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SURFACE SUBSIDENCE IN THE KARST MINING AREA IN CHINA

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ABSTRACT

Carbonate rocks are widely distributed in China, with extensively scattering of karst aquifer deposits associated with frequent surface subsidences. Particularly, most of surface subsidences occurred in karst aquifer mining areas in Southern China, but very few in Northern China

As a form of geological hazard, the surface subsidence in mining areas causes the increasing of both the amount of mine water inundation and the possibility of mine water and mud invasion, jeoperdising the environment of mining areas, and endangering the mining operation and people's lives. Generally, the distribution of surface subsidences is of regular pattern, principally controlled by karst development pattern. Therefore, it is likely to predict and prevent the occurrence of surface subsidence. In this paper, the distribution, the danger and the prediction and prevention of surface subsidence of karst aquifer mine area in China are discussed

INTRODUCTION

Surface subsidence is a physical/geological phenomenon of surface karst forced due to the impacts of karstification, and its genesis and mechanism of formation are rather complex. In karst mining environment, surface subsidence occurs mainly as the declining of karst groundwater table level due to the pumping, the dewatering and drainage of mine water or the water invasion in mines.

Surface subsidence is not only a unique phenomenon of karst deposit dominantly composed of filled karst caves, but also an acute problem of hydrogeology, engineering and environmental geology in the karst areas thinly mantled by Quaternary tectoria.

In China, karsts are developed and distributed extensively, which range in age from Archaeozoic to Cainozoic, predominantly in Palaeozoic. The distribution of carbonate rocks of the country occupies up to 3.25 million km^2 including bare karst of 1.25 million km^2, and the rest belongs to the covered and buried karsts.

Moreover, karst aquifers deposits are scattered widely in China (referred to the kind of deposit whose aquifer surrounding rocks or roof and bottom strata consist of carbonate aquifers), and abound with mineral resources such as coal, iron ore, aluminium ore, copper ore etc., and karst groundwater resources ranging in age from Pre-Sinian to Triassic Karstic water is the main source of both aquifer ore deposits and water supply in China

The majority of the well-known water-abundant deposits in China (referred to the deposit whose mine water inflow rate is more than 1 cubic meter per second) is karst aquifers where surface subsidences frequently occur in karst mining environment.

THE DISTRIBUTION OF SURFACE SUBSIDENCE OF KARST AQUIFERROUS DEPOSIT IN CHINA

China, where the distribution of karst is widespread, is one of countries with the most extensive development of surface subsidence. Over 23 provinces of the country exist surface subsidences in karst areas. According to incomplete statistical data, 797 subsidence regions with a total of 30005 subsidences are scattered dominantly in karst aquifer mine areas and source areas of karst water supply, along railways and roads of cities and towns in karst regions, and at reservoir sites.

Southern China is the region with the great connected distribution of carbonate rocks, with the highly developed karst, and with the wide dispersal of surface subsidences, where 768 subsidence regions have been found with 29165 subsidences, amounting to a total of 962 in whole country. Simultaneously, 29 subsidence regions, among a total of 48, with 840 subsidences have been found in karst areas in Northern China far less than those in Southern China.

It has been proved that pumping, dewatering, drainage and water inrush in the karst mining environment set off surface subsidence larger in scale, greater in number, and longer in duration. Up to now, 94 mining areas have been located with the occurrences of surface subsidences. According to the investigation in 34 mine areas, there have been 23,941 subsidences scattered in the Palaeozoic coalfields and the intrusive contact-polymetallic mining areas, most of which occurs in carbonate rocks of Ordovician, middle Devonian, Carboniferous, Permian, and Lower Triassic.

