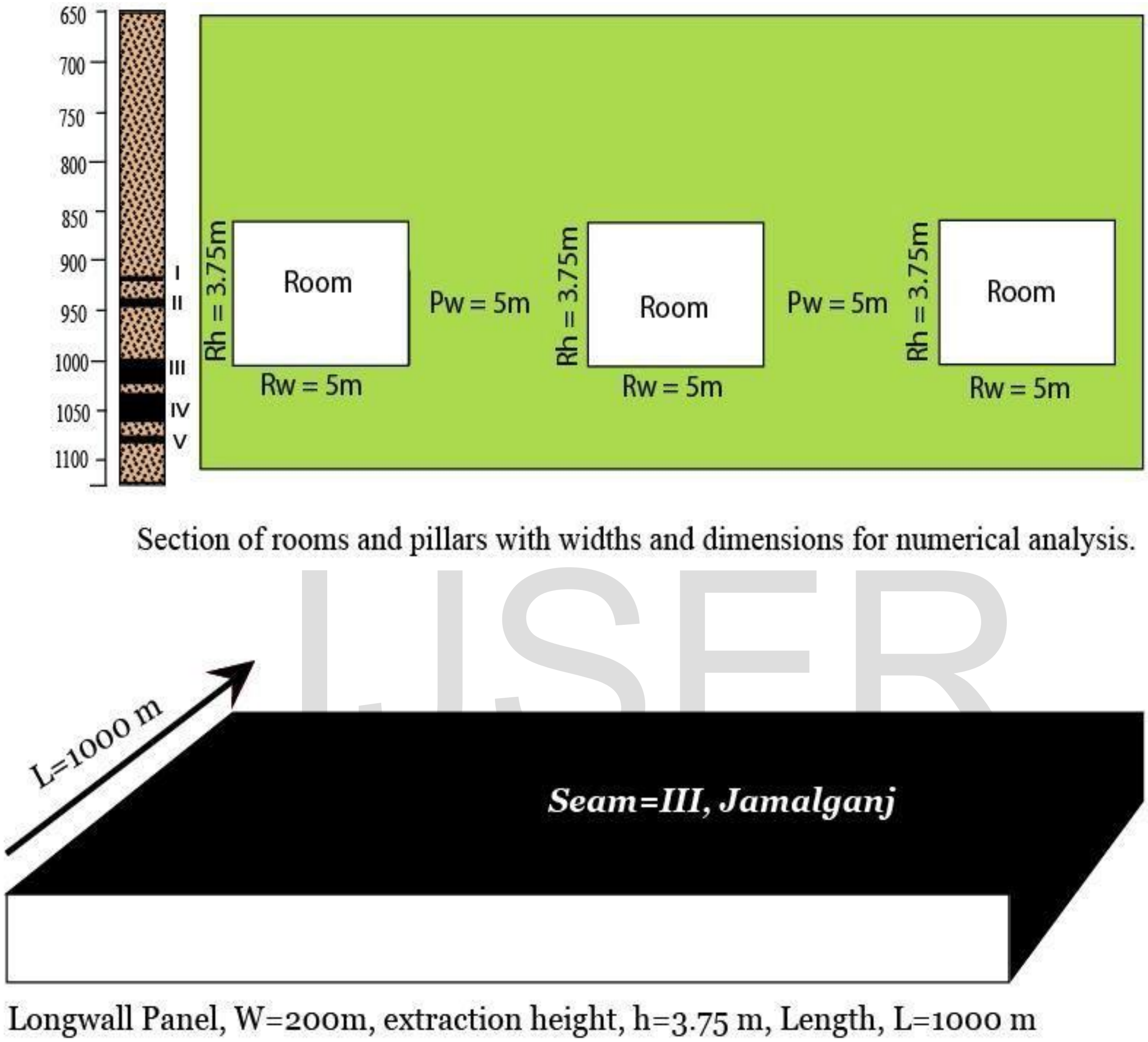
