Geotechnical Mapping in an Active Mine to Forecast The Roof Strata Behaviour in It's Virgin Extension Block

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Abstract

In the successful operations of Longwall technology, forecasting and interpretation of strata behavior as much close to reality as possible is essential in pre-mining and post-mining scenarios. For the purpose of achieving its goals, Singareni Collieries Company Limited (SCCL) had tie-up with CSIRO, Australia to work jointly. Initially it was proposed to introduce High Capacity longwall in I seam of Adriyala Shaft Block . In light of this , Adriyala Shaft Block is first of its kind to generate all needy data. As a part of it, underground Geotechnical mapping of the rise side property of Adriyala Shaft block that is GDK-10A Incl , where longwall mining is in practice in the same I seam, was taken up to help in forecasting the strata behavior of proposed longwall panels of Adriyala Shaft block.

Keeping the importance of acquiring the basic data , this paper is prepared by synthesizing all the investigations being carried out as various studies were conducted based on this data.

General

The mine block GDK –10 A covers an area of about 3.85 sq.kms and forms an integral part of the Ramagundam coalbelt the block constitutes the southeastern part of the coalbelt (Fig.1). About 86 boreholes were drilled with a metreage of 21120.69 in this block. In the block, I seam is under exploitation. Generally the coal measures trend in N 10°W –S 10°E with east-north easterly dips. The gradient of coal seam varies from 1 in 6 to 1 in 7.5.

The top set of seams (I and II) are under exploitation. The Seam is being mined by longwall method of mining. In the Longwall mining, about 3.20m i.e. part of seam, was left in the roof and height of extraction being 3.30m along the sandstone floor in the level panels. Presently, one dip-rise panel is completed and another dip-rise panel is in progress.

Geology and Structure of Ramagundam Coalbelt

Ramagundam coalbelt is located in the northwestern part of the Godavari Valley Coalfield on its western margin, it stretches over a strike length of 25 kms. The regional strike of Gondwana sediments in this area is NNW–SSE to NW – SE with corresponding ENE to NE dips of 6 ° to 12° with considerable deviation near fault zones. The Gondwana sediments owe their preservations mainly to a graben structure caused by the presence of two major faults (Fig 1). One fault runs partly along the river course of Godavari in NW – SE direction with south westerly down throw of considerable magnitude (>600m) and forms the Northern boundary fault. The other fault terminates the strike continuity of Lower Gondwana sediments in the southern part of the area. This forms the Southern boundary fault and it runs sub-parallel to Northern boundary

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fault with north easterly down throw. In the southern part of the area, around Vakilpalli (18°41: 79°34') and Alluru (18° 41': 79° 32') villages, the coal seams and the associated strata show the structure of gently plunging syncline with the limbs cut off by a NW- SE trending fault having northeasterly throw, which increases from South to North. It is not possible to indicate precisely the amount of throw of the fault in the southern part of the area, as the strike conformity of coal seams is affected due to abutting of Gondwanas against the Archaeans. Based on geological mapping interpretation of sub surface data coupled with geophysical investigations at places, many faults have been delineated which run in different directions with varying amounts of throw (Fig.1).

Geology and Structure of GDK-10A Mine block

The area, blanketed by a thin cover of soil, ranging in thickness from 0.61m to 4.35m is devoid of exposures and as such the stratigraphic sequence built up is solely based on the sub-surface data collected from the boreholes. The Talchir Formation is the oldest unit of the Lower Gondwana sequence intersected in the borehole No.GGK-17. The coal bearing Barakar Formation overlies the Talchir Formation with a gradational contact, like in the other blocks of Ramagundam coalbelt, Seven regionally correllatable coal seams viz., IA,I,II,IIIB,IIIA,III & IV are developed in this block in descending order. The Barren Measures succeed the Barakar Formations, conformably with the gradational contact around 10 to 15 m above No. IA seam. Generally the coal measures trend in N 10°W –S 10°E with east-north easterly dips. The gradient varies from 1 in 6 to 1 in 7.5.

