2013 2nd International Conference on Geological and Environmental Sciences
IPCBEE vol.52 (2013) © (2013) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2013. V52. 6

Feicheng Coalfield Ordovician Karst Features

Longqing Shi [1], Chao Niu [1], Mei Qiu [1], DongJing Xu [1+] and Zecai Wang [2]

[1]Shandong Provincial Key Laboratory of Depositional Mineralization & Sedimentary Minerals, College of Geological Sciences & Engineering, Shandong University of Science and Technology, Qingdao 266590 China

[2] Feicheng Mining Group Co., Ltd., Feicheng 271 610 China

Abstract. Basing on the collection of the hydrology and geophysical data in Feicheng coal field and the analysis of integrated coal water inrush point, collapse column and mine water inflow out of the coalfield, we conside that ordovician limestone karst is in transverse distribution . Combining with the water elevation and water quantity, water inrush points grouting quantity and the relationship between the depth of grout hole grouting in Ordovician limestone and grouting quantity, we reveal that Ordovician limestone Karst is in vertical distribution. We discover that the Ordovician limestone Karst in the coalfield landscape characterized by shallow fissures, deep channel Karst-oriented, dominated by ancient Karst in Eastern, Western modern Karst. We consider that the watery of Ordovician limestone above -400 m is stronger than that of Ordovician limestone following -400 m in vertical, which causes that the position of karst mostly mains the range of following within 40 m from Ordovician limestone top the layer sector.

Keywords: Feicheng Coalfield, Ordovician Karst, Distribution Characteristics Introduction.

1. Introduction

North China coalfield is a Carboniferous Permian coal field. It distributes among Shanxi Province, Hebei Province, Shandong Province, Henan Province, Anhui Province and Shaanxi Province. The total area of coal field is 727600 km^2, and its total coal resources take up 60% of country's. The underground water disasters occurred in this field frequently, though it is an important part of energy industry. We can conclude that above 80 percent of operating mines had more of less suffered the harm caused by karstic ground water from ordovician limestone. The water inrush of aquifer in ordovician limestone have the features that is a great deal of volume, a swift and violent velocity and a high frequency. If the water inrush occur, the lighter result is a exasperate production environment and the worse one will cause shaft submergence even the death of workers. Feicheng coalfield is one of the earlist group of coal field developed by the country after establishing China. It is a concealed coalfield of Permo-Carboniferous system in north china. Known as "the diggings suffered a great deal of water inrush", it has a complex hydrogeological condition. Since the under-group coal seams was developed, The number of accident have reached 238. These inrush came from ordovician limestone directly or went through the fifth-limestone overlying indirectly. The maximum volume of water inrush has reached 32970 m^3/h. So the study on the distribution of karst not only has benefits for the prevention and cure of the water inrush caused by ordovician limestone in Feicheng mine ,but also has a guiding significance in disaster prevention and control in north china[1-4].

2. The Features of Transverse Distribution of Ordovician Limestone Karst in Feicheng Mine

+ Corresponding author. Tel.: +86053280681108; fax: +86053286057855.
E-mail address: xudongjinggg@126.com.

2.1. The features of transverse distribution of ordovician limestone karst reflected by water-inrush point

According to the research, because of the complex structure, there is closely hydraulic connection between the fifth-limestone and ordovician limestone. They can be seen as an unified aquifer system [5-15].We drawn the sudden water point map which is based on the data of water inrush point. The numericalvalue of these data are above 30 m^3/h and based on the information of fifth-limestone and ordovician limestone water inrush. From the Fig.1, we can conclude that the features of transverse distribution of ordovician limestone karst reflected by the distribution of water inrush point indirectly is:

Table 1: Number of statistical tables of the mine water inrush

Mine	Water inflow(m^3/h)				Summation
	30~60	60~600	600~1800	>1800	
Dafeng Mine	8	30	3	1	42
Yangzhuang Mine	6	4	1	1	12
Caozhuang Mine	1	2	1	0	4
Taoyang Mine	6	8	2	1	17
Guozhuang Mine	3	4	0	2	9
Chazhuang Mine	3	15	1	0	19
Baizhuang Mine	1	6	1	0	8