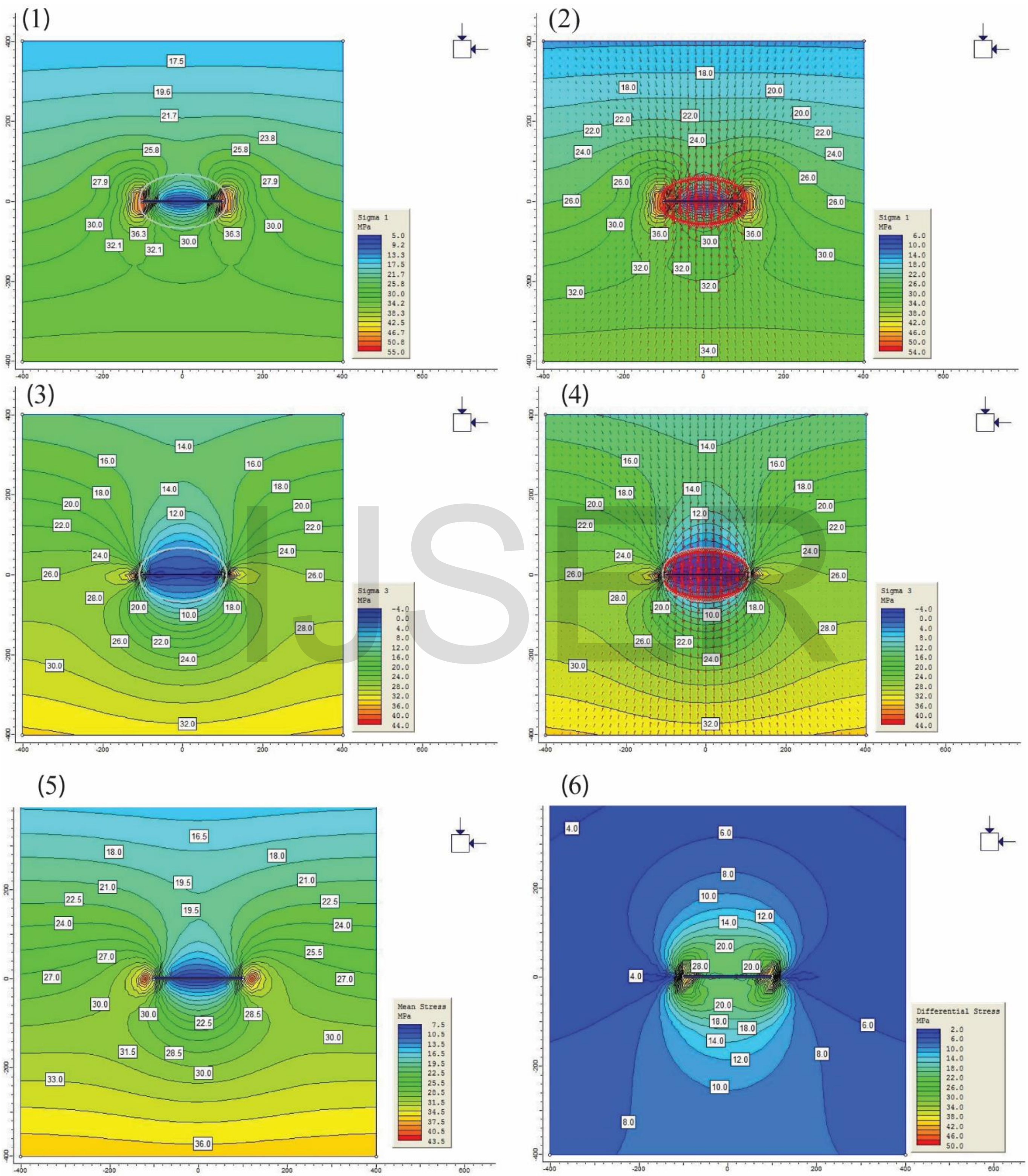



