# Coal seam roof stability prediction and evaluation based on GIS platform with multiple data sets


**Wang Huaihong**
*Shandong Bureau of Coal Geology*
*Taian Shandong province*
*China*
*tawhh@126.com*

**Gong Gu**
*Shandong Bureau of Coal Geology*
*Taian Shandong province*
*China*
*gonggu215@126.com*

**Lv Dawei**
*Shandong University of Science and Technology*
*Qingdao Shandong province*
*China*
*windylvdawei@163.com*



## SUMMARY

This paper, based on GIS technology, combines multiple data sets such as three-dimensional seismic data, drilling, geophysical logging and mining geology data to evaluate and predict the stability of the coal seam roof. By analysing every factor affecting the stability of the coal seam roof, we establish an evaluation model of the coal seam roof stability, and we take the first mining area of coal seam 3 of Longgu Mine from the Juye Coalfield as an example to predict the stability of the coal seam roof.



**Key words** multi-source information; coal seam roof; stability; predict; evaluation


## INTRODUCTION

Coal is one of the major energy sources in China. It provides 75% of the energy required by the nation (Hou, 1997; Xie, 1998). To meet the domestic demand of coal consumption, coal mines (both new and old) in China, especially in eastern China, become deeper and deeper. With the increase of mining depth, the pressure of the coal roof increases gradually, and the longwall roof support becomes a challenging task. The ability to understand the coal seam roof stability is fundamentally important to design and planning of effective longwall support, goaf gas drainage systems, and for assessing mining induced impact on surface and subsurface water bodies and to guarantee safe coal production.

The stability of the coal seam roof is mainly affected by lithology, geological structure, hydro-geological condition and rock mechanic parameters of the roof, which involve a large quantity of spatial data and attribute data. Conventional methods cannot easily manage these data for mine design and planning. However, a geographic information system (GIS) can easily integrate such large data sets and generate thematic maps. This provides a feasible platform for the quantitative prediction of the coal seam's stability (Xu, 2001).

In this paper, we will use GIS technology to integrate multiple data sets such as three-dimensional seismic data, drilling, geophysical logging and mining geology data for evaluation and prediction of the stability of the coal seam roof. The approach will be illustrated by an example of evaluation of the roof stability of coal seam 3 in the first mining area at the Longgu Mine in Juye Coalfield.

## PREDICTION MODEL OF ROOF STABILITY WITH MULTIPLE DATA SETS

In order to forecast the stability of coal seam roof by using multiple data sets, a stability prediction system was developed on the MAPGIS platform. The design philosophy is to establish a prediction model by analysing multiple data sets including 3D seismic, geological structures and roof lithology.

### Weight determination of the factors

As stated before, the coal roof stability is influenced by many factors. The stability weight of each factor must be determined before establishing the stability forecast model of the coal roof. The weight reflects the effected extent of each factor to the coal stability. Its determination affects the precision of forecast results of the coal roof stability and should be determined by comprehensive analysis for each survey area.

There are two approaches to assign the weight of the coal roof stability for each factor. The first approach is an average method, which uses the same weight for every factor. The second one is a manually-assigned weight, in which the weight is determined manually according to the specific circumstances of each mining area. Once the weight of each factor is determined, a prediction model can be established for the coal roof stability.

To improve the accuracy of assigned weight , in this paper, we map each factor affecting the stability of coal seam roof into the image, analyse its sensitivity to stability estimation of the coal roof, and then assign the weight according to the actual situation.

### Stability prediction model

To effectively predict the coal roof stability, a prediction model is required. Before establishing such a prediction model, the stability value for each factor is normalized between 0 ~ 1.

Assuming there are four factors affecting the stability of the coal seam roof: $A_1(x_1,x_2,\cdots,x_n)$ , $A_2(y_1,y_2,\cdots y_n)$ , $A_3(m_1,m_2,\cdots,m_n)$, $A_4(k_1,k_2,\cdots,k_n)$ and each factor has n data points. In this paper, two factors that affect coal seam roof stability are the roof structures (mainly faults) and acoustic impedance (reflecting lithologic features).

Let the weighting values for various stability factors be $a_1$, $a_2$, $a_3$, $a_4$, the vales of stability in the survey area are,

$$t_1 = x_1 * a_1 + y_1 * a_2 + m_1 * a_3 + k_1 * a_4$$
$$t_2 = x_2 * a_1 + y_2 * a_2 + m_2 * a_3 + k_2 * a_4$$
$$t_3 = x_3 * a_1 + y_3 * a_2 + m_3 * a_3 + k_3 * a_4$$
$$\vdots$$
$$t_n = x_n * a_1 + y_n * a_2 + m_n * a_3 + k_n * a_4 \quad (1)$$

Expression (1) can be used to compute the coal seam roof stability values $T(t_1, t_2, \cdots, t_n)$.