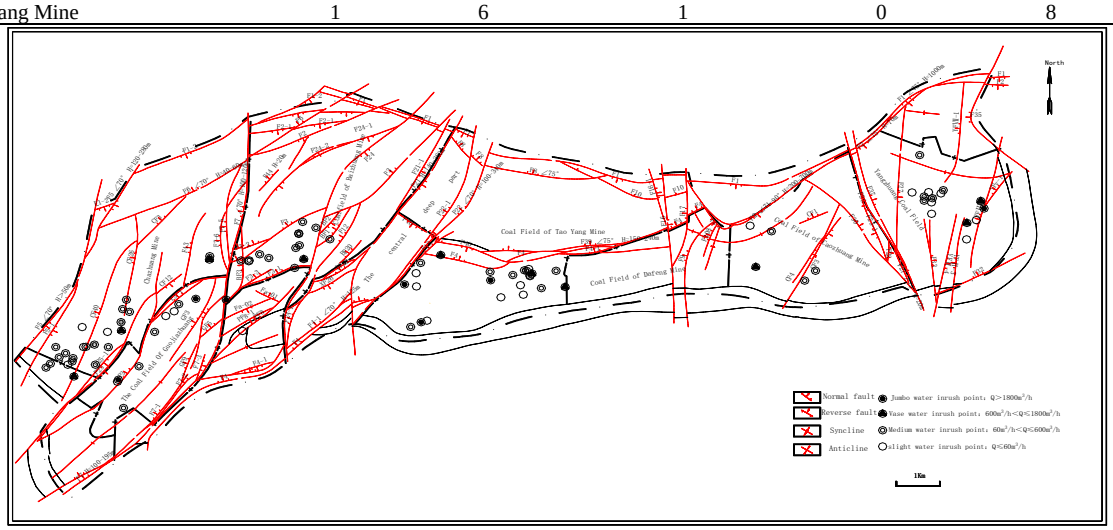

Fig. 1: Feicheng the coalfield sudden water point maps

(1) The scale and extent of development of karst in the west of coal field are stronger than the east's. The karst distributed in the west is a modern karst.

(2) The watery of karst in west is more rich. It is a strong runoff zone and discharge area of groundwater.

(3) The development strength of ordovician limestone karst becomes stronger from superficial part to deep part. The fracture formed in the shallow part while the runoff formed in the deep part. This characteristic is particularly obvious in the west of coal field. The overall distribution of ordovician limestone karst has a evident nonuniformity.

(4) The development of karst is controled by the principal structure. The main karst runoff zone is identify with the trend of principal structure. This reflect a control action offered by the fault to the distribution of Karst channel.

2.2. The features of transverse distribution of ordovician limestone karst reflected by collapse column

The 11 collapse columns which have been exposed intensively distribute at Yangzhuang mine in the east of Feicheng mine. Only one collapse column locates inthe Caozhuang mine and one locates in Pingyin mine. Most of collapse columns are thick filled and have a poor capacity of water diversion. Only the seventh collapse column in Yangzhuang has strong water conductivity and its volumn is 5~10 m^3/h.