Figure 6: Section of room and pillar and long wall panel

**Calculation for longwall mining method**



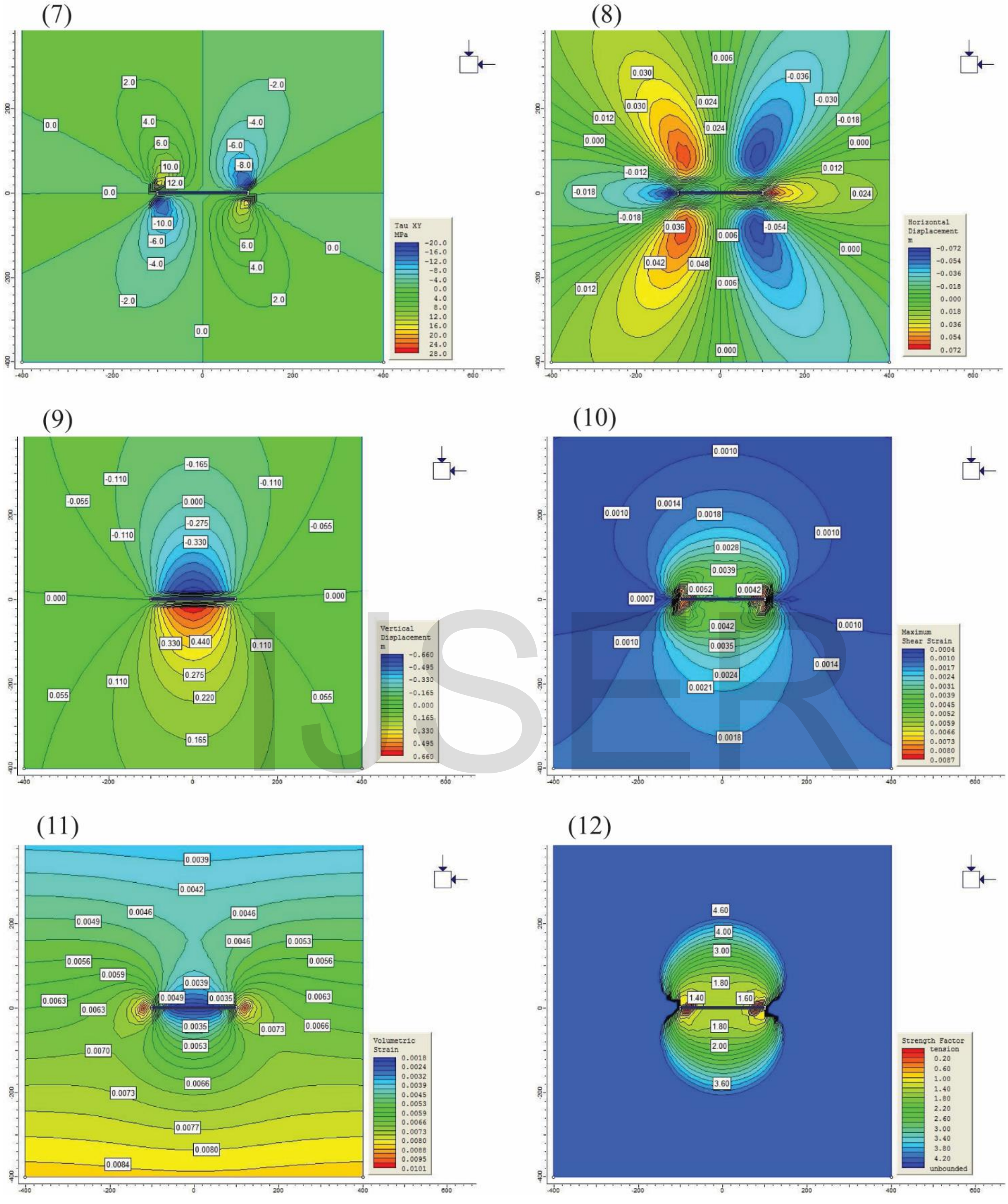




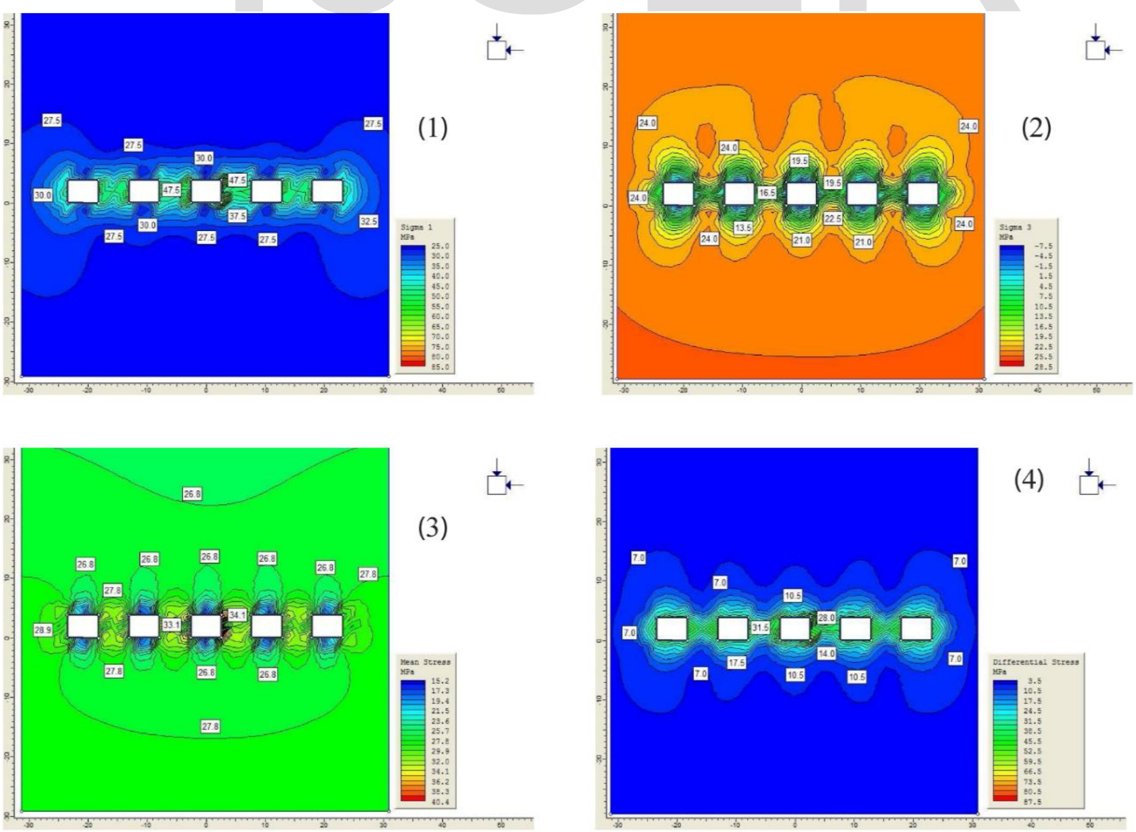

Figure 7: Distribution and magnitudes of: 1(Sigma 1 with Deformation Boundary), 2(Sigma 1 with deformation vector), 3(Sigma 3 with deformation boundary), 4(Sigma 3 with deformation vector), 5(mean Stress), 6(differential stress), 7(shear stress contours), 8(horizontal displacement), 9(vertical displacement), 10(maximum shear strain), 11(volumetric strain), 12(factor of safety).

Figure 7 shows the Distribution and magnitudes of Sigma 1 with Deformation Boundary, Sigma 1 with deformation vector, Sigma 3 with deformation boundary, Sigma 3 with deformation vector, mean Stress, differential stress, shear stress contours, horizontal displacement, vertical displacement, maximum shear strain, volumetric strain, factor of safety. Sigma 1 magnitudes are highest in the extraction region and gradually drop as you get closer to the surface. Above 400m from the extraction location, the effect of sigma1 is insignificant. Near the extraction area, the magnitude of the deformation vector is at its highest. Sigma 1 with deformation vector occurs up to 400m above the extraction area, but has little effect on the extraction zone's upper formation. The lower portion of the extraction region has the highest vertical tension. A cave structure can be formed by vertical force of up to 250 meters, and the cave structure reduces as the height approaches the surface. As a result, the upper layers of the extraction area are less affected. Sigma 3 with deformation vector occurs up to 400m above the extraction area although has little effect on the extraction zone's upper