Underground Geotechnical Mapping

A detailed underground geotechnical mapping was carried out in I seam to pick up the trends of Faults / Slips, Joints, Cleat, Sedimentary structures etc. Mapping is carried out along 1 Dip and 2 Dip from 30 Level to 53 Level. From 54 Level to 58 Level, both 1 Dip and 2 dip are not accessible due to sump. Hence, from 54 Level to 58 Level, mapping is carried out along 3 & 4 Dip galleries. Also mapping is carried out along 50 LN (Tailgate), 53LN (Maingate) and Face of Longwall Panel-8. In the study area, as many as 64 Joints, 76 Cleats, 8 faults / slips have been picked up besides sedimentary features viz. Sandstone dykes, Cut & Fill structures, pinch out of sandstone bands in the coal seam etc. Apart from all these features, major fractures with an opening of 8 cms. are common in the coal pillars(Fig- 2).Details of all these features are discussed .

Sandstone Dykes

Clay veins, clay stone dykes or sandstone filings are wedge shaped masses that occur in crevice of a coal bed (Fig-3). The common feature is that of the "Sandstone Dyke" or "Stone intrusions" or "Stone eye" (irregular masses of sandstone) that occur within the seam or penetrating into the seam. These generally range up to 1m in width . The pattern and character of these structures suggest that they formed as tension fissures in coal which later filled with clayey/sandy material and then were compacted after burial. The irregular masses of sandstone that occur within the seam or penetrating into the seam from top or bottom are the common features referred to "Stone intrusions" or "Stone eye" or "Sandstone dykes" (Raistrick and Marshall, 1939). Some sandstone dykes also indicate activity of faults which might have been active during Gondwana era.

Cut & Fill Structure

Among the most troublesome obstacles met within a coal mine are those partial or complete removals of a seam known as "Cut & Fill / Wash outs", which is the result of erosion at some period during or soon after the formation of the seam or seams. In its simplest form and on the smallest scale a "Wash out" cut into or through a coal seam, and filled generally with sandstone (Fig-4). Besides these structures, thin sandstone bands with pinch out in the coal seam are also identified.

Joints

The rose diagram drawn for 64 joints reveals two distinct direction of joints viz. J_1 and J_2 (Fig-6a). Joints poles were plotted on equal area projection lower hemisphere (Fig-7). The most prominent joint set J_1 is in the direction of N5°E and next prominent joints set J2 trends in N750 W. There is a coincidence that J1 joints are parallel to pronounced set of Face Cleat. Along the J1 joints , calcite fillings are observed. Further J1 joints dip at steeper angles. Spacing of these joints varies from 1m to 3m. J2 joints are closely spaced and tight, the spacing varies from 10 cm to 30 cm and are tight joints. No joint opening is observed (Fig-5). Nelson and Bauer opined that closely spaced joints occur in some mines that have high in-situ stress.

Nelson and Bauer(1987) found from their studies that throughout the Illinois basin,the predominant direction of jointing in roof is parallel to the major stress axis, Sharma and Chandra, based on their observations, found that the greatest principal stress direction s 1 is oriented parallel to the most prominent joint set J1.

Cleat Pattern

Cleat is a conjugate set of fractures occuring in coal mostly at right angles to each other. "Face cleat" is a continuous one and "Butt cleat" is discontinuous and abuts against Face cleat. A distinct cleat pattern is developed in the coal bands of I-Seam (Fig-8). About 76 readings of Face cleat and Butt cleat each are taken. The trend of cleat pattern is mapped and constructed a Rose diagram and depicted in Fig-6b. Face cleat trends in N5°E and Butt cleat trends in N80°W.

Slips

Only 8 slips having less than 1m. throw are mapped. It is inferred from the rose diagram (Fig-6c) drawn for the slips that the most prominent slip trend in N85°W. Down throw of the slips are mostly trending inN25° E (Fig-6d). In most of the cases, the slip angle is 60° and in few cases, it has been recorded upto 70°. Slicken sides are observed along the slip planes.(Fig- 9).

