REMOTE SENSING APPLICATION
IN HIGHER PERMEABILITY AREA PREDICTION OF COAL BED METHANE

Mao Yaobao Feng Fucheng Xie Zhiqing Bao Guibao

(Aerophotogrammetry & Remote Sensing of China Coal, Xi'an, 710054 - yaobaomao@hotmail.com)

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ABSTRACT:

As clean substitute energy source, coal bed methane is widely attractive worldwide. Remote sensing plays very important role in coal exploration in past experiences, it is also potential in coal bed methane evaluation and predication. It could be used in permeability prediction of coal bed methane and selection of interesting coal bed methane area, so as to reduce traditional exploration costs. Coal seam fissures and fractures are related to ground crack system in same Earth stress states, their strike, location and spatial arrangement are similar. It was found that fracture will improve the permeability of coal bed. On the basis of tectonic control analysis of methane and remote sensing interpretation of ground linear feature, ground cracks, coal seam fissures and fractures in mine and drill holes were systematically measured and analogue dimensions of cracks were calculated statically, the relationship between coal seam fractures and ground cracks could be established, then the developed areas and its direction could be defined after statistical analysis with rose map drawing of strike, fractal analysis and similarity dimensions calculations, these areas may have affiliated permeability and be prospective in industrial development. The characteristics of ground linear features demonstrate color, texture and shape changes in remote sensing imagery. Usually, ground linear features include water systems, gullies, steep, mountain ridges, linear erosion features and type changes of rock, vegetation, soil. These features can be interpreted from remote sensing imagery easily, so the higher permeability area of coal bed methane will be delineated effectively and economically by statistic analysis of linear feature and analogy analysis of known gas well, field and mine verification.

1. INTRODCUTION

As clean substitute energy source, coal bed methane is widely attractive worldwide. How to reduce the exploration costs and improve the exploration benefits to select target coalfield area with higher permeability and higher coal bed methane content is an interesting question for geologists. In past experiences, the permeability of coal bed methane were detected by traditional methods such as drilling, geophysical exploration and test in laboratory, it is very limited and lower efficiency and expensive. On the basis of geological, hydro-geological, tectonic and geomorphologic background analysis, this paper use remote sensing imagery to detect higher permeability area by interpretation of linear feature in remote sensing imagery, field fracture investigation and underground coal seam fracture measurements and final analogue analysis[Liu H.L., Wang H.Y., al et,2005].

2. REMOTE SENSING PRINCIPLE FOR PERMEABILITY PREDICTION

The main factors impact the exploitation of coal bed methane include permeability, pressure of coal bed, gas saturation, desorption. Remote sensing cold be used both in permeability detection and gas content estimation. Normally, Gas contents are estimated by traditional geological data of coal bed methane, drill hole, and laboratory test. Remote sensing can be used in coal exploration and analysis of tectonic stability and denudation and weathering of coal strata, it is helpful to eliminate the deep areas where it is difficult to develop and shallow areas where gas content is lower due to gas dissipation by geomorphologic interpretation and tectonic analysis of coal basin; it is also used in gas saturation analysis by hydro-geological condition investigation and in heat mature degree analysis by igneous body interpretation. But the application advantage and emphasis of remote sensing is permeability prediction in large areas. According to the tectonic control mechanism of coal bed methane, coal bed methane is reserved in the relative static areas of active tectonic region, and the permeability of coal bed is improved in active areas of the relative static region.

Coal seam permeability is determined by coal seam fissures and fractures. It was found that fracture will improve the permeability of coal bed. In same Earth stress state, coal bed fractures are related to ground crack system, their strike, location and spatial arrangement will be similar correspondingly. On the basis of tectonic control analysis of methane and remote sensing interpretation of ground linear feature, and ground cracks, coal seam fractures in mine and drill holes were systematically measured and similarity dimensions of cracks were calculated statistically, the relationship between coal seam fractures and ground cracks could be established, then the developed areas and its direction of coal seam fractures could be defined after statistical analysis by rose map drawing of strike and similarity dimension calculations, these areas may have affiliated permeability and be prospective in industrial development[Enever R E, Hening A. 1997].

