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Internal thermal origin mechanism of Karstic collapse column with no smoothly extrinsic cycle*

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Abstract Huainan coal field as main object, investigation of Karstic hydrogeological conditions were developed in Huainan structureal unit, and the basic conditions, features and rules of Karstic growth were summarized. Geology background and causes of Karstic collapse columns were analyzed. Combined with ancient physiognomy, environment and litho-facies features. After studying synthetically Karstic collapse columns, shape of collapse body, filling feature, hydrodynamic condition and agglutinate material in Huainan area, considering mine hydrogeological conditions of Xuhuai coal field and referenced Karstic collapse columns characters of other mines in North China, the internal thermal origin theory is elementarily formed for Karstic collapse columns extrinsic cycle can not operate smoothly. Finaly, three aspects including distributing features of different kinds of Karstic collapse columns in north China type coal field, conditions of Karstic collapse columns origined from internal thermal with no smoothly extrinsic cycle, mechanics of causes were analyzed and demonstrated.

Keywords collapse column, mine water disaster, Huainan mine, North China coal field, Karst

Introduction

Since Huainan coalfield established mine geology institution, Karstic collapse columns never have been incurred during coal exploration and mine for about 50 a. Most geology technicist always think Karstic collapse columns not existing in Huainan. Two geology abnormal bodys resembling as Karstic collapse columns were found by three-dimensional seismic prospecting in Xieqiao coal mine in 2004, authorization by expert group and exploration, they are the Karstic collapse columns. By investigation on foundamentally geographical and geological conditions of Huainan karst development, and summarizing development characteristic of the column in Huainan area, Karstic collapse columns appear on the surface near the Sunjia mountain in Kongji mine field, and one Karstic collapse column were revealed on 12318 working faces of Pansan mine field, and one column exists by conjecture in Zhangji mine field of the well. After comprehensively analysis and filling material qualification, karst collapse columns in Kongji, Xieqiao and Pansan mines developed in the same geological period and similar cause environment, then the collapse law and filling characteristic were extremely similar.

1 Geology background of Huainan Karstic collapse columns

Since Sinian period, Cambrian period, Ordovi-

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cian period, etc. until Quaternary of Himalayan movement in Huainan area, by analysis of lithofacies-es paleogeographic, the geological background that the Karstic collapse columns forms and transforms on later stage in Huainan is summarized as following.

Because of the Yeli movement on the latter stage of Cambrian period, the district rise and become the land and form obvious decency erosiona, and the karst section become the favorable latter transforms location for difference of karst rock and mechanical properties of stuff materials, which established the foundation for the development of Cambrian limestone karst.

In Huaiyuan movement on the end of Lower Ordovician, the sea water expanded southwards to Huainan area and deposited the limitation tableland facies deposition mostly of magnesium oxide and calcium carbonas, which makes Ordovician limestone relatively thin in thickness and bad solubility.

In Caledonian orogeny, North China risen and became land, then through the denudation of Silurian, Devonian and early carboniferous, and finally formed the Quasi-paraplain karst physiognomy, Ordovician limestone thichness greatly reducing and expanding to Cambrian limestone stratum, which Joint ancient karst system of Cambrian with karst system of Ordovician in favor of karst development to deeper department.

Yanshan movement making coalmine field synclinore structure, from Jura to chalk period, failure further developed;

In Himalayan movement early and latter stage of Yanshan movement, Huainan area rised to some extent, and denudation developed in various degree, make the fissure from closure to open system, under-lying karst developing strongly, in lower terrain of valley gulch and slope of mountain, where larger karst cave is easy to develop and form karst vollapse and Karstic collapse columns.

2 Geological characteristic of Huainan Karstic collapse columns

Huainan collapse columns distribute in the form of spotted state or catenate, mostly with irregular shape of upper big and lower small. Collapse columns of Xieqiao, Kongji and Pansan coalfield all have identical major axis direction of northwest.

Collapse columns of Xieqiao and Pansan, near the bed of No.8 coal layer, mainly collapsed downwards integrally, among them the crack and pyrite developed highly, the characteristic of side is mix material of broken sandstone and mudstone rock, soft and fragile and many scratch. Some crack of collapse columns in Xieqiao is full or half filled with calcite crystal, similar to Kongji mine. The most stuff of Kongji collapse column is Xuzhuang's cock, mainly with different sizes of rock and calcite crystal and glued crack, among big rocks filled with small rocks. In bottom of column, there are several sedimentary layers of refined sandstone, siltstone and mudstone, with color from brick red to dark purple red.