Table 2: Feicheng coalfield column list

No.	Shapes	Long shaft (m)	Short shaft (m)	Area (m^2)	Subsid-ence Angle (°)	Exposedelevation (m)	Reveal site and reveal method	Reveal time	Water condition
Yangzhuang No.1	Oval	100	50	3900	80	-24	Track 3100、chute driving, recovery of 3104 and3106 working face	1965	Anhyd-rous
		49	32	1250	60～77	-210	Advancement of 8609 haulage roadway	1999.01.01	Dry
Yangzhuang No. 2	Oval	120	45	4500	75	+10	Advancement of 8504 low return airway	1980.01	Mois-t
Yangzhuang No. 3	Oval	33	12	300	80	+10	Advancement of 8102 haulage roadway	1986.12	Mois-t
Yangzhuang No. 4	Oval	36	21	550	75～77	+35	Recovery of 9208 working face	1989.10.08	Dry
Yangzhuang No. 5	Oval	66	36	1900	72～78	+12	Advancement of 9402 cutting	1993.02.22	Dry
Yangzhuang No. 6	Oval	14	7	78	63	-33	Recovery of 8604 working face	1993.11.22	Mois-t
		20	13	204	76	-50	Recovery of 9412 working face	1994.12.05	Moist
Yangzhuang No. 7	Oval	10	8	62.8	75	-34	Recovery of 8701 working face	1997.04.21	water diver-sion
No. 8 of Yangzhuang	Oval	22	12	207	90	-210	Recovery of 8611 working face	2000.08.15	Mois-t
Yangzhuang No. 9	Oval	98	36	2968	70	-30	Advancement of 8610 haulage roadway	2002.01.02	Dry
Caozhuang	Oval	51	26	1600	75	+10	Central tunnel of 8301 track	1984.02	Anhyd-rous
Pingyin mine	Oval	70	40	3000	80	-50	Coal 3,5,6 exposure	1985.06	Anhyd-rous

The features reflected by collapse column of transverse distribution of ordovician limestone karst is:

(1) The ancient karst mainly distribute at east of the field while the modern karst distribute at west of the field.

(2) The ordovician limestone karst formed in different period. Its evolution start form the east and finish at the west.

(3) The ancient karst in coal field has stopped its development with few water in it. The modern karst is well developed with a large number of water.

2.3. The features of transverse distribution of ordovician limestone karst reflected by mine inflow

The variation of mine inflow could indirectly reflect the development of karst. Collecting and analyzing the data of mine inflow during 1994~2009, we drawn the average inflow duration curve diagram (Fig.2). From Feicheng Coalfield mine average inflow duration curve diagram we can conclude that the features of transverse distribution of ordovician limestone karst is:

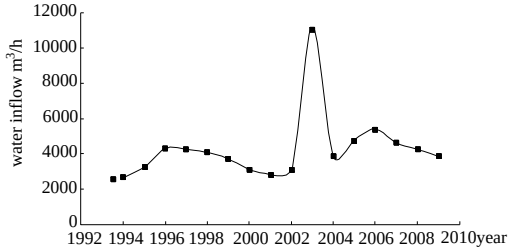

Fig. 2: Feicheng Coalfield mine average inflow duration curve diagram

(1) Ordovician limestone karst was distribute at the whole Feicheng coalfield area everywhere whether in shallow or deep. Generally speaking, as time goes on , the mine discharge of whole field should present a trend of increase or decrease with the coal seam mining depth increase gradually, but such laws is not presented obviously in Feicheng coalfield which can be seen from the change curve of Fig.3 shown. This shows that in the whole field the main factors which influence the mine water inflow don't have great changes from shallow to deep. In other word, the dominant factors of mine water inflow were controlled by the fifth limestone and Ordovician limestone in the whole filed. Therefore, it can be concluded that the Ordovician limestone karst was distribute at the whole Feicheng coalfield area anywhere whether in shallow or deep.

(2) Ordovician limestone karst in the shallow is mainly with fissure type, and there exists strong runoff karst channel in the deep. The Ordovician limestone water-invasion data of Guozhuang coal mine in 2002 suggest that the Ordovician limestone is the only factor which controlled the water inflow of the whole field mine increased accidentally .The Ordovician limestone water-invasion of large or giant scale mainly located in the relatively deep place, and there has not take place a large one in the field of the shallow. Therefore, we can infer that Ordovician limestone karst is given priority to karst fissure in the shallow coal seam, and crack is generally rich with water but not focused, and water invasion point is widely distribute with the feature that single inrush point produce little water . In the deep, the development of channel karst flow is concentrated with the possibility of induce a large scale water invasion. With the development degree of the karst increasing, the water was concentrated and the water abundance is also strengthen.