## ROOF STABILITY EVALUATION OF COAL SEAM 3 AT LONGGU MINE, JUYE COALFIELD

### Geological settings

Longgu Mine is located about 13~28 km west of Juye County of Shandong Province (Liu, 2004; Wang, 2007). It is in the middle of Juye Coalfield. The mine is controlled by the Tianqiao fault in the east, the base of coal-bearing strata outcrop in the west, the Xingzhuang and Liuzhuang faults in the south, and the Chenmiao fault in the north. The mine is about 15 km long from the east to the west and 12 km wide from north to south, and covers an area of ~180km$^2$.

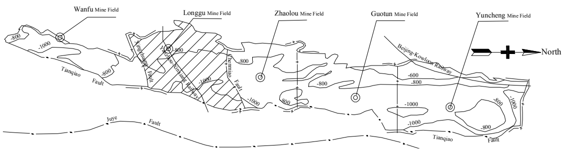


**Figure 1 The coal mines in Juye Coalfield**

The coalfield strata have a regional monocline with a strike roughly in the north-south direction and a dip to the east. There are subordinate folds developed with a number of faults and igneous intrusion. The structural complexity is medium.

The coalfield belongs to a North-type Carboniferous, Permian coalfield. The coal-bearing basement is Mid - Lower Ordovician deposited with the Carboniferous Benxi formation, Taiyuan formation, the Permian Shanxi Formation and lower Shihezi formation and upper Shihezi formation, and covered by Neogene and Quaternary sediments. The major coal-bearing strata are Taiyuan and Shanxi formation.

The thickness of the main mining coal seam 3 at Longgu Mine is 9.08 - 10.20m with an average thickness of 9.53m, which is a stable coal seam. The coal seam roof is relatively simple. The pseudo-roof is mudstone and siltstone with a thickness 0.20~0.76m. The immediate roof is mainly sandy mudstone and siltstone with a thickness of 0.80~11.60m and a compressive strength of 22.80~114.0MPa; or mudstone with a thickness of 0.80～2.50m and a compressive strength of 37.6～106.4Mpa. Some part of the immediate roof is fine-grained sandstone or medium sandstone with a thickness of 2.70～13.25m. The upper roof has a thickness of 2.20～26.7m and mainly consists of fine-grained and medium grained sandstones and it also contains siltstone or interbedded siltstone and fine-grained sandstone. In the area with igneous intrusions, the coal seam roof is lamprophyre or altered lamprophyre，which is strong with well-developed fractures.

### Fitting process and stability model of seam 3 roof

***Initial model***

There are two single-factor maps used in the roof stability prediction: structure (DCGZ) and lithology (BZK) of the seam roof. Determination of the initial mode is mainly based on the geological factors affecting the stability of coal seam 3 in this region.

The initial roof stability model for coal seam 3 in this area is,

ZHWDX=DCGZ×0.4+BZK×0.6 (2)

ZHWDX is the roof stability value for the coal seam 3 calculated from geological and lithological factors.

***Refinement of roof stability prediction model***

The specific process of fitting a correction for the roof stability is as following:

1) Compute the initial roof stability values for coal seam 3 using the equation (2) based on the stability values of each factor at available spatial data points;
2) Generate the spatial distribution map of the roof stability from the calculated initial stability values;
3) Compare the computed stability distribution with the actual roof stability of coal seam 3: if it is not consistent with the actual values, the distribution of weights is modified to match the actual situation.

By repeating the above process, optimised weights can be derived. In the case of coal seam 3 at Longgu Mine in Juye Coalfield, the ultimate weights for both factors are 0.5. Therefore, the final roof stability model for coal seam 3 is,

ZHWDX=DCGZ×0.5+BZK×0.5 (3)

### Zoning the stability of the coal seam roof

After obtaining all the points of coal roof stability $T(t_1, t_2, \cdots, t_n)$, these stability data are fed into program MAPGIS to generate a colour image or contour map showing the spatial distribution of the roof stability. As the coal seam roof stability ranges from 0 to 1, one can divide the colours or contours into 10 divisions (that each level are incremental steps of 0.1) or 5 divisions (each an incremental step of 0.2). Based on this map, we can classify the roof stability into different zones.

