POLISH MARITIME RESEARCH Special Issue 2015 S1 (86) 2015 Vol. 22; pp. 10-14
10.1515/pomr-2015-0025

# RESEARCH ON DEEP JOINTS AND LODE EXTENSION BASED ON DIGITAL BOREHOLE CAMERA TECHNOLOGY

**Zengqiang Han**[a],
**Chuanying Wang**[a],
**Hengyin Zhu**[b],

a) State Key Laboratory of Geomechanics and Geotechnical Engineering,
Institute of Rock and Soil Mechanics, Chinese Academy of Sciences
b) Geological Party of Anhui Bureau of Geology and Mineral Exploration,
Luan, China

## ABSTRACT

*Structure characteristics of rock and orebody in deep borehole are obtained by borehole camera technology. By investigating on the joints and fissures in Shapinggou molybdenum mine, the dominant orientation of joint fissure in surrounding rock and orebody were statistically analyzed. Applying the theory of metallogeny and geostatistics, the relationship between joint fissure and lode's extension direction is explored. The results indicate that joints in the orebody of ZK61borehole have only one dominant orientation SE126°∠68°, however, the dominant orientations of joints in surrounding rock were SE118°∠73°, SW225°∠70° and SE122°∠65°, NE79°∠63°. Then a preliminary conclusion showed that the lode's extension direction is specific and it is influenced by joints of surrounding rock. Results of other boreholes are generally agree well with the ZK61, suggesting the analysis reliably reflects the lode's extension properties and the conclusion presents important references for deep ore prospecting.*

**Keywords:** digital borehole camera, deep ore prospecting, dominant orientation, lode's extension direction

## INTRODUCTION

There are a large number of joints exist in deep orebody such as flow banding, interbed, fracture, bedding, etc, and the orientation of these joints is closely related to the extension direction of ore-lode. It has important significance for deep ore prospecting to investigate the development of mine of jointed rock and explore the relationship between deep rock-ore joints and the extension of deep ore-lodes. Through the joints exploration of Shapinggou Molybdenum Mine based on borehole camera technology, dominant occurrences of rock-ore joints are calculated and the relationship between joints dominant occurrence and extension direction of ore-lodes is analyzed. This research provides the basis for arrangement of holes in the next step prospecting and ore reserves estimation.

## JOINT ACQUISITION AND STATISTICAL ANALYSIS

### DIGITAL BOREHOLE CAMERA TECHNOLOGY

Digital borehole camera technology (DBCT) is a new exploration technology which can directly observe the internal of the borehole based on the optics theory. Borehole wall images can be quickly obtained and joints parameter information can be accessed by calculating. Based on this technology, Digital Panoramic Borehole Camera System (DPBCS) as shown in Fig.1 was successfully developed by Institute of Rock and Soil Mechanics, Chinese Academy of Sciences in 1998[4,5]. Electronic technology, video technology, digital technology and computer technology are used in this system which records and analyzes a situ video of borehole wall from a panoramic perspective. Through the direct research on the borehole wall, we can accurately detect joints within the borehole and reflect within the borehole strata occurrence in detail avoiding the influence of low core drilling rate and disturbance. The application of this technology can reflect the actual situation of drilling than in core drilling and resolve the accuracy and completeness of drilling engineering geology information collection [6, 7].

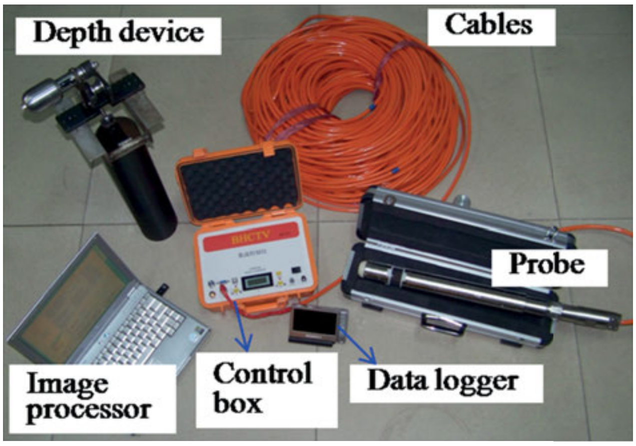


*Fig. 1. Digital panoramic borehole camera system*

The key of digital borehole camera system is the breakthrough in panoramic and digital technology. The panoramic technology can realize 360° three-dimensional displays of borehole walls which included azimuth information and can form flat panoramic image. Digital technology can digitalize videos to images and restore the real borehole wall, namely the digital image of borehole wall. The imaging principle of digital borehole camera technology is analyzed in Fig.2.