(3) The connectivity of Ordovician limestone karst fissure is very well and are closely related to surface precipitation. As it can be seen from the Fig.2, the total water-invasion within the scope of Feicheng coal mine presents undulating rolling characteristics no matter in shallow or deep mining. This characteristic is mainly caused by two reasons, one is the connectivity of water channel and the other is the effect of atmospheric precipitation When the connectivity of water channel is in good conditions, the changes of mine water inflow is effected by atmospheric precipitation obviously. In the whole south of Feicheng coalfield bared large area of Ordovician limestone and the atmospheric precipitation can be directly seep into atmospheric precipitation karst channel. According to the contrast and analysis of relevant meteorological data, the atmospheric precipitation to higher in the year of mine water inflow present peak than the year present low. The characteristics that mine water inflow was effected by atmospheric precipitation obviously reflects that in Feicheng coalfield the connectivity of Ordovician limestone karst fissure is very well. It was just because the connectivity of Ordovician limestone karst fissure in good condition that causes the entire Ordovician limestone karst fissure of Feicheng coalfield, whether in shallow or deep, widely full of water.

3. The Features of Longitudinal Distribution of Ordovician Limestone

3.1. The features of longitudinal distribution of ordovician limestone karst reflected the relationship between elevation of water inrush point and the volumn of water-inrush

According to the material of water inrush point in Feicheng coal mine, we sum up the data of water inrush volume of inrush point whose value is above 30 m^3/h and the information about the elevation of water inrush point. The karst developing features reflected by the relationship between water inrush volume and elevation of water inrush point is:

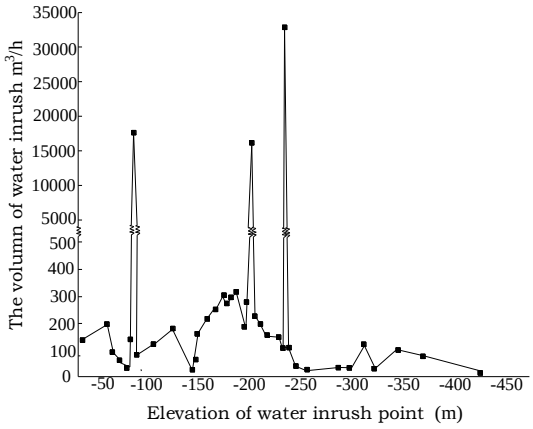

Fig. 3: Feicheng coalfield amount of water inrush of water inrush points and water inrush point elevation diagram

(1) In the range of 0~-100 m, the frequency of water inrush is high, while the volume is low. This shows that the shallow part of karst develops widely but distributes dispersedly. In other words, the development of release tension crack is well in shallow part. It has a better capacity of water conductivity.

(2) In the range of -100~-200 m, the frequency as well as the volume of water inrush is high. This shows that not only the karst fissure develop well but also have a strong strength.

(3) In the range of -200~-400 m, the distribution of water inrush is limited, the volume is very low. The strength of development of karst become gradually weak with the increase of the depth. The water abundance of karst becomes weak. This shows that the release tension cracks were replaced by the closed fracture and the capacity of hydraulic conductivity becomes weak.

(4) Below the 400 m, the fracture became closed with the increase of crustal stress. The fracture of karst is hard to find in this area and the water abundance is very weak. It is worthy to notice that strong runoff zone will develop intensively. So with the increase of depth, though the water gushing passageway of fissure type disappear rapidly and the possible of water inrush becomes lower, the large-scale even super-huge type water inrush caused by the concentration of strong runoff zone become more possible.

