The Existing and Extending of High Runoff–zones of Karst Water in Coal Mines of Karst Type and Water Hazards Prevention in North China

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ABSTRACT

In Carboniferous–Permian Coalfields of North China, the base floor of the coal series is thick–beded limestone aquifers of Ordovician–Cambian System. And the coal series contains several thin–beded limestone aquifers. All these aquifers have plenty of karst water. Very often, karst water inrushes into pits when mining. Hazardous inrushes has been more than 1000 times, and hundreds of them caused floodings of mines and working–faces.

There are tens of coalfields, hundreds of producing mines which are bearing the danger of karst water. It is well known that karst aquifers are hetergeneous. By the analysing of regional material and investigation, we conclude that karst water high runoff zones exist under many large coalfields, which contain abundance of water, and water flows through the zones unblocked and concentrated.

Consequently, the hydrogeological conditions of mines located in the runoff zones is more complicated. The complexity lies in that mines of this kind are highly water–charged, the daily drainage is large, and it is liable to cause a hazardous water inrush. Therefore, it is of practical meaning for us to predict the existing and location of karst water high runoff zones in coalfields, and the situation of their overlapping with coalfields, in order to work out plans of mine karst water prevention, to forecast mine water disasters. It is accurate and effective that using geological methods, hydrogeological methods, Redon content measuring method and comprehensive methods etc. to distinguish and encircle the high runoff zones, and has been verified at several sites. It has been playing an important role to the predictiog and decision–making of water prevention.

I. THE HIGH RUNOFF ZONES OF KARST WATER IN COALFIELDS IN NORTH CHINA

In North China, the Carboniferous–Permian coalfields are scattered mainly in front of mountains. They were remained by layers subside. Karst water from limestone mountains flows to lower lands, when this flow is blocked by faults, it discharges to rivers or other lower lands in spring form. The spring area and part of spring drainage area are coincides with coalfields.

The heterogenous of karst groundwater is depend on the heterogenous of karst development. There exist high runoff zones, low runoff zones and no runoff zones in limestone area. These areas exist often in irragular zones, especially high runoff areas often called high runoff zones. In South China, high runoff zones are more evident, and presented in underground tunnels.

Comparatively, high runoff zones nearly exist in all spring drainage area in coalfields. For example, in the South of Taihang Mountains, Jiaozuo mine field, the so–called Fenghuangling fault runing along Jiuli mountain is a high runoff zone. The groundwater temperature at the faults is 3–6℃ higher than that on both sides of the faults. When drainaging from mines at the faults, groundwater level drops slightly. Among these mines, water inrush amount of Yanmazhuang mine was larger than 320 m^3 / min. In Hebi mine field, it was found out that Hebi – Xujiagou spring, Lin county–Hengshui–Xiaonanhai spring are two high runoff zones related to mines. In Fengfeng mine field, on the east of Gu mountain, No.5 mine – No.2 mine – No.1 mine – Heilongdong springs, Nan mountain–Heilongdong springs, and No.4 mine–Wanfeng mine–Heilongdong springs are high runoff zones. In Jingxing mine field, it was found that No.3 mine–No.2 mine–No.5 mine–weizhou spring is a high runoff zone through analysing the scatter of collapse collumns, water–bearing of drilling holes, water inrushes of mines, and other information, see the following table for details. In Jincheng mine field, the east side of Dan river, the north of Zhongtiao mountain, and the west of Gaomiao mountain are high runoff zones. And there're Yang mountain high runoff zone range from south Yang mountain, Huaibei city, to Xulou, Suixi county, and Wangchang high runoff zones, which lies in the west limb of Wanchang reverse anticline.

The general directions of high runoff zones are from recharge area to discharge area. Geo–structures often control the extending of high runoff zones, such geo–structures as fold axis and limb, water–bearing faults, the zones range from high incline to low incline, etc.. The Yang mountain high runoff zone, Huaibei coalfield as stated above, is located in the west limb of Longyang anticline. In the zone, layers stand vertically to reversely, fissures and dissolved holes and caves are developed. It is showed as a low resistence zone wide 300 metres by exploration. 20 wells produce water amount of 158400 m^3 / d. This proved the abundance of water in it. For another example. In Hancheng mine field, the turning part of high–incline to low–incline of Ordovician limestone at shallow is a high runoff zone. Concentrated joints and fissures caused by pressure constructed a water–charged zone with large transmibility coefficient. Water levels in the zone are coincide. The disturbing sensitivety when dewatered, large water inrushes into mines and large dewatering amount, showed and proved the existence of the high runoff zone.

