Research on the Development Features of the Shengquan Minefield Fault Structure in Shandong Province

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Abstract : In order to figure out the complexity of Shengquan Minefield fault structure, the required sample data was reorganized and collected in accordance with the field measurement data and the geological information of the 15th coal layer of the minefield. Firstly, according to the exposure condition of the drilling hole, the rose diagram of the fault direction was drawn after specifically collecting the nature, direction, and height gap and realize the visualization of the fault field measurement data, so the complexity of sectional structure can be initially analyzed. Secondly, the similarity dimension model was built through the box-type covering method in order to count the grid number of the fault trace under each sideline, and then the result was applied to the logarithmic coordinate system. By using the least square method, the slope of the bridging curve and, moreover, the fractal dimension value were achieved. Finally, Sufer was applied to draw the contour map of the fractal dimension value. The research result indicates that, through a series of quantitative analyses, this field can be divided into a simple tectonic area, mid-complex tectonic area, and complex tectonic area.

Keywords: Shengquan Minefield, The complexity of fault structure, Fractal dimension space, Statistical analysis.

1. INTRODUCTION

Mine water inrush is the main reason for mine accidents. The development of minefield, especially the development of fault structure, is of serious impact on the safe production of a minefield. The pace of researches on the impact caused by fault structure on the mine water inrush has never stopped [1-25]. Making effective research on the complexity fault structure can reduce unnecessary economic loss. Among various evaluation methods, the fractal dimension method is a relatively mature computing method till now, which is able to make an effective evaluation on the complexity in accordance with the development features of the fault structure [26-51]. The 15th coal layer of Shengquan Minefield is the nearest coal layer to Ordovician limestone. The statistical analysis of the minefield fault structure of the 15th coal layer after mining exposure can provide valuable data for the 15th coal layer of other minefields as well as guide the underground engineering exploration and the prevention and control of minefield flood.

2. STUDY AREA

Shengquan Minefield is located in the Quangou County, Xintai City of Shandong Province, longitude 117°35'58"-117°38'38"E, latitude 35°58'09"-36°00'00"N. The terrain there is typically hilly one with ground-level between +170 m to +205 m, a height gap of 35 m. The terrain in the middle and south is high, while the terrain in the north and west is low. There is no wide river or large waterlogged land in the area, and there are two seasonal rivers at the east and west edges of this minefield only (Fig. **1**).

3. FAULTS DISTRIBUTION CHARACTERISTICS

3.1. Faults Nature

By counting the faults of the 15th coal layer of Shengquan Minefield after exposure, a total of 350 faults have been found, including 289 normal faults (83%) and 61 reverse faults (17%) (Fig. **2**). There are 80 arc faults (23%) and 270 linear faults (77%) (Fig. **3**).

The statistical results indicate that this minefield is mainly formed by linear normal faults, which is mainly caused by the following two reasons: Firstly, the coal-control structures within the minefield are all normal faults, such as Lianhuashan Fault. Secondly, the backbone faults within the area are also normal ones. The secondary faults are closely related to the coal-control faults and the backbone faults in the area. The nature of the faults indicates that the fault structure is formed mainly by the tension stress field effect, and the secondary compressive shear stress field appears only in the local area.