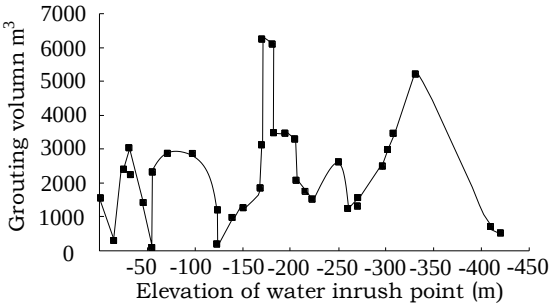

Fig. 4: Relationship between the grouting amount and water inrush point elevation in Feicheng coalfield

Table 3: Feicheng Coalfield the Grouting amount of water inrush points level division table

Range of elevation of water inrush point	Relative level of water inrush point	Feature of variation of grout amount
Above -150 m	A bit large	Grout amount vary with the position
-150m~-350 m	Large	Totally Large
Below -350 m	Not large	Particluary decrease

3.2. The features of longitudinal development of ordovician limestone karst reflected by the volumn of grout amount

Fig.4 shows that when water inrush occur and then do the grouting and blocking water, the relationship between the elevation of leakage and grout amount. According to the elevation of leakages, the grout amount could be divided into three parts (Table 3), the enormous grout amount,the biggish grout amount and the smaller grout amount. Due to the grout amount of leakage and the developing level of ordovician limestone karst crack have a positively relationship, so the longitudinal development of ordovician limestone karst reflected by the figure is as follows:

(1) The grouting amount in shallow part (above-150 m) is low, this shos that the developing level of ordovician limestone karst is week and the major type of ordovician limestone karst is cracky.

(2) The central part (-150~350 m) is located in the junction between karst of cracky type and runoff zone of karst. Some leakages were influenced by the karst of cracky type. So the grout amount is small and it is opposite to the leakages influenced by the karst runoff zone.

(3) The numbers of leakages in deep part (below-350 m) become low. This reflect that this area is influenced by the karst of runoff. The reduction of grout amount mainly caused by the two reasons: the one is high closure of crack in deep part, the connectivity between crack and run-off channel is weak. The other one is an increase of pressure in deep part and an inequacy of grouting pressure. At last the grouting holes did not hit the runoff belt.

3.3. The features of longitudinal distribution of ordovician limestone karst reflected by the grouting well

The figure indicates feicheng coalfield grouting holes into the ordovician limestone depth and grouting volume diagram. This diagram shows that the features of longitudinal development of ordovician limestone karst are as follows:

(1) The connectivity of karst crack and the effection of grouting is weak at the depth of 10 m below the top of ordovician limestone. This position is located in the paleocrust of weathering. So the karst has stopped developing because later material fulfill the karst crack.

(2) The connectivity of karst crack and the effection of grounting is well at the depth of 10 m to 20 m below the top of ordovician limestone. This position is mainly influenced by the cracky type and the connectivity among the fracture is well. This would be the best position to grout in the feicheng mine.

(3) The connectivity of karst crack and the effection of grounting is common at the depth of 20 m to 40 m below the top of ordovician limestone. This position is influenced by main karst flow zone. There are a large number of grout amount when the hole dig the main flow zone directly. Though the fractures in this position developed at some level, we don't consider this position as the best horizon to receive the grouting reconstruction.

(4) The connectivity of karst crack and the effection of grouting is preferably at the depth of 40 m to 70 m below the top of ordovician limestone. Below the main runoff zone, though the connectivity and the development of crack are right, so it is not suitable for the grouting.

(5) The connectivity of karst crack and the effection of slip casting is weak which is 70 m below the top of ordovician limestone. This position has a high closure and isn't a right location for the development of karst.

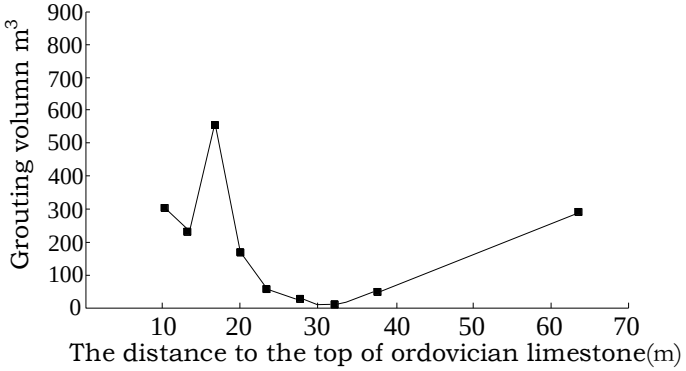

Fig. 5: Feicheng Coalfield grouting holes into the Ordovician limestone depth and grouting volume diagram