Stress Studies

In-situ stress measurements tests were conducted by CMRI in collaboration with MeSy (India) Pvt.Ltd. in the adjacent block i.e. GDK-8 Incl. for I seam at a depth of 140m. Based on the interpretation of the test results ,the Major Principal Stress direction s_1 is in N15°E with a magnitude of 5.309 Mpa , whereas the Minor Stress direction s_3 is in N75°W with a magnitude of 3.298 Mpa.

The stress mapping technique is extensively used in many countries to avoid heavy expenditure on conducting tests for In-situ stress measurements. As a substitute, procedures have been developed to estimate the orientation of the major principal stress. Nelson and Bauer(1987) found from their studies that throughout the Illinois basin, the predominant direction of jointing in roof is parallel with the major stress axis, Sharma and Chandra (1988) found based on their observations that the greatest principal stress direction sH 1 is oriented parallel to the most prominent joint set J1. Features such as roof "guttering" or roof "pots" are mapped in underground workings and the stress direction is inferred from their orientation and severity. Using such techniques, Stress mapping studies were conducted in the SCCL mining blocks viz. 5 Shaft & VK-7 Shaft of Kothagudem, Goleti-1 Incl etc., In the present study area, it is observed from the Tailgate and Maingate of Longwall Panels 3A and 8 that the guttering is confined to dipside of the gateroadways (Fig-10). Conversely, Dip Galleries are stable. Further, the most prominent Joints (J_1) and

Face cleat trend (N5°E) is matching with the orientation of Principal Stress direction established in GDK-8 Inc.(N15°E). Hence it was presumed that in the study area, the Principal stress direction could be between N5°E to N15°E.

Subsequently, in-situ stress and permeability Measurements were carried out successfully in the deeper borehole (BHNo:1205) of proposed Longwall Panel-1 of Adriyala shaft block. A total of 18 In-situ Stress and 30 Permeability Measurements were carried out from 77.50m to 522.00m depth in various horizons. The work was carried out by MeSy (India) Pvt.Ltd Lucknow . As per their report, the major Horizontal stress s_1 direction is varies from N11°E to N23°E, and quoted that it essentially is in close agreement with the classical approach of N(24+14) degrees and the magnitude is 3.13+0.0106 Mpa.

Coal Rock Mass Rating (RMR)

The expert group on guide lines for drawing of support plans in board & pillar workings in coal mines (Directorate General of Mines Safety,1990) constituted by the Directorate General of Mines Safety (DGMS) recommended that the support plan should be drawn up based on geomechanical classification of the roof strata using the COAL ROCK MASS RATING (RMR) approach.

The work includes, detailed field investigations of sub-surface, geotechnical data collection from underground, rock sample collection for testing of strength and Weatherability to enable for evaluation of the support requirement & formulation of support plan.

I Seam (Top Section) is mined through GDK-10A incline keeping sandstone as the immediate roof. This seam having an average thickness of 6.5m is being exploited through machine mining (Road header for Long wall) method. The seam contains mostly coal, carbshale and shale bands. RMR studies were carried out in 57 Level south of 8 dip and the details are as follows-

- Combined Coal RMR = 75.63
- Classification: II A GOOD
- Rock Load =1.32 t/m^2

Geotechnical Hazard Map

In addition to underground geotechnical mapping, a Geotechnical Hazard Map has been prepared (Fig. 11) using the additional exploration data generated in Adriyala Shaft Block to forecast the strata behavior of 1st Longwall Panel. This Hazard map will be useful in anticipating the roof strata behavior both in the preparation as well in the retreat of the Panel.

The steps involved in the preparation of the Hazard Map are as follows-

- The main gate and tail gate sections are constructed on the vertical scale. For this, 100m strata above the working seam and up to one sequence of formation down below the working seam are considered. Within this 100m strata, different lithological units are taken into consideration.
- The Clay forming the immediate roof of I Seam is shown both in the plan and sections.
- Geological disturbances within the panel anticipated are taken into consideration.
- Orientation of Principal stress direction with reference to Longwall panel.
- On the sections with bore holes, the seismic data and UCS from seismic logs are shown as < 30 Mpa and > 30 Mpa.
- Immediate roof of I Seam is taken into consideration while constructing the Section and contouring the variation of its thickness on a plan.
- Depth cover is taken into consideration in the process of preparing Hazard map.
- Coal RMR data of GDK-10A, classifying the roof strata of I seam is considered.