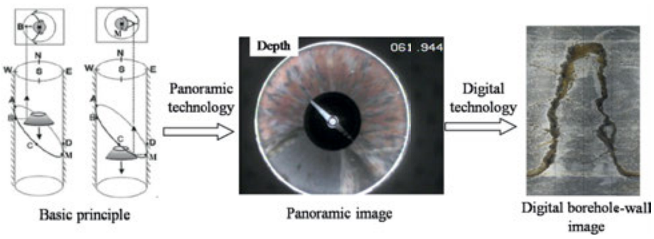


*Fig. 2. Sketch of system imaging principle*

By using video image analysis system as shown in Fig.3 to process the borehole wall video obtained through field testing, the planar image of borehole wall and virtual borehole core image are obtained.

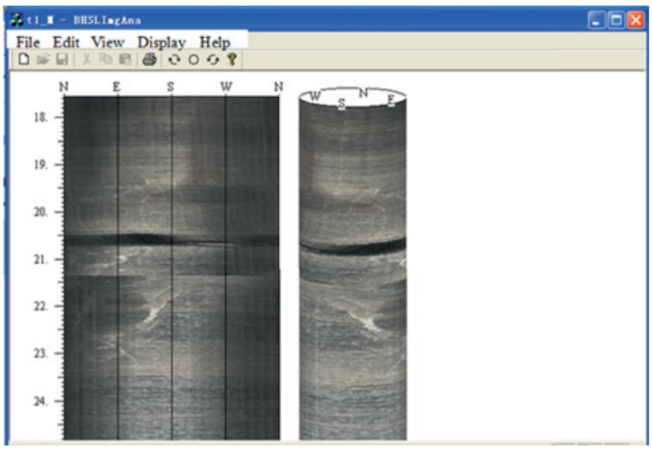


*Fig. 3. Analysis software of the system*

The planar image presents a complete two-dimensional expanded view of inner borehole wall, which vertically sections the inner wall in the north direction. From the image, joint information, including the orientation, color of orebody, fracture width, filling and borehole damage, etc. is obtained. Due to this article research the extension of deep ore-lodes based on joints occurrence, the calculation principle of joints are introduced. As shown in Fig.4, assuming that the joint in the borehole is a 3D plane and completely cut the borehole [3, 6].

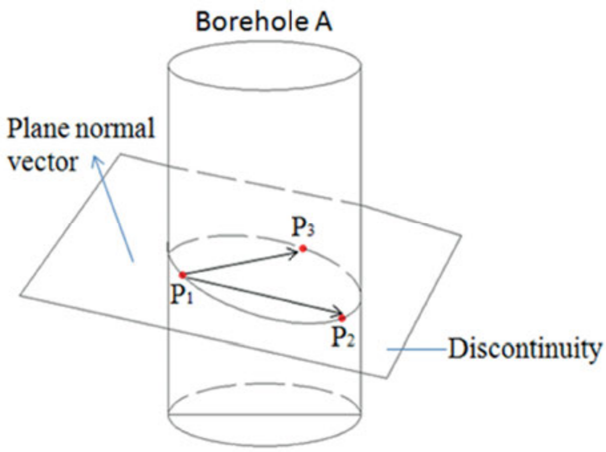


*Fig. 4. Sketch of calculating discontinuity occurrence*

The method to calculate fracture orientation is introduced by taking three non-collinear points P1, P2 and P3 on the planar fracture as shown in Fig.4. Thus, vectors $\vec{V_1}$ and $\vec{V_2}$ on this plane can be obtained as:

$$\vec{V_1}=\overrightarrow{P_1P_2},\quad \vec{V_2}=\overrightarrow{P_1P_3} \tag{1}$$