formation. Near the extraction zone, the mean stress is highest and gradually decreases up to the surface. Mean stress contours between 21Mpa and 19.5Mpa form a cave structure in the extraction zone, which gradually diminishes as the distance from the extraction area increases. As a result, longwall extraction has had less of an influence on the upper levels of the rock strata. The impact of stress is most significant around the extraction region and gradually diminishes as you get closer to the surface. As a result, longwall extraction has had less of an influence on the upper levels of the rock strata. Figure 7 depicts the distribution characteristics of shear stress.

The highest number is -8 Mpa, which is then lowered to -2 Mpa. The influence of tensional stress is minor beyond 250 meters from the extraction zone; hence, the coal seam's upper formation remains intact. The vertical displacement value is highest near the extraction region and gradually decreases as you get closer to the surface. Therefore, a height above 300m vertical displacement is negligible, which means the upper formation of the coal layer would be unaffected. Shear strain maximum at extraction area and gradually decreases above roof sides. Shear strain impacts up to 300m of rock strata, although other rock strata are unaffected. Near the extraction zone, the volumetric strain may form a cave structure, but this structure gradually diminishes as the distance from the extraction zone increases. Longwall extraction will have less influence above 300 meters from the extraction zone. The factor of safety is lowest near the extraction zone and steadily increases as you get closer to and below it. As a result of the extraction, the overlying layer is unaffected.