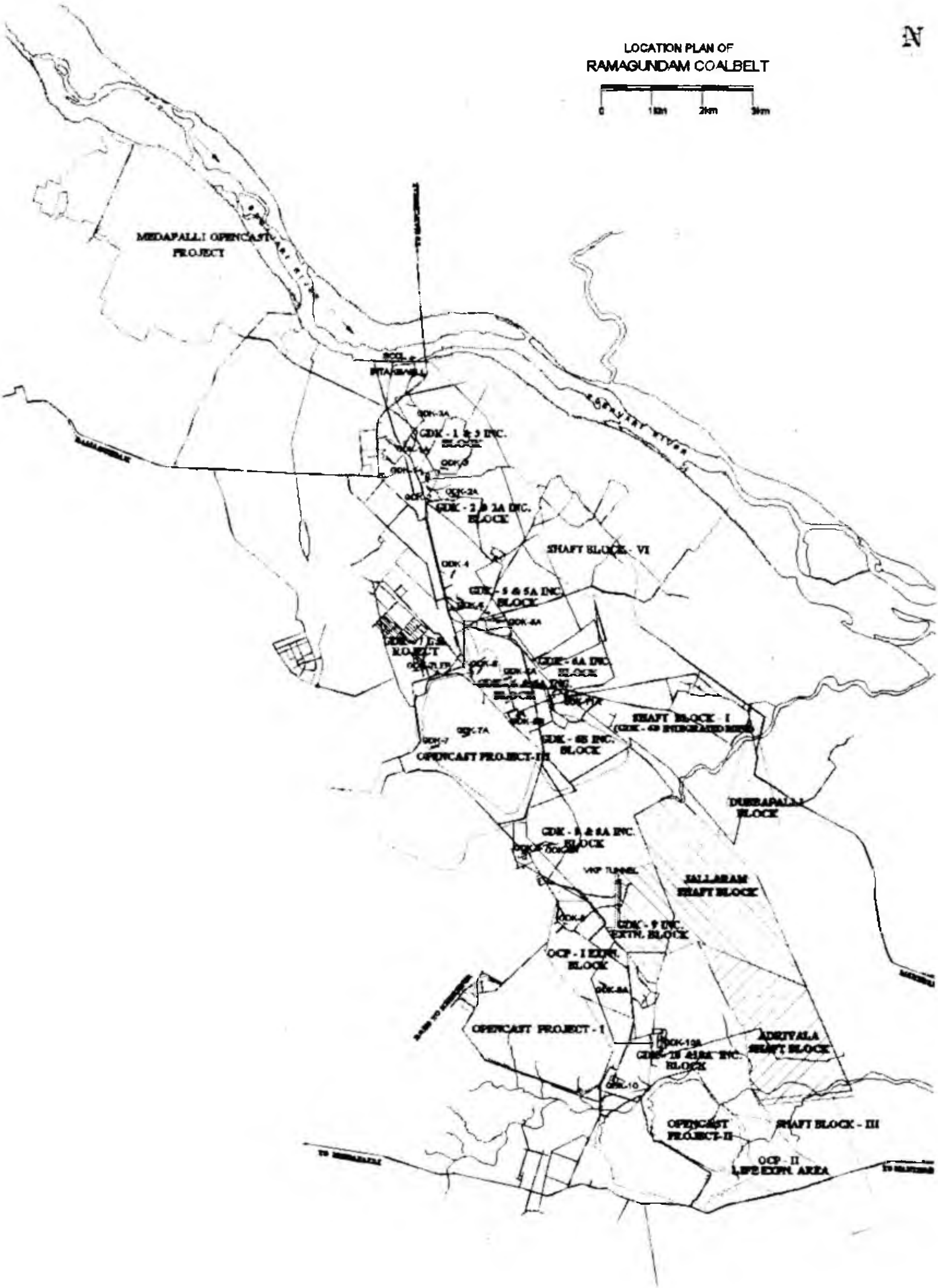

Fig. 1. Location plan of Ramagundam Coalbelt.