### Evaluation of GIS-based coal roof stability

Figures 2, 3 and 4 show the roof stability distributions for the 10m, 20m and 30m intervals above coal seam 3 roof, respectively. Figure 5 is a 3D display of the above-roof stability distribution maps.

Analysis of these maps suggests that the roof stability of coal seam 3 is mainly controlled by tectonic structures such as faults and is less affected by the lithological factors.

Based on the stability values, we divide the roof stability into 4 different zones: 1) Very stable areas coloured in blue and purple with stability values > 0.8; 2) Stable areas coloured in light blue with stability values in the range of 0.6-08; 3) relatively stable areas coloured in brown and red with stability values in the range of 0.4-06; and 4) unstable areas coloured in yellow and green with stability values < 0.4.

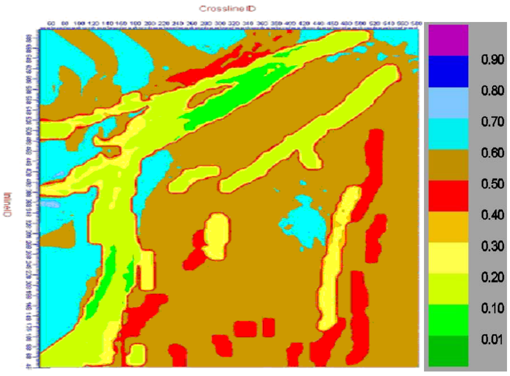


**Figure 2 The roof stability distribution of the coal seam 3 for the interval of 10m above the roof.**

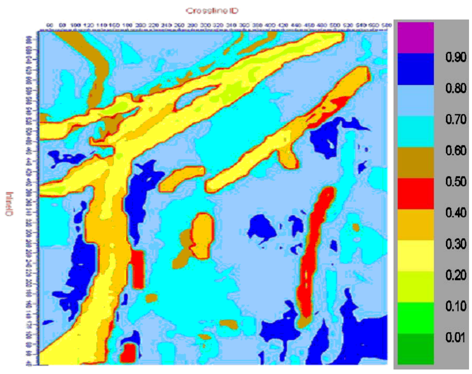


**Figure 3 The roof stability distribution of coal seam 3 for the interval of 20m above the roof.**

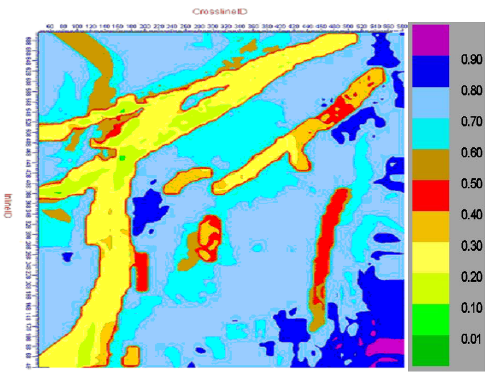


**Figure 4 The roof stability distribution of coal seam 3 for the interval of 30m above the roof.**

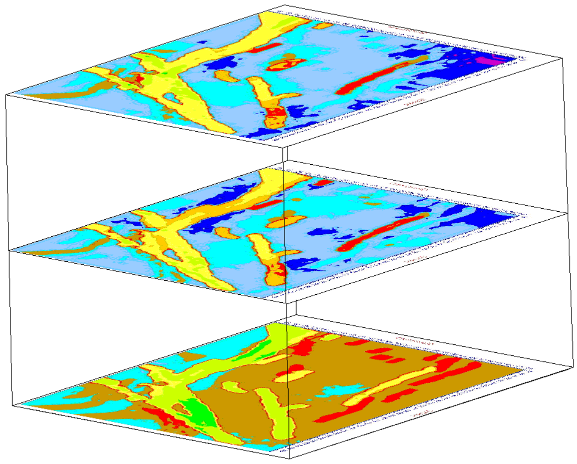

**Figure 5 3D view of the roof stability for intervals of 10 ~ 30m above coal seam 3 roof.**

## CONCLUSIONS

The investigation of the roof stability of coal seam 3 at Longgu Coal Mine in Juye Coalfield was based on structure and lithology information, which are from the interpretation of the migrated 3D seismic data and the analysis of the inverted acoustic impedance data from the same 3D seismic volume. In addition, geophysical borehole logging, drilling data and mining data were also used during analysis of the structure, lithology and stability and the analysis was performed on a GIS system. Therefore, the coal roof stability prediction presented here is an integral interpretation and analysis of multiple data sets.

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