The longitudinal developing condition of karst and crack reflected by the grout amount can be divided into excellent, fine, medium and bad four levels. Its distributed position and features are as follows:

3.4. The longitudinal features of ordovician limestone karst reflected face geephysical work

The three-pole electrical method detection technology or dipole electric method detection technology is based on two-dimensional data. They have many shortages: the one is that we can only get one profile which is perpendicular to the exploratory line. It will restrict the prospect of hydrogeological condition. For instance, in a rectangular working face, we arrange the two-dimensional electrical prospecting and only get the information about the two plate profile we explored. We can't get the data of internal floor which is the most favorable for us. The other one is that the depth of electrical prospecting is 50 m. It will not reach the ordovician limestone or the space explored is not enough. To solve these problems, Shandong University of Science and Technology has manufactured a method that we lay cables around the working face, collect the equipment and processing software of 3D data of floor then combine three-dimensional graphy and finally, realize the technology of 3D detection and 3D data body vertical-horizontal cutting. This technology allows the depth of floor watery exploration reach 300 m. It has an important value of the study on the developing position of ordovician limestone karst.

Table 4: Ordovician limestone karst layer development characteristics reflected by the amount of water inrush points grouting

The Distance to Top of ordovician limestone	Development Level of Karst	Development Level of Fracture	Inflence to grouting
Above 10 m	Bad	Bad	Filled Fracture, Unsuited condition for grouting
10m~20 m	Medium	Excellent	High Connectivity, The best position for grouting
20m~40 m	Excellent	Medium	Runoff zone position, Unsuited condition for grouting
40m~70 m	Medium	Fine	Medium Connectivity, Unsuited condition for grouting
Below 70 m	Bad	Bad	Bad Connectivity, Unsuited condition for grouting

Fig.6-Fig.10 show the results of three-pole electrical method detection in 101002 working surface of Caozhuang mine. From this figure we can see that ordovician limestone has two low resistance area at the depth of 40 m below the top of ordovician limestone, while there are two high resistance area under the 40 m. This reflects that the watery of ordovician limestone decrease from top to bottom. The range of water depth is from top to the depth of 40 m. We can conclude that the crack of karst mainly distribute in the depth of 40 m below the top of ordovician limestone.