Linear Features: Linear steep, ridge; water system and gully; Linear Erosion Feature; changes of Soil and Rock Type; Changes of Vegetation Type and density.

The interactive relation and detection principle demonstrate as Figure 1.
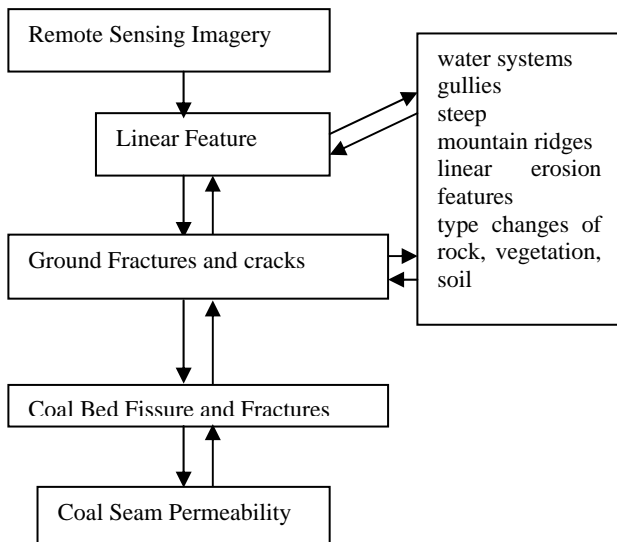
Figure 1 Remote Sensing Prediction Principle

3. WORK PROCEDURE OF REMOTE SENSING PREDITECTION OF COAL BED METHANE

3.1 Data collection

Remote sensing data(TM image and SPOT image), coal geological data，coal chemical and physical data, coal bed methane exploration data, coal basin tectonic data, hydrogeological data, paleo-seismic data should be collected for gas content analysis and coal bed permeability prediction of remote sensing.

3.2 Geological Regularity and Tectonic Analyses

Based on collected tectonic data of coal basin, tectonic stable region of coal basin should be delineated by using remote sensing imagery, these areas will be target area contained high gas to do linear feature interpretation and statistical analysis.

3.3 Linear Feature Interpretation

The characteristics of linear features demonstrate color, texture and shape changes in remote sensing imagery. Usually, ground linear features include water systems, gullies, steep, mountain ridges, linear erosion features and type changes of rock, vegetation, soil. These features can be interpreted from remote sensing imagery, the developed areas and its direction could be defined after statistical analysis based on fractal theory with rose map drawing of strike and similarity dimension calculations

3.4 Field Investigation of Ground Cracks and Fractures

To explore the interactive relationship between linear feature and ground crack and fracture, ground cracks and fractures of coal bearing strata and above overlaid strata should be investigated to find their dominant strikes and developed degree, statistical rose map is suggested to draw.

3.5 Coal Seam Fissures and Fractures Measurements

Furthermore, coal seam fissures and fractures should be measured in some underground coal mines, it will be much clear to know the coal seam fissure and fracture system and its

original permeability, their directions, strikes and density should be calculated statistically. Curvature analyses could be applied for developed areas of coal seam fracture[Zhang H., Wang X.G., 2002]

3.6 Earth Stress Analysis

Earth stress state should be analyzed according to paleo-seismic data and current seismic data collected from local seismic monitoring stations, it will be helpful to know the stress state, coal seam fracture properties(opened or sealed) and permeability potentialities.