The normal vector $\vec{N}$ of the plane can be expressed as:

$$\vec{N}=\vec{V_1}\times\vec{V_2} \tag{2}$$

In order to express unit normal vector, the above function can be transformed into:

$$\vec{N_u}=\frac{\vec{N}}{|\vec{N}|} \tag{3}$$

If the Z-component of unit normal vector $N_u$ is less than zero, the opposite vector $\vec{N_0}=\{X_0,Y_0,Z_0\}$ is taken which satisfies:

$$\vec{N_0}=-\vec{N_u} \tag{4}$$

Thus, the dip angle β of the fracture can be deduced through the following function as:

$$\beta=\cos^{-1} Z_0 \tag{5}$$

Assuming that vector $\vec{N_p}=\{X_p,Y_p\}$ is the projection of $\vec{N_0}$ on the XY plane, then the dip azimuth α of the fracture can be obtained through the following formula:

$$\alpha=\begin{cases} 90°-\tan^{-1} Y_p/X_p & \textbf{when } X_p>0 \\ 90° & \textbf{and } Y_p>0 \\ 270°-\tan^{-1} Y_p/X_p & \textbf{when } X_p>0 \\ 270° & \textbf{and } X_p<0 \end{cases} \tag{6}$$

Through the calculation principle of structural plane, DBCT resolve the problem which traditional core drilling cannot calculate joint orientation improving the accuracy of the angle calculation.

## ANALYSIS OF BOREHOLE IMAGE

Located in the southwest of Jinzhai County, Anhui Province, Shapinggou Molybdenum Mine is China's largest existing proven porphyry molybdenum deposit. It is classified as an ultra-large type with 500,000 tons of Molybdenum reserve according to preliminary estimate. The mining area locates at the east section of Qinling-Dabie Mountain Molybdenum metallogenic belt, and Northeast to the intersection of North-West-West Tongbai-Mozitan Deep Fault and the secondary Yinshan-Sihe Fault of North-East Shangma Fault. Magmatic activities are frequent in the region. Acid-intermediate alkaline magmatic rock in Late Yanshanian is largely distributed [10]. Most of the overlying strata are eroded, exposing breccias and various brecciform geological bodies in the center. There are various types of magmatic rocks, ranging from ultra basic, acid to alkaline rocks. Rock types include explosion breccias, quartz syenite, biotite syenite, medium and fine-grained monzogranite and plagioamphibolite. They provide favorable conditions for the formation of molybdenum ores.

Borehole ZK61 is 1201.9 m deep, and there are visible molybdenum ores with thickness of 689 m at the depth range of 512 - 1201 m. Due to limits of casing pipe and water quality in the bottom of the borehole, the actual borehole camera prospecting range is 104 - 880 m. Through the borehole wall image based on borehole camera technology and rock core image, main rock color of borehole ZK61 is gray white while the main types of rock consist of quartz syenite, biotite syenite, medium and fine-grained monzogranite and plagioamphibolite. Main ore body color is taupe as shown in Fig. 5.

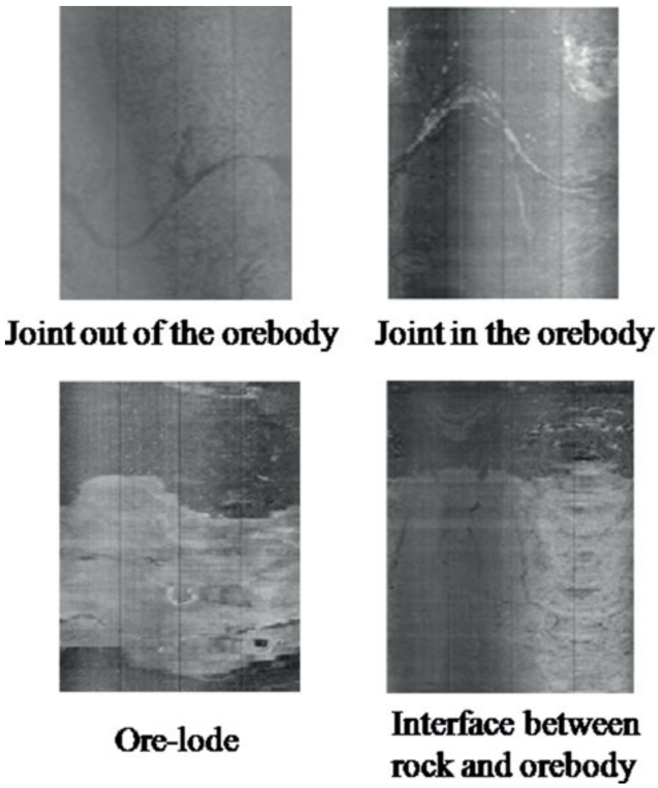


*Fig. 5. Different discontinuities in borehole ZK61*

## STATISTICAL ANALYSIS OF JOINTS IN BOREHOLE

Parameters including occurrence, depth and width in more than 741 joints are calculated based on digital borehole camera technology in order to fully reflect geological features of rock-ore in deep borehole. Due to the large number of joints and great differences in genetic type, formation period and distribution region, Advisable statistical method is used in this research for the statistics of joints [1, 2]. The results are as follows:

(1) Statistical analysis of the occurrence data is implemented to calculate the dominant occurrence with the assumption that joints causes of formation and distribution region are ignored. The results show that the dominant occurrences are N78°E∠55°, S61°E∠57°, S3°E∠61°, N72°W∠43°.