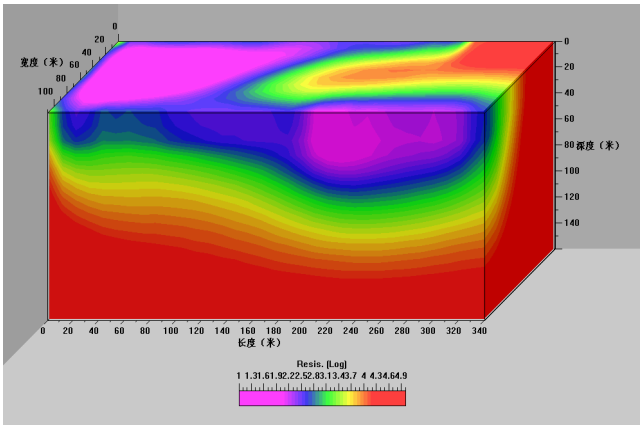

Fig. 6: Caozhuang Coal Mine 101002 face floor formation resistivity 3D data

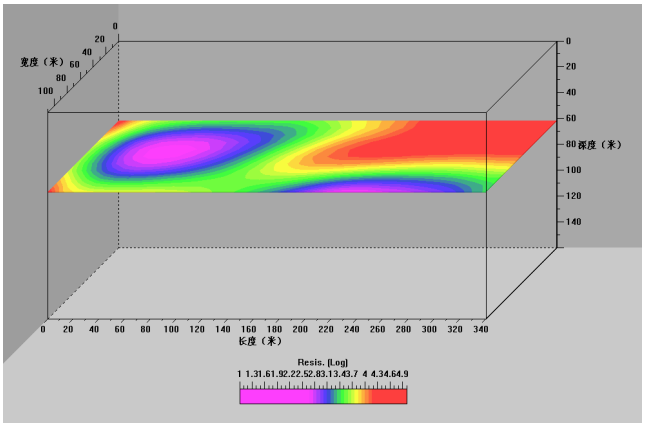

Fig. 7: Into the Ordovician limestone 20 m deep horizontal slices

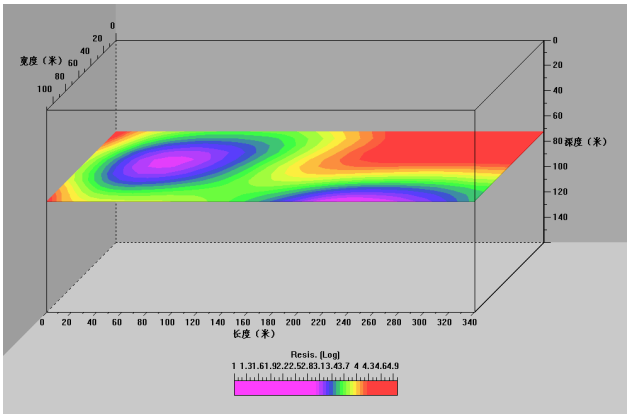

Fig. 8: Into the Ordovician limestone30 m deep horizontal slices

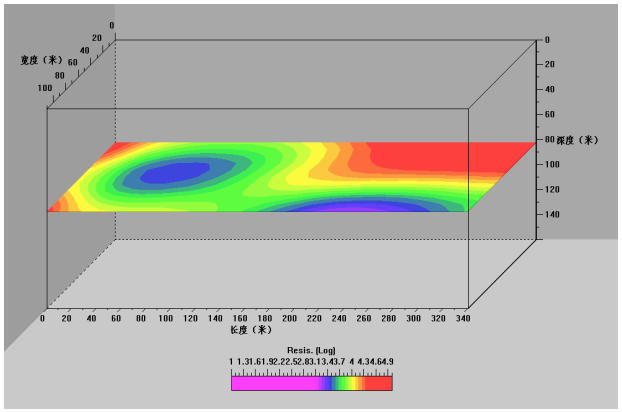

Fig. 9: Into the Ordovician limestone 40 m deep horizontal slices

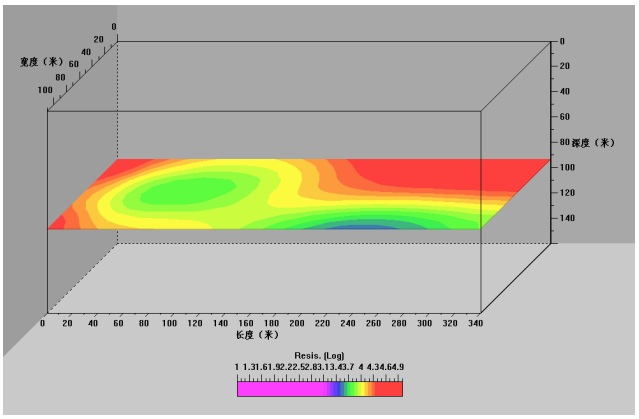

Fig. 10: Into the Ordovician limestone 50 m deep horizontal slices

4. Conclusions

(1) No matter in deep or shallow part, ordovician limestone karst are ubiquity and the connectivity of cracks develop well. In shallow part, the fracture-type karst gives the first place, while in the deep part the runoff zone karst gives the first place.

(2) The watery of ordovician limestone karst is related to the elevation. The watery over the depth of 400 m is more sufficient than the depth below 400 m. In deep part, the runoff is well developed.

(3) The paleokarst gives first place in the east of feicheng coal field. Its watery is weak. The modernkarst give first place in the west of feicheng coal field and its watery is adequate.

(4) The development of modernkarst in feicheng coal field mainly distribute at the depth of 40 m below the top of ordovician limestone.