At east side of Gu mountain, Fengfeng area, the high runoff zone range from No.5 mine to Heilongdong springs is blocked by F18 fault and other faults striking south to north. Karst water flows along the fault running north to south, to Heilongdong springs. In Hebi mine field, the high runoff zone from Hebiji to Xujiagou, converges groundwater from east limb of Panshitou anticline. The flow turns south to Xujiagou springs at northside of Qi river when blocked by faults. 7 wells in the zone gives a supply of 9336 m^3 / d. Besides horizontal resistence to water flow, some faults are vertically transmissible, such as Jiuli–mountain fault forming Jiuli mountain high runoff zone in Jiaozuo mine field, which is horizontally and vertically transmissible. Some high runoff zones cross faults, such as Jingxing No.3 mine–No.2 mine–No.5 mine–Weizhou spring high runoff zone. It flows windingly. The high runoff zone runs along the axis of Jingxing syncline basin crossing Xigangtou, Xingangtou, Nanzheng and Zhaocunpu faults, converges water to Weizhou spring. In the zone 2–3 km wide and more than 10 km long.

71 collapse collumns were found in No.3, No.2 and No.5 mines; 38 water inrushes occured; the product of irregating wells in the zone is one times larger than that on both sides of the zone.

II. Basic features of high runoff zones

In Table 1 there are some high runoff zones found and proved, their geological and hydrogeo logical features and some related mine inrush information.

In Table 1, hazardous water inrushes occured in all mines located in the zone of Jiuli mountain fault, and Yanmazhuang was flooded several times by karst water inrushes; Hebi No.9 mine and Anyang Tongye mine was once flooded because of located in high runoff zone; Fengfeng No.1 mine, Jingxing No.3 mine was ever flooded by karst water inrushes also, etc.. It can be seen that mines located in karst high runoff zones determines the complexity of their hydrogeological conditions.

III. The basis and methods to determine karst runoff zones in karst type mine fields

To find out and determine runoff zones is of directly meanings to recognizing the hydrogeological complexity, to forecast water inrush, and to prevent and tackle karst water so as to assure mining safty. In principle, high runoff zones can be determined from following aspects.

1. Following geological conditions are basis for high runoff zones to develop:

1). Fold axis and reverse layers where stress is concentrated.

2). Range of limestone high–incline changing to low–incline.

3). Tensile and / or tensile–twisting conductive fracture zone.

4). Unconductive fracture zone in front of a limestone mountain.

5). Dissolved fissures, collapse collumns and other zones karst developed.

2. Following are common hydrogeological features of high runoff zones:

1). Water quality is often HCO3–Ca.Mg type, low total mineral content. And Redon content is low than 3×10^{-10}Ci / L (3 eman / L).

2). Despite of winding flow, its direction points to discharge area and hydraulic gradient is low.

3). Water level is high sensitive. It often appears as a plate–shape funnel when mine inrushed or dewatered. The yearly change of water level is comparatively small. When there's recharge verticaly from deep, there will be obvious changes in water temperature, quality and water level.

4). Can be selected as perspective water supply site because of highly water–bearing.

5). Mines in the zones are liably water inrushed and having high inrush frequency.