Inner fissures and cave determine the column's water abundance and transmissibility, the intensity of which mainly depend on the degree of compression, cementation, weathering and tectonic movement on later stage, then the development degree of crack and cave is different at different position of same column .

Rocks of the column is mainly filled with calcite crystal near No.8 coal roof in Xieqiao mine, bigger karst pipeline is glued with mud sand and gravel, etc.. On positions influenced by structure and groundwater in later stage, the water abundance and transmissibility is weak and impermeable, but after column is formed, the greatly tectonic movement destroyed calcite crystal, so compression and shear strength of calcite crystal is relatively light, and calcite crystal is easy to become white powder after pressing and dissolve, transport and move into groundwater. In the west part, in fissures of column there are not almost calcite crystal due to relatively moving of rocks, its water abundance and transmissibility are strong and provided place and channels for groundwater movement and storage [1].

3 Cause and mechanism of Karstic collapse columns outside circulation non-smoothly

Huainan columns have following generality: ① Haveing karst action in advance(succession); ② Deep hydrodynamic energy relatively weak, column bottom under the modern erosion base level as far; ③ Unusually high earth temperature; ④ Column collapsing not to the rock base; ⑤ Majority of collapsing wholly, not forming disorderly and unsystematic rocks, forming date is relatively close; ⑥ Influencing belt of column is relatively wide, and cracks not filled fully or compacted, geology holes all for leak near the column, and water quantity of coal roof sandstone is heavy. In addition, Xieqiao laneway cross No.2 column, there are airflow sound and high-temperature gas emitting phenomenon, very similar to phenomenon of modern karst collapsing. For influence of column No.2, in Dongfeng mine of Xieqiao, water rushed since 1993, water sources include Ordovician and Cambrian limestone groundwater, the yield was about 200~400 m^3/h, and reduced to about 100 m^3/h after plasm-filling and ponding to No.2 column about 50 000 m^3 during 2006—2007.

Comprehensive research and survey of Karstic collapse columns in Huainan and karst collapsing rock and water damage of Xuzhuang coalfield, geological characteristic of columns is comparatively analyzed in other mine areas. As the type of groundwater circulation non-smoothly, cause and mechanism of columns are summarized.

3.1 Permeable columns in abnormal geothermal district of North China coalfield

The geological structure has certain influence on growth of columns. Review distribution law of different kinds of columns in North China mines, impermeable column is formed in relatively old time, and usually not distribute on modern strong ground-water flowing belt and higher abnormal geothermal districts, contrarily columns is usually permeable on higher abnormal geothermal district.

(1) After research of Karstic collapse columns in North China coalfield, columns are usually impermeable in normal geothermal district.

The columns are neither permeable nor water abundance generally in Shanxi plateau coalfield where the ground temperature is relatively low. district existing columns do not appear high abnormal geothermal district, while columns are revealed, more than 95% of them have not the phenomenon of water dripping and pouring, and can bear the water pressure of underlying Ordovician confined aquifer. In coal stratum, there is not the sign of Ordovician column conducting underlying limestone aquifer, so which has a little effect on security of coal exploitation. For example, 56 columns are actually revealed in 5 mining areas of Gequan mine, internal structure densely, the glued intensity highly, the majority is dry and anhydrous and only 4 among them have phenomena of dripping [2].

Columns in east Feicheng coalfield is dense, without recent active sign, the scale is relatively wide, the last forming time ia about Palaeozoic era to Mesozoic era according to classifying scheme that Li Yongjun offered, the majority of columns is in the end period [3]. Till the latter stage of Yanshan movement, groundwater flow condition in the Midwest of coalfield changes, and southwest Guozhuang mine become the collecting and runoff exit of groundwater, intense area of karst collapse activity transfer from east Yangzhuang mine to near western Guozhuang, the columns concealed under the No.4 limestone, and began to form in the end of Mesozoic era or Cenozoic, and in the stage of initial development or strong growth modern. The column often connect with the strong runoff belt of groundwater and has strong ability of transmissibility, which threaten the safety in mine production greatly [4].

In addition, columns mainly develope in the horst Xiandewang mine of Xingtai, where the ground temperature is normal and the coal metamorphic grade is high, all columns revealed are not permeable. In Liuqiao mine of Wanbei area, column developing, normal ground temperature, but coal is high metamorphic anthracite, and all columns revealed are not permeable too. Although the ground temperature is normal in Cheji mine of Yongcheng area, the coal is high metamorphic anthracite, and all columns revealed are not permeable too.