3.7 Permeability Prediction and Result Confirmation

The higher permeability area of coal bed methane will be predicted effectively and economically in unknown permeability areas based on analogue analyses of the value of similarity dimension of fractal in the area where known gas well distributed. In order to confirm the prediction results of remote sensing, integrated analyses should also be made to check the coherence of linear feature, ground crack and fracture and coal seam fracture in strike, density, and finally make verification of remote sensing prediction results. (See Figure 2)
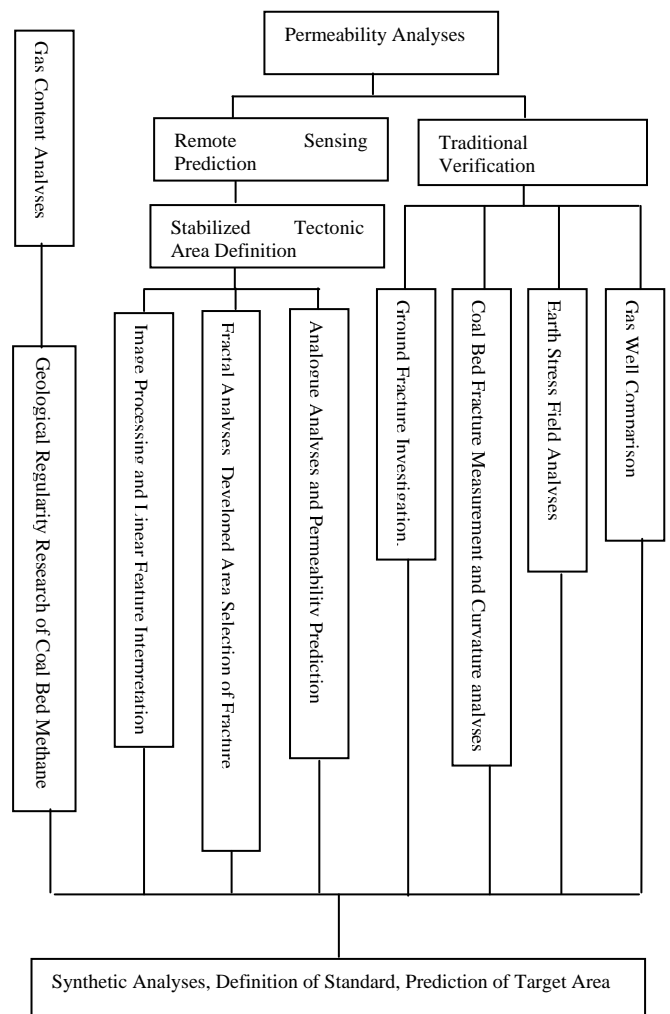

Figure 2 Procedure of Remote Sensing Prediction

4. FRACTAL ANALYSES AND SIMILARITY DIMENSION CALCULATION

After statistical calculation and rose map drawing of linear feature in defined stable areas of coal basin, the dominant direction of linear feature will be determined. It will represent tectonic tendency. To define the tectonic developed degree, similarity dimensions of linear feature are suggested to calculate based on fractal theories, it is suitable for anomalistic, invariable measure and self-similarity objects. The calculation method is to divide tectonic-geomorphology units into foursquare grids with side length r and calculate N(r), the numbers of foursquare grids containing linear features[Murry(1968), Xu Z.B(1996)］, When r changes, a formula forms:

$$N(r) \propto r^{-D} \qquad (1)$$

where   r = side length of foursquare
         N(r) = numbers of foursquare grids
         D=similarity dimension

Correspondingly, logarithm formula is

$$\ln N(r) \propto -D\ln r \qquad (2)$$

where   r = side length of foursquare
         N(r) = numbers of foursquare grids
         D=similarity dimension

Obviously, lnN(r) and lnr is linear relation. Absolute value of slope is similarity dimension N(r).

According to calculation results of similarity dimension, the grade of D could be defined, and the developed degree of fracture and crack and permeability grade could be predicted. See figure 3.