3. Determine karst high runoff zones in terms of regional Redon content.

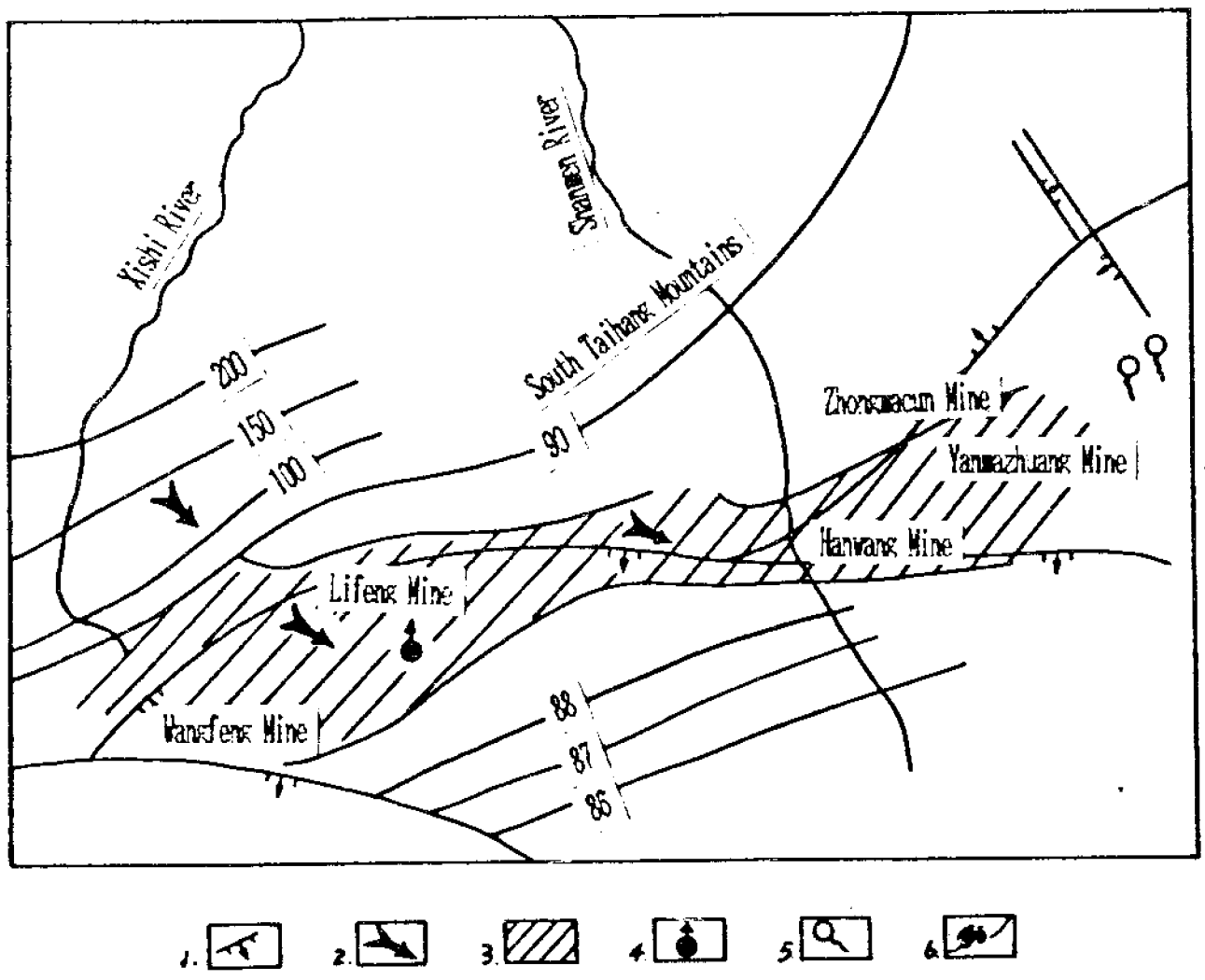
When fissures and karst developed and karst water flows unimpeded, Redon content is low. Otherwise, Redon content is high. Water Redon content shows groundwater flow condition. And from this, we can determine high runoff zones. Applying this method to several mine fields, we have determined presisely several high runoff zones. For

example, in Fengfeng mine field in North China, which is well known for its seriously water-charged, more than 200 sampling places were chosen from flowing springs, water supplying wells and inclined shafts, civil wells, or drills in mine having water flowed for a long time, and other places where karst water circle condition are good and samples are representative. The sampling and measuring were carried on in terms of groundwater Redon measuring rules.

Redon content of samples taken from sampling places above were measured. The data were marked at hydrogeological maps of mine fields. In terms of the sampling places where Redon content is low than 1.5×10^{-10}Ci / L, combining with hydrogeological information analysis, four low Redon content zones were determined in the mine field. That is from the northwest, the west, the southwest and the east part of Gu mountain to Heilongdong springs. The four zones were proved as four concentrated flow zones of Ordovician limestone groundwater in the mine field by other hydrogeological information. This is coincide with practice. The water amount of supplying wells, inclined shafts, and drills in the zones is large. Mine water inrush amount in the zone is large too.