(2) During surveying hydrogeology conditions in Xuhuai coalfield, the columns in high ground temperature area are permeable almost.

The ground temperature is relatively high in Xieqiao mine of Huainan, when Karstic collapse columns are revealed, there are emitting air phenomena, the top of cylinder is dry, but the water seal section is relatively fragile and easy to activate under the influence of mine, which is apt to seriously threaten the mine production. Water rush from Cambrian and Ordovician limestone influenced by No.2 column well explain this question. In addition, Renlou mine of Wanbei area there are abnormal geothermal belts, and two columns both are permeable. Sanjianhe mine of Xuzhou area there are abnormal geothermal belts, and all columns are permeable too. For Wutongzhuang mine of Fengfeng area,Liangbei mine of Yuzhou area, Nanding and Lingzi mines of Zibo area and other mines in north China, columns in high geothermal belts mostly are permeable.

(3) As to column found in Huainan mine, although they do not lie in the strong runoff belt, the column easy to activate and become permeable when the coal is exploited, such concealed Karstic collapse columns are probably still in course of developing.

After analysis of the calcite crystal layer and sandstone rock specimen in well coal section of the column, the interior calcite of crack do not form on same stage of groundwater activity, it is the results of experiencing three times of collapsing at least. It also can be inferred that calcite crystal in early periods, the scale of the crack development is relative lighter than later and end stage. And all there is certain disconnected time in every for calcite crystal that is not deposited and crystallized continuously under saturated environment. In karst collapse body of Kongji mine, large amounts of calcite crystalline grains insert in sargilo arenaceous deposit, which can explain that collapse column and subsided body are formed after several times of collapse.

During the course of ponding and plasm-filling construction in east air shaft of Xieqiao mine in 2006,

nearly 50 000 m^3 mud fluid flowed to column direction, it is shown that there is larger karst space in bottom part of column, which is foundation and prerequisite of continuously collapsing in the development of column, and water temperature of Ordovician and Cambrian groundwater is above 44 degrees, the ground temperature appears abnormal high district and can offer energy and place for groundwater convection. For non-smooth outer circulation of Karstic collapse columns, its development is a slow course under bury karst function, to Xieqiao Karstic collapse columns, they are probably in slowly development period.

3.2 Forming conditions of Karstic collapse columns outside circulation non-smoothly

(1) Karst cavity with certain scale formed in earlier stage, is the foundation and prerequisite condition that the karst of burying type development and collapse on later stage.

The development of the karst of Huainan is controlled by its lithologic composite and geological structure, ancient physiognomy and ancient hydrology network, and the karst development generally have generation, succession and superposing. its essence is in the historical course of geology, the karst phenomenon that has already developed, is stopped, buried, or activated again, developed again etc. by the geologic process on later stage, conditions such as its development's geographical geology are basically similar with modern karst, etc..

The main reason that Karstic collapse columns relatively develops in North China is influenced by the karst development from latter Ordovician to middle Carboniferous. In this period of 150 million-years weathering and erosion, a karst development belt is formed mainly with dissolving cracks and different sizes of caves. Karstic collapse columns outer circulating non-smoothly inherit and develop the karst of this period, karst development evolved from circulation of the regional groundwater as dynamical factor originally to groundwater convection as main power that produced by vertical upward difference of ground temperature finally, the development velocity of karst becomes slow.

On the foundation of cave development, the movement of the groundwater relies mainly on form of the convection because of groundwater circulating non-smoothly. And main factors influencing convection intensity of groundwater include two sides, one is space and its shape that groundwater store, the other is the distribution of the groundwater temperature field. So, the previous karst cavity has offered the favorable place for groundwater convection on later stage, and the vertical distribution of karst cavity also offered dynamical power for convection of the groundwater for the difference of vertical groundwater temperature field. On this basis, the difference of ground temperature and pressure field resulted in the difference of the solubility of groundwater to soluble rock, which expand further underpart of soluble rock to larger space constantly, and the karst happens to collapse when expanding to certain scale.

(2) For Karstic collapse columns with circulation non-smoothly outside, the primary condition of development include soluble rock and nearby stratum appearing high abnormal ground temperature.