In the karst mining areas in Southern China the occurrences of surface subsidences are prevaled and extensively developed in the provinces such as Guangxi, Hunan, Jiangxi, Guangdong, Yunnan, Hubei etc., where the number of surface subsidences reaches 23513, according to the statistical data of 25 mine areas (Table 1). For instance, more than 6100 subsidences (including repeated subsidences) have occurred in Enkou mine area in Hunan province with an influential area of over 25 km^2. Especially at its karst development section, there are 800 subsidences within 0.1 km^2 in extent. Only 418 subsidences are found, according to the figures of 14 mining areas (Table 2), in some karst aquifer mining areas of Northern China's provinces such as Liaoning, Shandong, Hebei, etc., rock mass mainly consists of in limestone of middle Ordovician age. Therefore, the scale and number of subsidences in Northern China are far less than that in Southern China

THE DANGER OF SUFACE SUBSIDENCES IN ORE AREAS

Beyond doubt, surface subsidence is a form of geological hazard. It causes such danger as follows: to worsen the environments of mining areas; to trigger the alteration of the hydrogeological and engineering geological conditions; to add to the complexity of factors in water impregnating through deposits; to raise the mine water inrush; to bring about the water and mud invasion; to result in drying up of wells and springs and

Table 1 The Distribution of Surface Subsidences of Karst Mining Areas in Southern China

Ore Area Karst	Subsidence Amount (n)	Maximum Subsidence Length (m)	Width (m)	Depth (m)	Aquifer
Enkou Coal Mine, Hunan	6100	40		30	P_{1m}
Doulishan Coal Mine, Hunan	2200				P_{1m}
Meitanba Coal Mine, Hunan	>2200	85			P_{1m}
Qiaotouhe Coal Mine, Hunan	530				P_{1m}
Yijiaqiao Coal Mine, Hunan	100				C_{2-3}
Shuikoushan L-Z Mine, Hunan	850	80	60	30	P_{19}
Fankou L-Z Mine, Guangdong	1950	44		>30	C_{2-3}
Shitu Copper Mine, Guangdong	3176	100			C_2
Makou Brasses, Guangdong	>3000	45	45	42	D_3, C_1
Zhangken Troilite, Guangdong	90				D_2
Heishigong Brasses, Guangxi	228	43	45	42	D_2, C
Siding Lead-Zinc ore, Guangxi	>600				D_3
Heshan Coal Mine, Guangxi	200	36			P_{1m}
Xiwan Coal Mine, Guangxi	118	35	35	10	C, J
Tonglushan Copper Mine, Hubei	258	60	40	8	T_{1-2}
Yehuaxian Copper Mine, Hubei	170	>10		>10	C-T_1
Houzidong Coal Mine, Hubei	>100	5		3	C_2-P_{1m}
Shuangqiu Coal Mine, Hubei	100				C_2

Table 2 The Distribution of Surface Subsidences of Karst Mining Areas in Northern China

Karst Ore Area	Subsidence Amount (n)	Maximum Subsidence Length (m)	Width (m)	Depth (m)	Aquifer
Yezhuang Iron Mine, Shandong	26	53		6	O_2
Gujiatai Iron Mine, Shandong	18				O_2
Xigang Coal Mine, Shandong	2				C
Datong Coal Mine, Shanxi	2				0
Lier Coal Mine, Anhui	6				0
Xieyi Coal Mine, Anhui	9	30			0
Kongji Coal Mine, Anhui	6	3 9			C_3
Tongguanshan Copper Mine, Anhui	100	30	30	>30	C_{2-3}, P
Xiqiao Coal Mine, Anhui	200				O_2
Fangezhuang Coal Mine, Hebei	17	27 5		12	O_2
Xibeiiing Coal Mine, Hebei	2				O_2
Linxi Coal Mine, Hebei	2	12		15	O_2
Weiiiacun Zillerite Mine, Liaoning	20	15		8	Z_2
Fuzhouwan Claystone Mine,	8				O_2

surface reservoirs, subsidence of buildings, cutting off of streams, injuries and deaths of man and livestock; to destroy bridges, roads, and railways; and seriously threaten mine production and safety.

For example, in Fankou area of Guangdong, there are 1950 surface subsidences. The volume of subsidences amounts up to 5.50 million cubic meters with an influence area of over 8.30 million m^2. Mine water gushes with 2 million cubic meters of mud. As a result, 70,000 m^2 surface buildings have been damaged, and over 164.7 acres farmland, 1 5 km long roads, 45 km long railways have been destroyed. In Enkou mine area of Hunan, surface subsidences have damaged about 1640 acres farmland, 18300 m^2 houses, and 8 small reservoirs. In Daguangshan mine area of Hubei, surface subsidences caused railway tunnels sunk, high voltage wire poles declined, electric power cut and mines submerged.