5. CASE STUDY RESULTS

Taking Qinshui coal basin as case study, we firstly delineated the coal bearing areas based on geological regularity research, secondly eliminated the areas where gases were easy to dissipate due to weathering, erosion and tectonic activeness and the areas where was difficult to develop due to deep depth, thirdly concentrated in the areas within a buried depth of coal seam from 300 meter to 1500 meter, fourthly we interpreted linear features from TM and SPOT images and selected dominant orientation based on ground fracture investigations and coal seam fracture measurements, finally 6 A and 4 B class coal bed methane areas with high permeability and gas content were delineated according to the similarity dimension value of fractal dimension analysis and analogue analyses from known gas well exploration (See figure 4). Exploration of coal bed methane in coming year confirms our remote sensing prediction results.
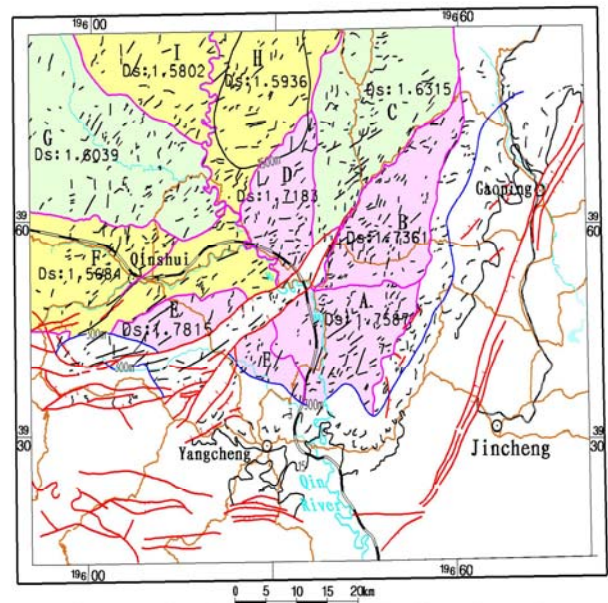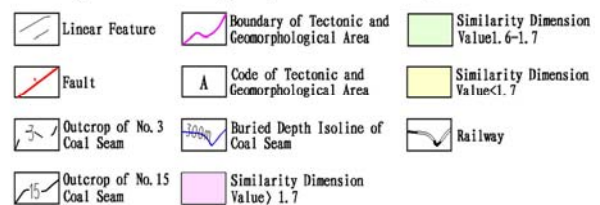

Figure 3 Grading Map of Similarity Dimension

6. CONLUSION

6.1 A principle is suitable for favorable area selection of coal bed methane, that is that selecting stable areas from tectonically active region, where the gas content is higher and selecting active areas from stable region, where permeability is improved;

6.2 Coal seam permeability is determined by coal seam fissures and fractures and it was found fracture will improve the permeability of coal bed. In same Earth stress state, coal bed fractures are related to ground crack system, their strike, location and spatial arrangement will be similar. Correspondingly, therefore, remote sensing is an effective and low-cost method to predict the permeability.

6.3 Case study proved that remote sensing prediction results are reliable by gas well data, coal mine measurement and field investigation confirmation.

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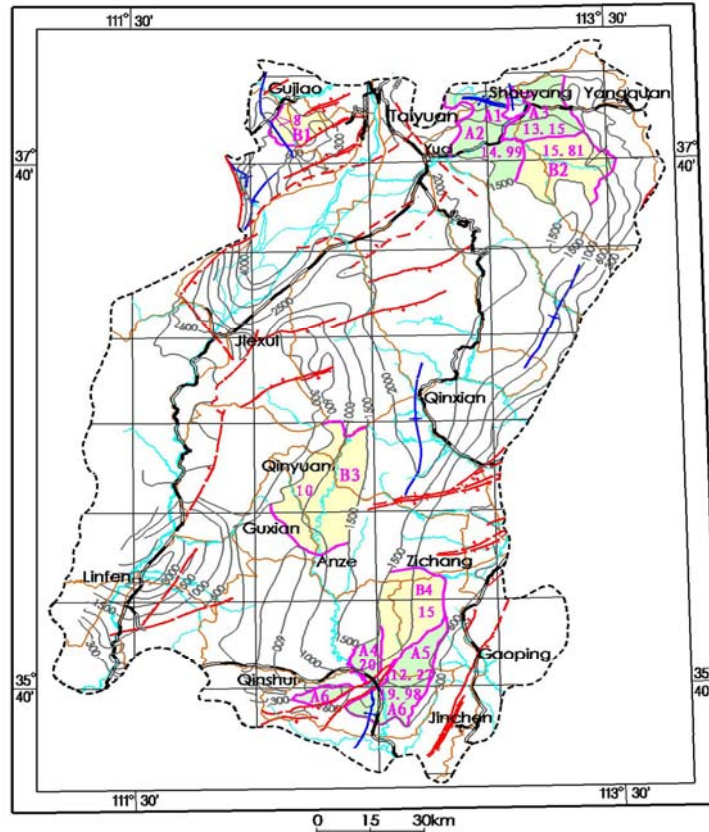

Figure 4 Remote Sensing Prediction Results of High Permeability and Gas Content Areas in Qinshui Basin