Fig. 2. A major Fracture in the Coal Pillar with an opening of 8 cm.

Fig. 3. Sandstone dyke/"Stone Eye " exposed in the coal.

Fig. 4. Cut and Fill Structure exposed in the roof

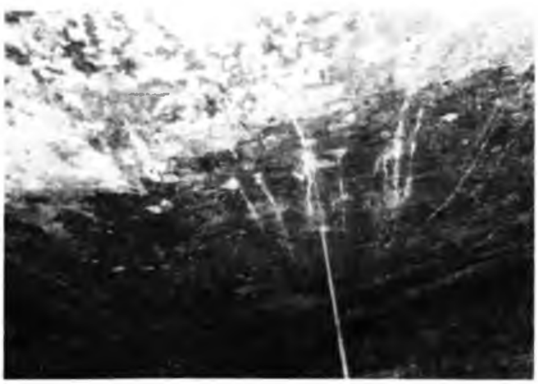

Fig. 5. Tight Joints exposed in the sandstone roof

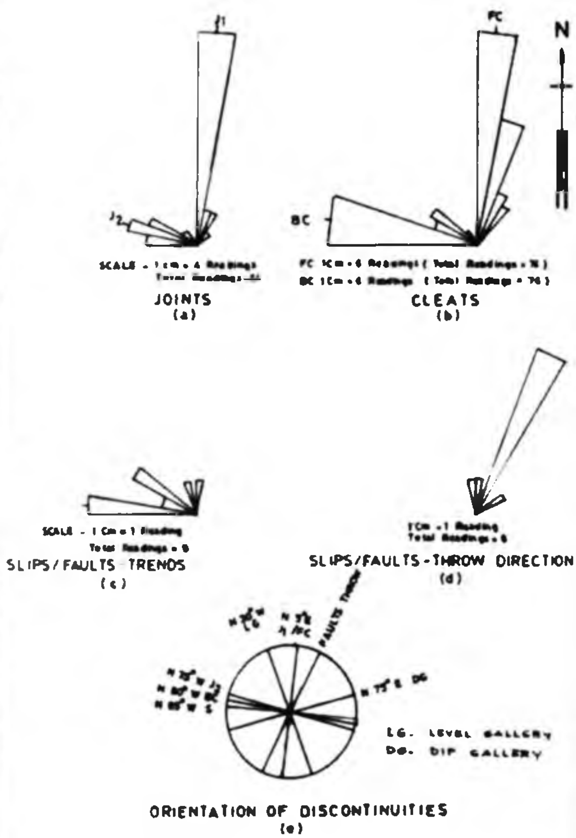

Fig. 6. Rose Diagrams

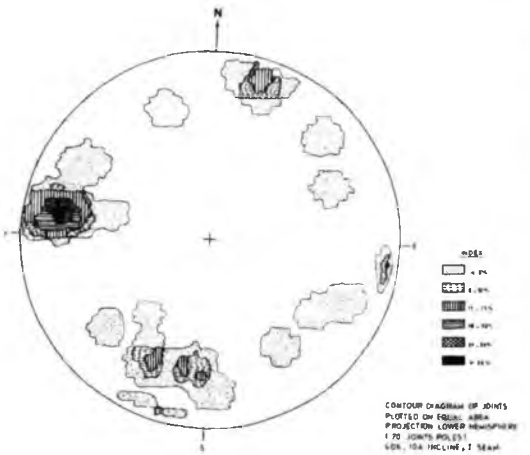

Fig. 7. Contour diagram of Joints plotted on equal area projection lower hemisphere

Fig. 8 Face and Butt Cleats in the Coal Pillar

Fig. 9. Slickensides along the slip plane

Fig. 10. Roof Guttering in the dip side of Tail gate observed in Longwall panel-8.