High ground temperature is the primary condition of the columns development. Only in the previous karst cavity of convection, comparatively strong groundwater convection circulation can't happen yet, there must be underground heat source to produce relatively greater geothermal gradient vertical. The bigger the geothermal gradient is, the larger intensity that produced the groundwater convection and circulated is. The heat source of the geothermal gradient come from the deep department of the earth's crust, in some areas, because fracture structure lead coherent deep heat source or nearby magmatic intrusion area remaining energy can form some high geothermal districts. As to the North China coalfield, huge thick layers of Ordovician and Cambrian limestones underlying the coal stratum,

Because of tectonic movements, crack is relatively developed, and groundwater is abundant. Because the groundwater is the good carriers of geothermol power, and can send heat energy of deep to shallow department constantly upwards, which make geothermal gradient of limestone stratum diminish gradually, finally ground temperature in rock is relative higher about 10 ℃ than upper coal stratum approximately. In limestone stratum, karst fissure or cave belts that can relatively store water, because of groundwater convection, show highly geothermal comparing with peripheral stratum.

3.3 Mechanism of Karstic collapse columns outside circulation non-smoothly

(1) In relatively close environment, main power of karstic collapse columns development is convection of groundwater firstly, secondly lixiviation of other upper aquifers in short time, and thirdly the microcirculation of regional groundwater.

The temperature of deep groundwater is higher, but the shallow department relatively low. On the

foundation of groundwater circulation non-smooth and karst cavity development in the region, the groundwater in the cavity and crack belt around can form the convection environment, geothermal energy can be transmited from deep to shallow department constantly, so the areas column distributing demonstrate high temperature. Under the function of groundwater convection, soluble materials are carried from deep to shallow departments.

when karst collapse to shallow or middle department of aquifers (Such as sandstone crack aquifer of coal stratum), especially connect with new stratum, it can be recharged by sandstone crack aquifer or new aquifer. Groundwater moving from shallow to deep department, on one hand can transport soluble materials such as calcite etc. in shallow department downwards, on the other hand, because of the solubility of soluble rock (calcite) increasing during transported downwards, the soluble rock of the lower part of column is dissolved. With water in column flowing outwards slowly, the soluble material is transported out-wards, and the cavity space is increased in columns.

In Ordovician and Cambrian limestone aquifers with columns outer circulating non-smooth, although they are not the strong flow belt of groundwater and not high aggressive, for the whole, hydraulic connection of aquifer is very fine. For example, when water rushing happened in east air shaft of Xieqiao mine, groundwater level of Ordovician limestone decline obviously in Renlou mine about 70 km far from Xieqiao. Ordovician and Cambrian limestone aquifers under column participate in regional cycle of ground-water, but alternative pace of circulation is relatively slow. In long geological periods, the regional cycle can take some soluble material and a small amount of argillaceous materials in the column away.

(2) Under the power of groundwater convection, the groundwater temperature field and pressure field comprehensively influence on the $CaCO_3$ solubility in groundwater, which led to the fact that the concealed columns outer circulating non-smooth develop constantly.

Temperature influence $CaCO_3$ solubility lightly than water pressure, it can be demonstrated by sinter and the phenomenon of sinter apt to form in inner negative pressure area when spring turn direction after flowing outwards.

In the deep part of columns, high temperature increase the dissolving pace of $CaCO_3$, and high pressure increase the solubility of $CaCO_3$. Under the power of the water convection, $CaCO_3$ of the deep part is carried to the shallow part continually, in deep part cavity scale increase to some extent for material losing, cavity will collapse while developing to a certain degree, with the constant development of collapse, the collapse column is formed gradually. Sand mud stone in the coal stratum is invaded by groundwater with high concentration of $CaCO_3$ too, and bring a large amount of $CaCO_3$ so as to calcite content up to more than 44% among stuff of column in Huainan mine.

4 Conclusions and suggestions

At present, the domestic and internationally research of Karstic collapse columns is still at the stage of exploring, theoretical system is not comparatively ripe yet. The view of inner heat cause mechanism is offered for Karstic collapse columns outside circulating non-smooth in this paper, it is analyzed and summarized in many aspects under the research of geological characteristic of collapse columns in Xuhuai coalfield, that rich mechanism's theory of columns cause and provide references for prevent and cure of water damage and exploitation safely. But at the same time, there are limitations on means and method of the column study, and relatively less areas studied, inner heat cause mechanism of karstic collapse columns outside circulating non-smooth might not have universality, the relevant research of this theory should be launch in other mines too in the future.

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