**Calculation for room and pillar mining method**



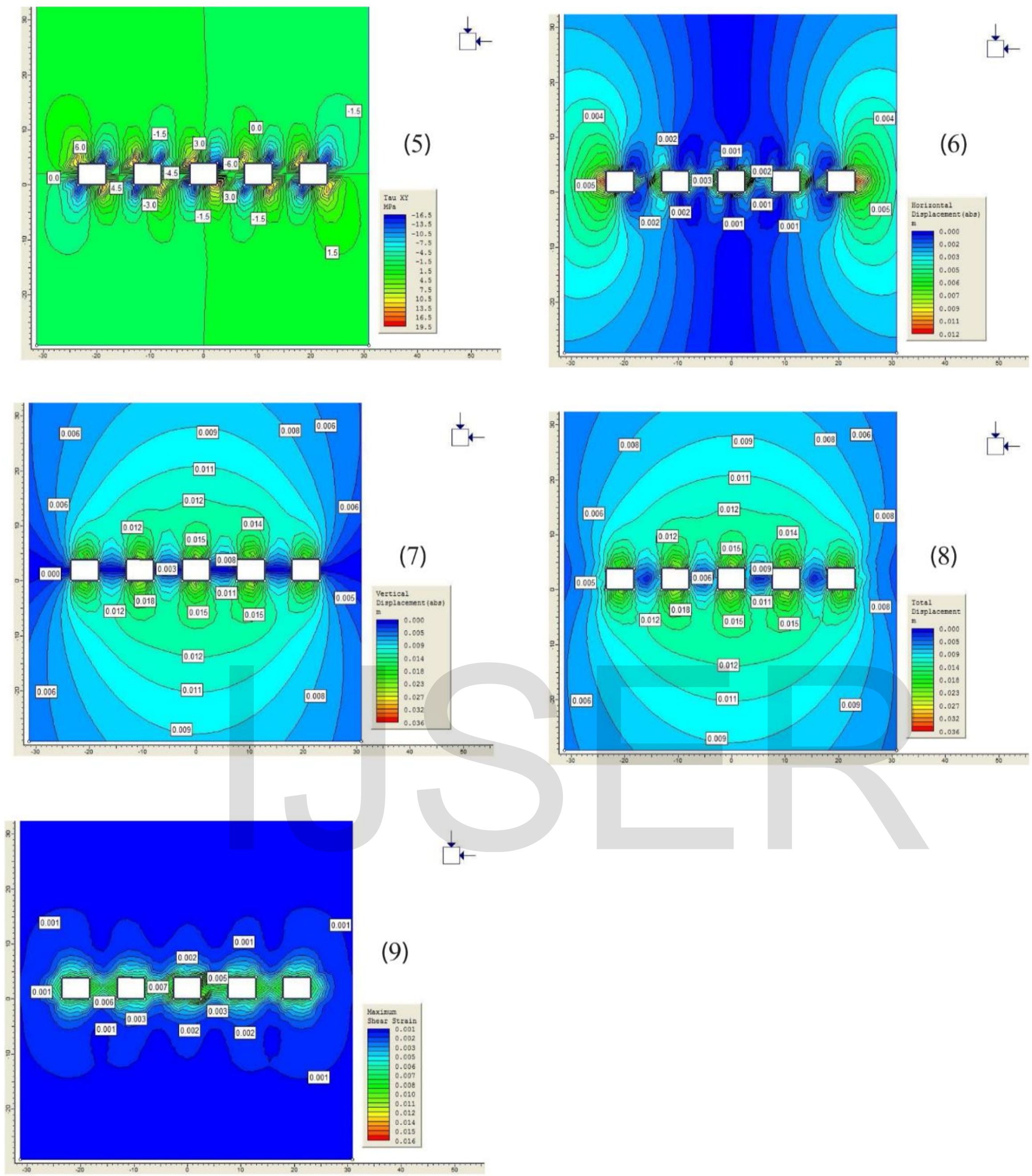



Figure 8: Distribution and magnitudes of: 1(Sigma 1), 2(Sigma 3), 3(mean Stress), 4(differential stress), 5(shear stress contours), 6(horizontal displacement), 7(vertical displacement), 8(total displacement), 9(Maximum shear strain)