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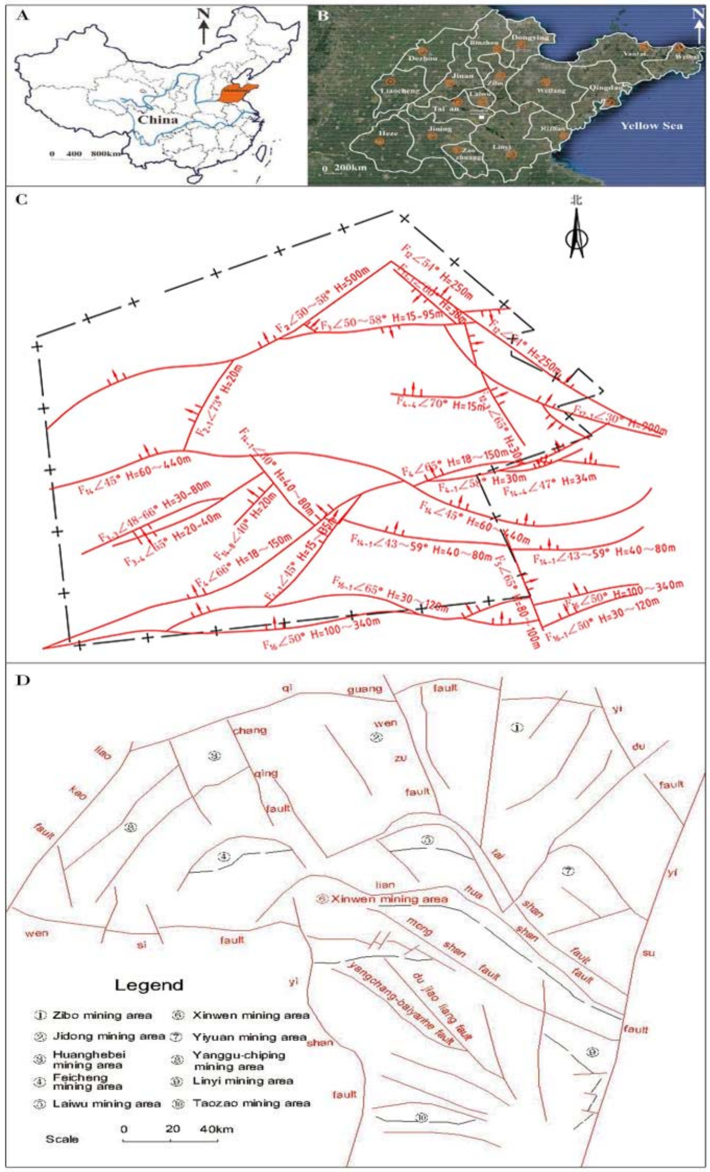

Figure 1: Locality map and structural map of the Shengquan Minefield.

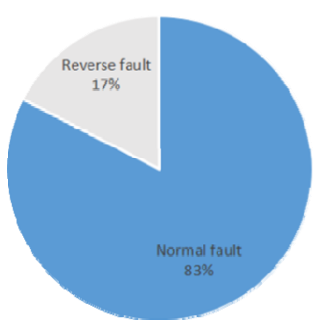

Figure 2: Scale map of fault nature.

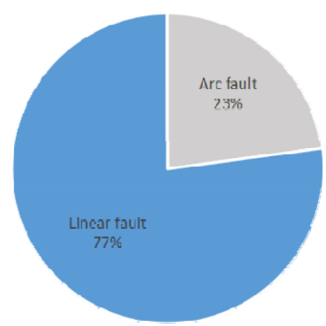

Figure 3: Scale map of fault shape.

3.2. Fault Strike Direction

Fault strike direction information, which is not difficult to achieve, is an important indicator of fault nature which can reflect the complexity of the structure from a side view and can also make full use of the information from exploration and exploitation [52]. In accordance with the law of direction, the tectonic movement of the whole minefield can be roughly predicted, and the structure of the minefield can be figured out more simply. On the layout of the 15th coal layer of Shengquan Minefield, the number of the faults were counted at different angles every 10 degrees, and the results are shown in Table **1**. This has been taken as the basis of drawing the rose map of the fault strike direction (Fig. **4**).