5. Acknowledgements

This work was financially supported by National Natural Science Foundation (No: 41072212); Supported by Natural Science Key Foundation of Shandong Province (No:ZR2011EEZ002); Supported by SDUST Research Fund (No:2012KYTD101), Supported by SDUST Sci.&Tech. Innovation Grant (No: YCA120318), China.

6. References

[1] YANG Qi, HAN De-xin. Chinese *Coal Geology (Volume 2)* [M]. Beijing: Coal Industry Press, 1979.R. Dewri, and N. Chakraborti. Simulating recrystallization through cellular automata and genetic algorithms. *Modelling Simul. Mater. Sci. Eng*. 2005, **13** (3): 173-183.

[2] SHI Longqing, HAN Jin. *Floor Water-inrush Mechanism and Prediction* [M]. Xuzhou: China University of Mining Press, 2004.

[3] GAO Yanfa, SHI Longqing, et al. *Floor Water-inrush Law and Water-inrush Preferred Plane* [M]. Xuzhou: China University of Mining Press, 1999.

[4] SHI Long-qing. Research summary of water-inrush from floor mechanism. *J Journal of Shandong University of Science and* Technology, 2009, 28(3):17-23.

[5] DONG Shu-ning, LIU Qi-sheng. Study on relative aguiclude existed in mid-Ordovician limestone top in North China coal field. *J Journal of China Coal Society*, 2009, 34(3):289-290.

[6] HAN Jin,SHI Longqing,LI Bin,ZHAI Peihe,LI Shucai,YU Xiaoge. The using of Multi-attribute decision and D-S evidence theory in Mine water accident decision. *J Chinese Journal of Rock Mechanics and Engineering*, 2009, Vol.28 Supp.2:3727-3732.

[7] YU Xiao-ge,HAN Jin,SHI Long-qing,WEI Jiu-chuan,ZHU Lu,LI Shu-cai. Forecast of destroyed floor depth based on BP neural networks. *J Jouranal of China Coal Society*, 2009, 34(6):731-736.

[8] Ozkan H, Hasan S, Nohut M. Nature of a regional dogleg pattern in mature profiles from these basin, northwestern Turkey:A newly discovered unconformity or a thermal anomaly. *J AAPG Bulletin*, 2005, 89(10):1373-1396.

[9] Harris P M.Delineating and quantifying depositional facies patterns in carbonate reservoirs:insight from modern analogs. *J AAPG Bulletin*, 2010, 94(1):61-86.

[10] Georgia P P,Shawna W M.Early disgenesis of inner-shelf phoshorite and iron-silicate minerals, lower creataceous of the orpheusgraben, southeastern Canada:Implications for the origin of chloriterims. *J AAPG Bulletin*, 2008,92(9):1153-1168.

[11] Esteban M,Taberner C.Secondary porosity development during lateburial in carbonate reservoirs as a result of mixing and/or cooling of brines. *J Journal of Geochemical Exploration*, 2003,78(3):355-359.

[12] Morad S,Khalid A R, Ketzer L F, et al.The impact of disgenesis on the heterogeneity of sandstone reservoirs:A review of the role of deposit ional facies and sequen ce st rat igraphy. *J AAPG Bulletin*,2010,94(8):1267-1309.

[13] Qian,Y.X.,Chen,Q.L.,Chen,Y.,et al.2009. Mineralogical and Geochemical Identification for Diagenetic Settings of Paleo-Caves and Fractures-Filling & Vugs Calcites in Carbonate:Taking Wells S79 and S85 for Example.*Acta Sedimentologica Sinica*,27(6):1027-1032.

[14] Li, H.J., Ding,Y.,Zhou,X.G.,2010.Study on Hercynian and Middle Caledonian Karstification of Ordovician in the Tahe Oilfield, Tarim Basin.*Geological Review*, 56(3):413-425.

[15] L ü,H.T.,Zhang, D.J.,Yang,Y.C., 2009.Stages of Paleokarstic Hypergenesis in Ordovician Reservoir,Tahe Oilfield.*Geological Science and Technology Information*,28(6):71-75.