Conclusions

1. The structure of Ramagundam coalbelt between two major faults is a gently plunging anticline with limbs cut off and forms a graben structure.GDK-10A block is free from major faults and the gradient varies from 1 in 6 to 1 in 7.5. I seam is being mined, through longwall method of mining.
2. Based on the underground geotechnical mapping the following observations are made-

- Sandstone dykes, Cut & Fill structures and sandstone bands pinch out in the coal seams.
- The most prominent joint set J_1 are in the direction of N5°E and coincide with the pronounced set of normal slips. Next prominent joint set J_2 trends in N75° W and joints closely spaced.
- Face cleat trends in N5°E and Butt cleat is in the direction of N80°W.
- Minor Slips/faults are observed and are trending in N85°W.

3. Based on the In-situ stress measurements data of adjacent GDK-8 incl block generated prior to underground geotechnical mapping, the Major Principal Stress direction s_1 is in N15°E. Based on mapping carried out in the present study area, it has been estimated that Major Principal Stress direction s_1 could be between N5°E to N15°E. Subsequent In-situ stress tests conducted in Adriyal shaft block indicates that Major Principal stress s_1 is in N11°E to N23°E.

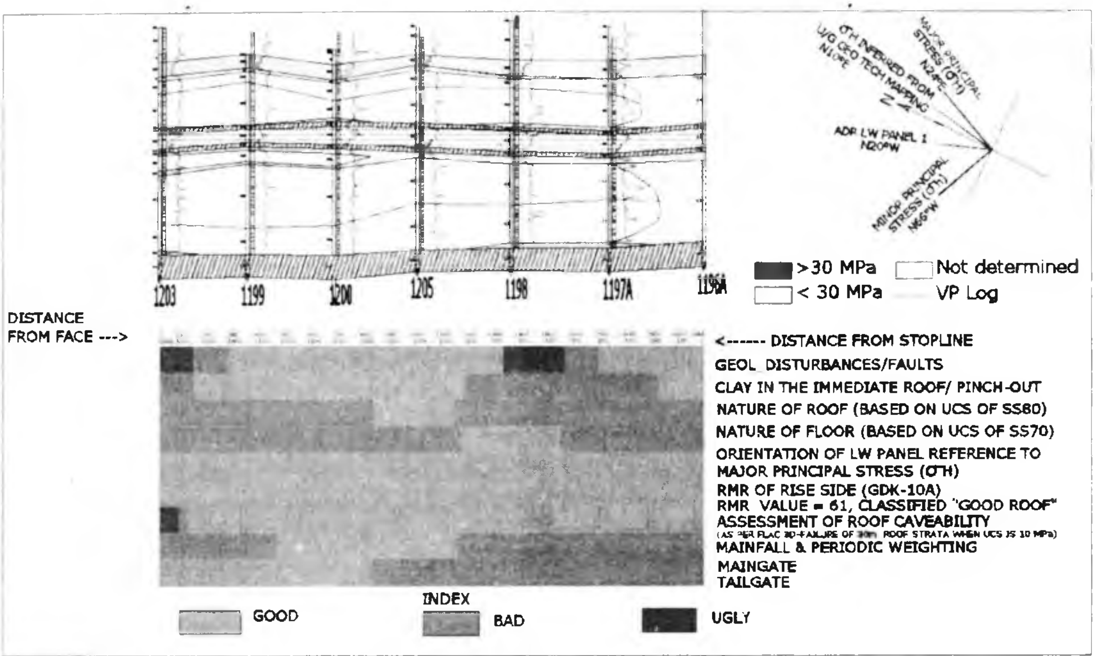

Fig. 11. Geotechnical Hazard Map of Longwall Panel-1, Adriyala Block

4. RMR of the roof strata of I seam (Top section) is 75 and the rock load is 1.32 t/m^2.

5. The Geotechnical Hazard map, which has been prepared from all the data gathered, gives reasonable assessment of roof strata behavior and is expected to be immensely useful in the operation of Longwall Panel.

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