Table 1: Statistical Table of Fault Strike Direction

Strike (°)	Number (Item)	Strike (°)	Number (Item)
0~10	4	270~280	24
10~20	11	280~290	16
20~30	7	290~300	14
30~40	19	300~310	21
40~50	26	310~320	16
50~60	35	320~330	20
60~70	48	330~340	5
70~80	39	340~350	6
80~90	38	350~360	1

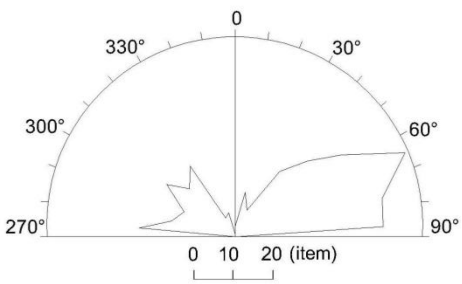

Figure 4: Rose map of fault strike direction.

Figure **4** shows that the small faults center around 60°-90°, and they are mainly formed by the Indosinian Movement in Mesozoic, Neozoic Yanshanian Movement, and Himalayan Movement.

3.3. Gap of Fault

The gap of fault, an important indicator when evaluating the complexity of the minefield, can reflect the damage degree of the coal layer or the stratified rock. In the 15th coal layer, there are a total of 350 faults, covering 110 ones (31%) shorter than 1 m, 200 ones (57%) between 1 m and 5 m, 15 ones (4%) between 5 m and 10 m, and 25 ones (8%) longer than 25 m. On this basis, the following conclusions are drawn:

1) Gap height mainly centers around 1 m to 5 m. These faults, horizontal or vertical, have a poor layer-penetration force and limited extension length.

2) The gap between each coal layer is basically the same, namely shorter than 5 m, and the secondary faults are all shorter than 1 m, which reflects that the faults in each coal layer are formed by the tectonic stress field-effect during the post-forming stage of coal measures.

3) Faults shorter than 5 m in each coal layer all develop abnormally, which indicates that the floor rock stratum is damaged seriously.

4. FRACTAL FEATURES OF FAULTS

4.1. Concept and Establishment of Fractal

Fractal is a kind of morphological character which uses non-integer dimensional form, and it is a similar form existing between a part and the whole. The part is more or less similar to the whole, known as the self-similarity, which means that, when the local space or time changes, the structural feature of the research object will not change, except for the amplification or reduction of the original size of the whole, and the whole is the infinite nesting of the part. The measurement of the fractal is called fractal dimension, and fractal dimension has multiple types. This research mainly uses a similarity dimension to describe the complexity of the faults, and the fractal dimension can be used to describe the complexity of the minefield structure exactly.

Relatively speaking, the similarity dimension (D_S) is the most widely used fractal dimension. Let F(r) be any nonempty bounded subset on Rn, and N(r) be the minimum number set of similar sets r_B covering the fractal primitive B required by F(r). When the geometric figures with similarity are separated by similarity ratio r, N(r) similar figures can be obtained. (the smaller the r is, the larger the N is). That is, when r→0, N(r)→∞, then the similarity dimension of set F(r) is defined as:

$$Ds = \dim F(r) \lim_{r \to 0} \frac{\lg N(r)}{-\lg r}$$

The most commonly used method to calculate fractal dimension is the box cover method. The existing fault grid trace map in the minefield was projected on transparent paper, and then the study area was divided into several square blocks by using a square grid with a side length of r_0. The number of grids N(r) with fault trace passing through each block was counted, and the grid was continuously reduced so that $r = r_0 / 2$, $r_0 / 4$, $r_0 / 8$. The number of grids with fault trace passing through each level block was recorded, and the result of each block was obtained. A fitting line can be obtained by putting them into lgN(r)-lgr coordinate system. The absolute value of the slope of the fitting line is the similarity dimension ds of the block. The slope of the fitting line was calculated by the least square method, and its absolute value is the similarity dimension of the block.