Surface subsidence results in convenient access for the inflows of atmospheric precipitation and surface water to mines. For instance, in Siding mine area of Guangxi, within an area of less than 1 km^2 of cone of depression, 600 subsidences occurred. During the rainy season on May 14, 1976, June 7, 1977, and March 29, 1979, river water flowed into mines through subsidence pits of river bed with the largest inrush of up to 24 cubic meters per second, causing flooding of mines three times. In Fankou mine area of Guangdong, river water flowed downwards through the subsidences of river bed, with the increasing of mine discharge from 0.37 cubic meters per second to 0.78 cubic meters per second.

Furthermore, surface subsidence results in surface soil erosion, and inflows of much sand to mines through subsidence pits. In Meitanxian coal mine of Hunan, over two thousand subsidences have caused water and mud invasion of the mine on 20 occasions. On September 23, 1980, for example, a mud inrush of over 500 cubic meters resulted in clogging of gallery over a length of more than 600 m, causing injuries and deaths of miners, and shutdown of the mine.

PREDICTION AND PREVENTION OF SURFACE SUBSIDENCE

In general, the distribution of surface subsidence is of regular pattern, dominantly controlled by the development of karst

Surface subsidence generally occurs in areas where the coverage thickness of Quaternary is thinner (generally less than 30 m) and where shallow karst is intensely developed and in zones of runoff with heavy inflows of groundwater, or near zones of shallow rift development.

In addition, surface subsidence commonly emerges and is dispersed at both sides of river valley with shallow groundwater table, or along river bed, swampland, depression and chough.

The occurrence and distribution of subsidence zones are often within the cause of depression of ore area. Once mining groundwater table falls karst aquifers, surface subsidences usually take place abruptly. The number of subsidences increases along with the increasing of mine drainage, the declining in groundwater levels, and the raising of hydraulic gradient. For example, in Shaikoushan mine in Hunan, while mine drainage was 588 cubic meters per hour, 20 surface subsidences occurred and 202 as mine drainage reached 1100 cubic meters per hour.

Usually, there are warnings before surface subsidence occurs, even though it is rather difficult to predict the occurrence of subsidence. The analysis of comprehensive geological conditions and the qualitative prediction are still the basic methods. In order to determine the subsidence distribution, the investigation of surface subsidence in mine areas should be carried out using remote sensing techniques and geophysical methods (such as electric survey, seismic prospecting, gravitational method and well logging), and drifting shallowly. Simultaneously, based on studying the development pattern of karst, the conditions of subsidence development, the causes of subsidence are examined by using the conjunctive methods of qualitative and semi-quantitative analyses. For instance, by means of mathematical and statistical analysis, predicting and evaluating areas and development trends of subsidences have been proved to be remarkably effective in some mine areas and to be scientific basis for preventing and controlling surface subsidences. The policy of taking preventive measures against the occurrence of subsidence should be considered firstly as to the prevention of surface subsidences, and then harnessing subsidences in a comprehensive way. Finding the dominant cause of subsidence is also of great importance with regard to eliminating or reducing the possibility of subsidence occurrence and development.

For preventing surface subsidences in karst water-abundant ore deposits, the key measure is to control the intensity of mine dewatering and drainage. It is better to drain karstic water mildly than to drain intensely with deep draw-down, in order to avoid the rapidly declining groundwater table which results in a lot of subsidences. Under mines, the measure of prospecting in advance should be taken so as to seal off water invasion points in time, and turn the situation of water invasion into man-controlled discharge.

As the subsidence reaches, the measures, the surface, for backfilling and covering subsidence pits, intercepting streams and diversion of river channels should be taken in order to decrease the rate of groundwater influx to mines through subsidence pits. In Enkou mine area in Southern China, for example, the approaches of back filling and covering subsidence pits, grouting screen to cut off karst groundwater flows of runoff zone, cementing channels and the alteration of stream paths have been adopted and proved to be considerably effective in both decreasing the groundwater influx to mines through subsidence pits and controlling the development of further collapsing.

Generally, in respect of harnessing surface subsidences of mining areas, comprehensive measures should be taken in view of local geological and hydrogeological conditions.

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