The distribution and magnitudes of horizontal stress (1) and vertical stress (3) with deformation boundary, mean stress, differential stress, shear stress contours , horizontal displacement, vertical displacement, total displacement, and Maximum shear strain are shown. Sigma 1 magnitudes are greatest near the extraction area and gradually diminish up to the surface. Above 20 meters from the extraction zone, the effect of 1 is insignificant. Near the extraction zone, the largest vertical stress exists. Sigma 3 has a greatest magnitude near the extraction area and gradually declines up to the surface. Above 25 meters from the extraction location, the effect of 1 is insignificant. Near the extraction zone, the mean stress is highest and gradually decreases up to the surface. As a result of the chamber and pillar extraction, the upper layers of the rock strata show less influence. The maximum stress value is 31 MPa, and the lowest is 7 MPa. The stress effect can be felt up to 15 meters away from the extraction region. As a result, due to room and pillar mining, the upper development of the coal layer would be unaffected. Near the extraction zone, the shear stress is at its highest. The influence of tensional stress is minor beyond 20 meters from the extraction zone; hence, the coal seam's upper formation remains intact. From the roof sides to the surface, the displacement values dropped steadily. Displacement occurs up to 15 meters above the extraction zone, but does not impact the extraction zone's higher formation. As you got closer to the roof and floor, the displacement values started to drop. Therefore, in room and pillar mining, the coal layer's top development would be unaffected. The shear stress is most robust around the extraction zone. Beyond 20 meters from the extraction zone, tensional stress has no effect, hence the coal seam's top formation is unaffected. The displacement values continuously decreased from the roof sides to the surface. Displacement occurs up to 15 meters above the extraction zone, but does not affect the higher formation of the extraction zone. The displacement values started to decline as you moved closer to the ceiling and floor.

## Discussion

The study's simulation results for various stress and strain system parameters could be the key to predicting a reliable mining procedure in the Jamalaganj coal deposit. According to the results of computer modeling, both longwall and room pillar mining methods are applicable in the Jamalganj coal deposit. Because neither mining process will have an adverse effect on the basin's aquifer system. The overburden layers above the coal seam are unaffected by stress and strain or the factor of safety. Both mining methods leave the weak and loose formation and the water-bearing Dupitila formation untouched. However, as more coal was removed, the strain on the remaining pillars of coal increased until one collapsed, causing subsequent pillars to collapse. It is difficult to extract coal at a depth of 1000m below the surface level due to a large geothermal gradient and a lesser ventilation system in the room and pillar mining method. In addition, the rate of coal extraction in room and pillar mining is lower than in longwall mining. Longwall mining is more economically viable because to its high extraction rate and acceptable safety factor. As a result, we believe that longwall mining would be a better mining method for the Jamalganj coal resource. On the other hand, deep longwall mining has a negative economic impact due to the poor recovery rate (about 40% of the total deposit). Furthermore, because the coal seam is extra thick (37m), only a single slice mining will extract a relatively small amount of coal. Due to its larger depth, multi-slice longwall mining is too challenging.

Finally, it is reasonable to conclude the sustainable alternative like conventional UCG (Underground Coal Gasification) can be used for the better utilization of this reserve.

## Conclusion

The entire deposit of around 1053 million tons of coal is split primarily among seven seams, some of which are well developed and quite thick, and are found at depths ranging from 600 to 1150 meters below surface, providing good mining prospects (Rahman and Zaher, 1980). Despite differences in opinion about the mining method, all parties involved agreed that mining Jamalganj coal is technically possible. PD-NCB diverged from Krupp and recommended the longwall approach over Krupp's Room and Pillar method in mining methods. In their response, Krupp agreed that the longwall system and other alternatives might be considered but that backfilling would render the project economically undesirable (Rahman and Zaher, 1980). Room and pillar mining will have some ventilation issues because to the great depth and geothermal gradient. The most significant issue is that we should consider the prospective mining process, which is the subject of my thesis. Numerical modeling using the boundary element method (BEM) was utilized to simulate mining-induced stress and strain characteristics in the coal seam of the Jamalganj coal deposit. From the foregoing, it is evident that longwall mining is more practical than room and pillar mining. However, the extraction rate will be reduced because of the greater depth, as seen in the Barapukuria, where multi-slice longwall mining extracts about 9% of total coal. My modeling results reveal that both mining methods will not be hampered the regional aquifer, although major questions are related to production rate. Usually in underground mining, production rate is 10-40%. So, the maximum 40% of the total coal reserve will be extracted. If underground coal gasification is applied in that case rest of the coal might be used for the energy resource of the country.

## Recommendation

The geological structure and depth of the coal deposit are used to evaluate various mining methods. As a result, geological knowledge of the Jamalganj coal deposit is critical for determining the best mining method. The Jamalganj coal deposit's western, eastern, and southern boundaries are unknown. For appropriate calculation, the thickness of each formation of each and every bore hole is required, which is insufficient. Coal will play a significant part in Bangladesh's present energy dilemma. As a result, the progress of the Jamalganj coal mine demands immediate attention.

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