(2) According to the respective statistical analysis of joints in area outside of orebody and area within orebody, it shows: orientation distribution for joints outside of the orebody is relatively scattered, and there is no prominent dominant orientation; dominant orientation within the orebody is S58°E∠23° and S57°E∠51°.

(3) For the typical geological interfaces between orebody and rock, specialized statistical analysis is needed to carry out. The result shows that:

I) distribution of joints outside of orebody is dispersed with no obvious dominant occurrence;
II) distribution of joints in orebody is more concentrated;
III) Occurrence of several larger width joints is similar.

## ANALYSIS OF ORE-LODES EXTENSION

## CORRELATION ANALYSIS ON JOINTS OCCURRENCE AND ORE-LODES EXTENSION

Orebody is natural aggregates of mineral with a variety of different forms, occurrence and scales which embeds in the crust or the surface of the earth. Its geometry figure is decided by the mineralization and the ore controlling geological factors such as strata, rock and tectonic. Ore-lode is tabular orebody formed in all kinds of rock joints that its occurrence is similar with joints in the rock and orebody. In terms of prediction and prospecting, the distribution and characteristics of potential orebody can be deduced based on the research of joints and ore-lodes. These are "interface mineralization theory" about deposit mineralization [9, 11].

The interfaces in "interface mineralization theory" are geological surfaces as shown in Fig. 6 including: 1) the physical and chemical conditions exchange interface of the ore fluid; 2) joints of ore-forming structures; 3) interlayer gliding surface; 4) intrusive contact surface; 5) conversion surface of siliceous and calcareous rock; 6) transition surface of basic and ultra basic rock; 7) sediment interface; 8) sedimentary discontinuity.

There is transport process of minerals in most deposits metallogeny process and most deposits show a certain pattern. The interfaces and mutation belts which are significant different in physicochemical properties are often the physical and chemical barriers of ore fluid migration on the road and these are the emplacement of the deep orebody. This theory makes it possible to analyze the extension of deep pre-lodes. Combined with the deposit mainly vertical change type as shown in Fig.6, this research can provide accurate basic data analysis for prediction of extension direction of ore-lodes based on shape and occurrence information of ore-joints.

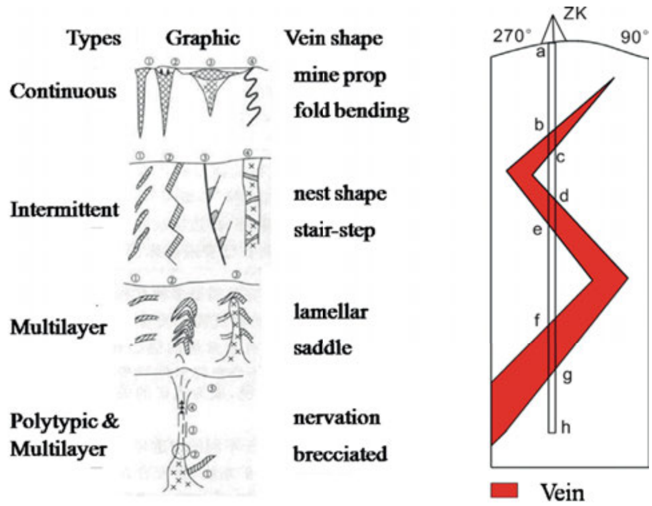


*Fig. 6. The main change types of deposit and sketch of drilling cutting through the vein*

## ANALYSIS OF DEEP ORE-LODES EXTENSION DIRECTION

Statistical results of rock-ore joints in Shapinggou Molybdenum Mine are shown in Tab. 1. The dominant occurrences of joints in rock stay the same as joints in ore body: orientation distribution concentrates in 105~139 ° and dip angle distribution concentrates in 55~78 °. The dominant occurrences of several rock-ore interface are 118°∠67°, 115°∠63°, 129°∠61°.