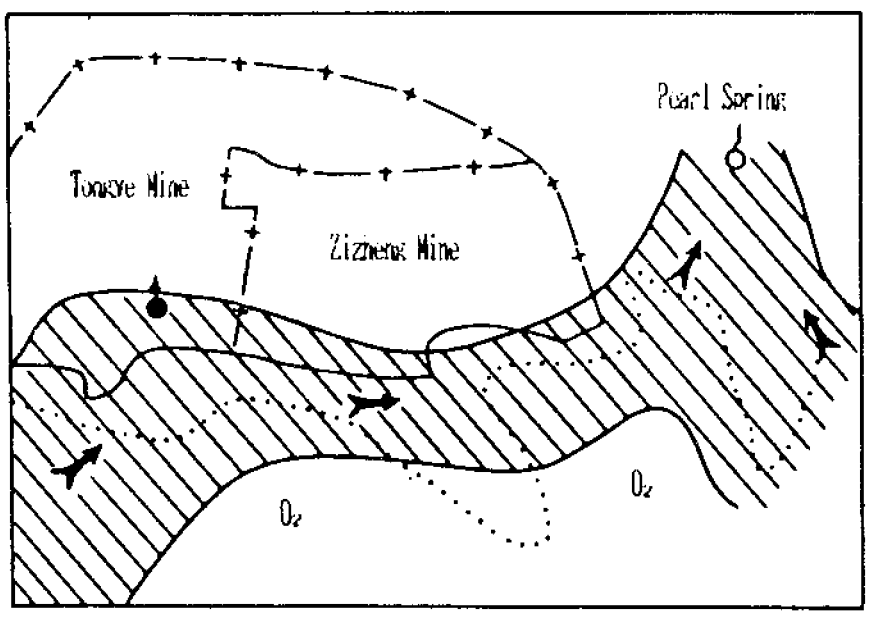
Table 1. Features of High Runoff Zozes in Mine Fields in North China

Mine field	High runoff zone	Features	Mines in zone	Water inrushes	Remarks
Jiaozuo	Jiuli mountain faults	3–6℃ higher water temperature than that on both sides of the zone , low total mineral content, stable water level despite of long drainage in Yanmazhuang and Hanwang mine, high frequency ofwater inrushes into mine.	Yanma zhuang, Hanwang and Jiulishan mine	inrush amoount was 240 m^3 / min at No.21 track in Yanmazhuang mine on Mar. 9,1979. Inrush occured at same site in 1985, the amount was 320 m^3 / min.	The zone runs along Chizhuang –Fangzhuang fault and Fenghuangling fault.
Hebi	Hebiji–Xujiagou, Lin county–Hengshui–Xiaonanhai springs	Drills revealed karst caves , the larger reached 2.44 m. Water discharges from Xiaonanhai springs, the amount is 6 m^3 / s.	N0.6, No.8, and No.9 mine	Inrush amount was 68 m^3 / min in No.9 mine.	Total spring drainage area is 1015 km^2, 120 drainage wells located in the zone
Anyang	Tongye–Zizhou–Shuiye pearl springs	South–north long 12 km, east–west wide 2.4 km, converging groundwater of northeast part of Heshun – Nangonglingfrom north to south, the gradient is 1 ‰.	Tongye mine and Anyang county mine, Guoyuan mine	Water inrush amount was 24 m^3 / min in Tongye mine on Aug. 25,1965.	Spring drainage area is 240 km^2, 25 drainage wells locatcd in the zone.
Fengfeng	No.4 mine–Wangfeng–Heilongdong, Nan mountain –Heilongdong , No.5 mine–No.2 mine–No.1 mine–Heilongdong springs	The discharge rate of Heilongdong springs is 4–10 m^3 / s.	No.4, No.5, No.2, No.1 mine and Wangfeng, Jungong mine	Water inrush amount was 150 m^3 / min in No.1 mine in 1960.	All zones link with Hei–longdong springs.
Jingxing	No.3 mine – No.2 mine – No.5 mine	31 collapsc collumns scattered from suothwest to northeast.Average hydraulic is 7 ‰.	No.3, No.2 and No.5 mine	Water inrush amount once reached 85m^3 / min in No.1 mine in 1985.	The zone discharges water at Weizhou springs. The springs' flow rate is 3.7–7.8 m^3 / min
Huaibei	Yang mountain – Xulou zone and Wangchang zone	20 wells in an area of 300 m wide and several ten km longgives a supply of 158400 m^3 / d.			Water level drawdown is around 2 m while dewatering 158400m^3 / d. The zones locate in west limb of a anticline.
Hancheng	High runoff zone at shallow part in Hancheng	The zone runs along the turning oflayers from high – incline to low – incline at the shallow.	Xiangshan mine and Magouqu mine	Xiangshan mine water inrush amount was 7 m^3 / min, Magouqu mine water inrush amount was 200 m^3 / min.	