$$Ds = \left| \frac{N * \sum_{i=1}^{n} N(r)iri - \sum_{i=1}^{n} N(r)i \sum_{r=1}^{n} ri}{n \sum_{i=1}^{n} ri^2 - \left(\sum_{i=1}^{n} ri \right)^2} \right|$$

ri -- the number of grids with fault trace passing through in the i'th block

n -- the number of blocks

Therefore, the specific calculation method of the fractal dimension value of No.15 coal seam in Shengquan minefield is as follows: take the 500×500 grid formed by the longitude and latitude network as the basic unit, count the number of grids N(r) with fault trace passing through each block, and then gradually shorten the grid side length to 250×250, 125×125, 62.5×62.5, count the number of grids with fault trace under each side length, and put them into the grid In the lgN(r)-lgr coordinate system, a fitting line can be obtained, and the absolute value of the slope of the fitting line is the similarity dimension ds of the block. Use the least square method to calculate the slope of the fitting line, whose absolute value is the similarity dimension of the block, assign the fractal dimension value to the grid center coordinate point, and draw the fractal dimension contour map of the region with surfer software, as shown in Figure **5**.

4.2. Fractal Features and Division of the 15th Coal Layer

There is no influence of magmatic rock in the whole area of the Shengquan minefield. According to the Regulations of Coal Mine Geological Work, there is no extremely complex area in the minefield [53]. Thus, the field can be divided into a simple tectonic area, mid-complex tectonic area, and complex tectonic area in accordance with the field materials. Details are as follows:

Ⅰ. District (<1.2): This district mainly distributes in the small areas in the middle and edge of the minefield, namely the Ⅰ district in the figure. In this district, there is little big fault development. Neither small faults, structural intersections, and endpoints are relatively fewer in this area, and the faults scale and development degree are small.

Ⅱ. District (1.2-1.5): This district has a relatively wider area. The structural intersections and endpoints here have an average development degree. Small faults are densely distributed here, and there are a few big ones here. The damage degree of rock here is medium, and the fault fractal is put in a relatively middle position.

Ⅲ. District (>1.5): This district distributes in the northeast and mid-west areas of the minefield, namely the Ⅲ district in the figure. In this district, the development degree of faults is relatively bigger, and big faults cross with each other intensively with gaps usually of 20-100 m. The longest gap in this district is the F14 gap of 440 m. As the density of faults here is big and the biggest fractal is 1.76, the rocks here are relatively broken.

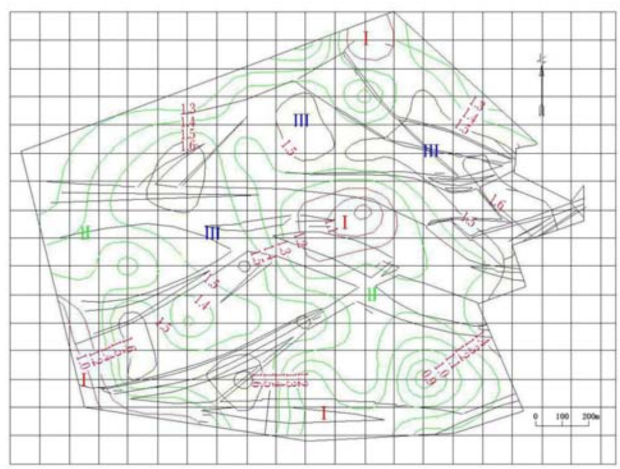

Figure 5: Contour map of the 15th Coal layer fault fractal dimension.

5. CONCLUSION

1) Faults in the minefield are mainly normal and linear ones, and the reverse faults and arc faults are small ones that only develop in local areas.

2) The angle of the fault direction mainly focuses between 60-90°, namely NEE direction. The fault structure has a deep impact on the work surface, and the 15th coal layer is nearer to Ordovician limestone, so the floor water inrush is more likely to happen there.

Thus more attention should be paid to the relation between faults, and effective measures shall be taken to prevent floor water inrush.

3) Faults in the minefield are mainly high-angle normal faults with gaps mostly centering around 1-5 m.

4) In accordance with the fractal and the geological conditions, the minefield can be divided into a simple tectonic area, mid-complex tectonic area, and complex tectonic area.

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