*Tab. 1. Comparison of different discontinuities*

| Types of Joints | Depth | Dominant Orientation |
|---|---|---|
| In rock | 387.2~511.8 | none |
| In orebody | 512.5~1201.9 | 114~139° ∠65~73° |
| | 583.5 | 118°∠67° |
| Interface | 622.3 | 115°∠63° |
| | 637.2 | 129°∠61° |

In conclusion, the dominant occurrences of joints in borehole ZK61 show some regularity that orientation and dip angle are in a certain range. Based on interface mineralization theory, this regularity can reveal the extension of deep ore-lodes in certain. The dominant occurrences of joints in rock are close to joints in ore body regardless of regional distribution and output form, so we can analyze the extension of ore-lodes especially large ore-lodes. The result in this article will provide the basis for guiding drilling borehole position and mineral reserves evaluation.

## CONCLUSION

Through the investigation of borehole mine jointed rock mass, the different packet structure distribution is obtained and it provides basic data for the correct evaluation of the extension direction of vein.

According to interface of metallogenic theory and based on dominant occurrence of different packet discontinuities in rock and ore body, a conclusion is verified that dominant occurrence in and out of ore body stays the same as dominant occurrence in the whole borehole. Analysis of the relationship between the joint fissure advantage occurrence and extension direction of vein is developed and the results have the important guiding significance for the next deep prospecting.


## ACKNOWLEDGMENTS

This study is subsidized by National Natural Science Foundation of China (41402278) and by Strategic Research Program of the Chinese Academy of Sciences (XDB10030200).


## REFERENCES


1. CHEN Jian-ping, SHI Bing-feng, WANG Qing. Study of the dominant orientations of random fractures of fractured rock masses[J]. Chinese Journal of Rock Mechanics and Engineering, 2005, 24(12): 241-245.

2. JIANG Jian-ping, ZHANG Yang-song, LUO Guo-yu, et al. The application of preferred plane theory to geotechnical engineering practice [J]. Journal of Hydraulic Engineering. 2001, 16(8): 90-96.

3. John Kemeny, Randy Post. Estimating three-dimensional rock discontinuity orientation from digital images of fracture traces [J]. Computers & Geosciences, 2003, 9: 65-77.

4. PRENSKY S E. Advances in borehole imaging technology and application[C]//Borehole Imaging: Applications and Case Histories. London: Geological Society, 1999: 1-43.

5. WANG Chuan-ying, LAW KTIM. Review of borehole camera technology[J]. Chinese Journal of Rock Mechanics and Engineering, 2005, 24(19): 3440-3448. TR-07-56, Vicksburg, Mississippi: US Army Engineer Research and Development Center, 168p.

6. WANG Chuan-ying, ZHONG Sheng, SUN Wei-chun. Study of connectivity of discontinuities of borehole based on digital borehole images[J]. Chinese Journal of Rock Mechanics and Engineering, 2009, 28(12): 2405-2410.

7. WANG Chuan-ying, GE Xiu-run, BAI Shi-wei. The digital panoramic borehole camera system and its application[J]. Rock and Soil Mechanics, 2001, 22(4): 523-526.

8. WANG Jin-liang, LI Jun-ping, LI Yong-feng, et al. The current research situation and suggestions of deep exploration for crisis mines[J]. Conservation and Utilization of Mineral Resources, 2010, 4(2): 45-49.

9. ZHANG Shou-ting; ZHAO Peng-da; CHEN Jian-ping, et al. Multitarget minerals prediction and assessment and their significance[J]. Joural of Chengdu University of Technology, 2003, 30(5): 441-446.

10. ZHANG Huai-dong, SHI Dong-fang, Hao Yue-jin, et al. Geological features of the Shapinggou porphyry molybdenum ore deposit, Jinzhai country, Anhui province [J]. Geology of Anhui, 2010, 20(2): 104-108.

11. Zhao Peng-da. Quantitative mineral prediction and deep mineral exploration[J]. Earth Science Frontiers, 2007, 14(5): 1-10.

## CONTACT WITH AUTHOR

Zengqiang Han

Chuanying Wang

State Key Laboratory of Geomechanics and
Geotechnical Engineering
Institute of Rock and Soil Mechanics
Chinese Academy of Sciences
Wuhan Hubei
430071 China

tel: +86 027 87197362,
fax:+86 027 87197362

e-mail: zqhan@whrsm.ac.cn

Hengyin Zhub

No.313 Geological Party of Anhui Bureau of Geology
and Mineral Exploration
Luan
China