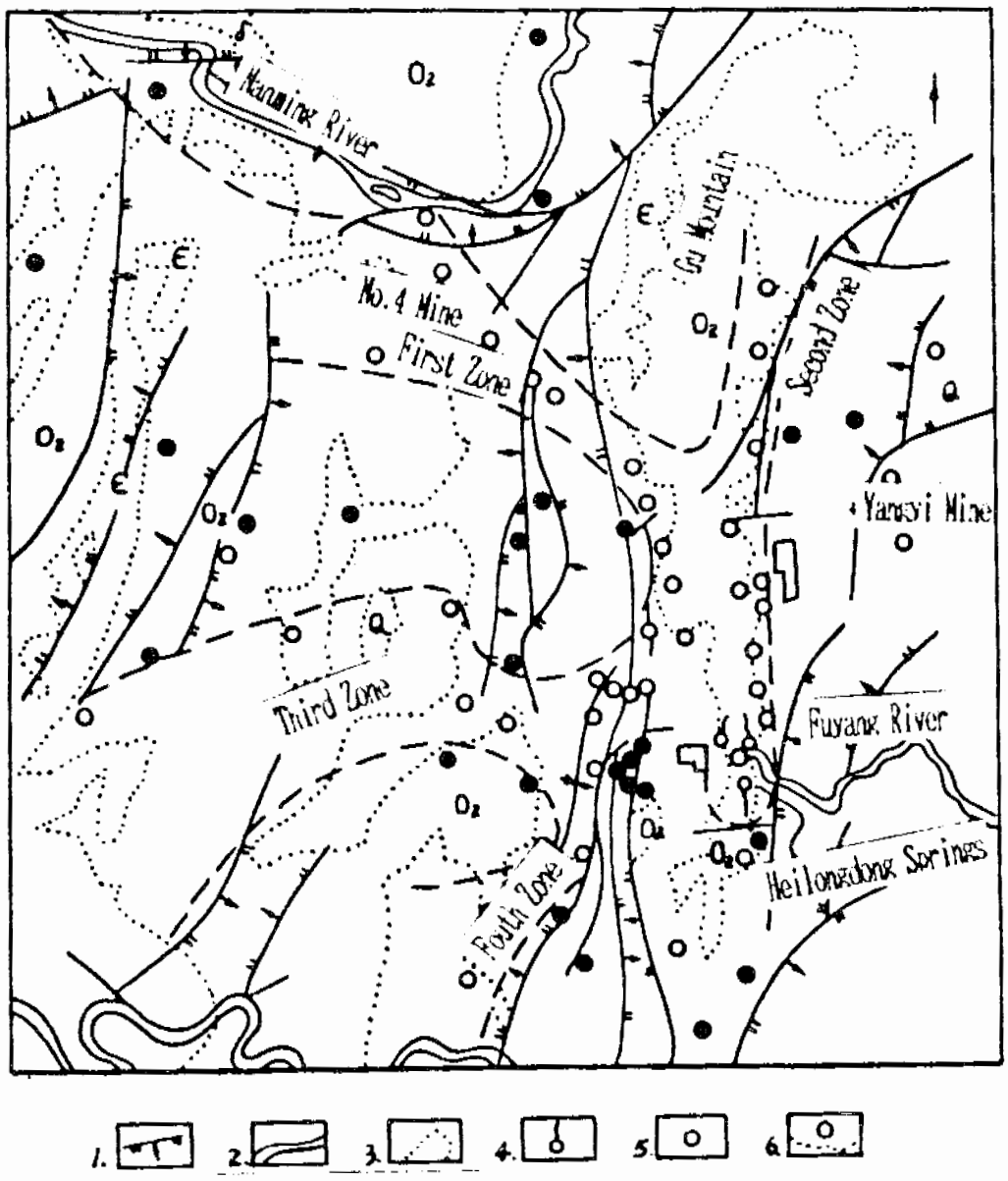
1. Fault, 2. Flow Direction of O_2 Limestone Water, 3. Runoff Zone of O_2 Limestone Water, 4. Collapse Collumn Water Inrush Site, 5. Spring, 6. Water-level Isopleth of O_2Limestone Water

Figure 1. Extending Map of Karst Water Runoff Zone of Ordovician Limestone in Jiaozuo Mine Field



1. O_2 Runoff Zone, 2. O_2 Boundary Line, 3. Collapse Collumn Water Inrush Site, 4. O_2Spring

Figure 2. Location of Collapse Collumn Water Inrush and Runoff Zone in Tongye Mine, Henan Province



1. Fault, 2. Boundary Line of Layers, 3. River, 4. Spring, 5. Low Redon Content Drill, 6. Runoff Zone

Figure 3. Map of Runoff Zone Determination of Ordovician Limestone According to Low Redon Content Drills in Fengfeng Mine Field (from NI Pingzhe)