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- COMMUNIST CHINA -

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[Following is the translation of an article written by the 309 Brigade Geological Section in Ti-chih yu K'an-t'an (Geology and Prospecting), No. 7, Peiping, 8 April 1960, pp 11-14.]

Hydrological survey is one of the geochemical prospecting methods. Its main principle is the study and utilization of the rate of hydrological changes, caused by ore deposits, to map out the abnormal hydrological areas.

According to our experiences, hydrological survey is economical, fast (Table 1 includes field and analytical test activities), and its abnormal area can be applied to study the detail content of metal distribution in an unknown area and to serve as a geochemical basis for deposit survey and geological survey. Hydrological survey can greatly economize on manpower and material resources in an entire area's non-keypoint metal survey and geological survey. It is an excellent method to implement the spirit of the general line in overall mining-prospecting.

Table 1

Type of Survey	Scale	Unit	Time Required	Cost Required
Metal Survey	1:50,000	km^2	4 day/team	180 yuan
Hydrological Survey	1:50,000	km^2	1 day/team	40 yuan

I. Ore Deposit Geological and Hydro-Geological Conditions

1. Ore deposit geological conditions:

The ore deposit of this lead mine is mostly formed along the shear zone of the igneous rock contact structure and related structure and remains in the igneous rocks and in the neighboring sandy shales. It is a complicated formation. With the exception of a portion of the mining district containing a very small amount of sphalerite and chalcopyrite with no industrial importance, the structure of the metal deposit has certain characteristics. Most of the mineral is galena, basically belonging to the single lead ore deposit, but with a strong pyritization. Pyrite appears in scattered spots and in small veins, distributed among the ore and eroded in the surrounding rock. The lead ore deposit in the whole district is classified into three preliminary ore deposit types:

(1) The lead ore may occur in silts (kaolinization and sericization), chalcopyritized porphyritic syenite and fine veins of impregnation lead deposit in porphyritic syenite igneous breccia. It exists in either the shape of enormous kidney beans or in grouped parallel closed mineral veins. The depth of the zone of oxidization is about 20÷70 meters.

(2) The lead ore may occur in large vein lead deposit that exists in carbonate and pyrite and in barite sericite quartz sandstone. The deposit is found along the vein-shaped prophyritic syenite contact zone in the sedimentary rocks and in closed fissure group that are parallel to the contact zone. It shows many high-degree dip angles and a relatively long strike, but the lead deposit shows very strong expansion and contraction. The metallic minerals are sulphides and the zone of oxidization is about 20-50 meters. The large structure of the individual ore deposit may reach the depth of more than a 100 meters.

(3) The lead ore may occur in the laminate-like lead mine in the carbonatized clay shale. The mode of occurrence is similar to the strata of the earth. The ore deposit appears to be in the shape of a large kidney bean, with a relatively gradual dip angle. The ores are mostly composed of oxidized minerals, principally of cerussite, lead-iron alum, anglesite, and lead phosphate chloride but a small amount of galena. In regard to the development of the ore deposit, as shown in deposit prospecting data, the ore deposit's zone of oxidization has a depth that may be greater than 200 meters.

2. Ore deposit hydro-geological conditions:

The rocks in this mining area are principally composed of cretaceous igneous rocks and triassic-jurassic sandy shale. Generally, they are dense and hard with a relatively low porosity which is not continuous. The rocks basically are impermeable and non-hydrous, so they are not found in a completely well-watered stratum but in the structure of shear zone which contains structural crevasse water. Thus, this forms a structural shear zone that is generally similar to a structurally water-containing shear zone. The amount of water welling up from the rocks is rather small (0.1-10 litres/second) and 89 litres/second maximum. The main source of underground water is rain water. Because the surface soil is very thick, it is not a very good source for water supply. The chemical properties of the underground water are mainly characterized by the presence of bi-carbonates of sodium and calcium. The underground water in the neighboring ore deposit and the mineralized area contains bicarbonates of sodium sulfate and calcium sulfate. The general conditions are shown in Figure 1.

In this area, from the standpoint of hydrological survey, the hydro-geological factors in this mining area are very favorable because:

(1) The topography is of moderate fault, with a specific altitude generally of 100-300 meters and a relatively well-developed water network, most of which is rather densely distributed into streams that have a medium amount of flow at a moderate flow rate. According to the "Ni-i-man" [Nieman?] method, the density of water network is 394M per square kilometer. These factors are advantageous to samplings for hydrological survey.

(2) The underground water of this mining area is mainly composed of structural crevasse water. Because the ore deposit is located in the structural shear zone, the opportunity for contact between metallic ore deposit and underground water is increased, resulting in the fomration of lead mineral ions, which are not easily dissolved in water and which produce hydrological abnormalities.

(3) The rate and amount of the underground water, with the exception of individual area where they may be higher or greater, are both generally low and small. The water replacement reaction is weak and slow, enabling that small amount of metals dissolved in the water to attain a certain degree of rich concentration.

(4) The underground water of the non-mineralized area in the entire mining district is primarily sodium-

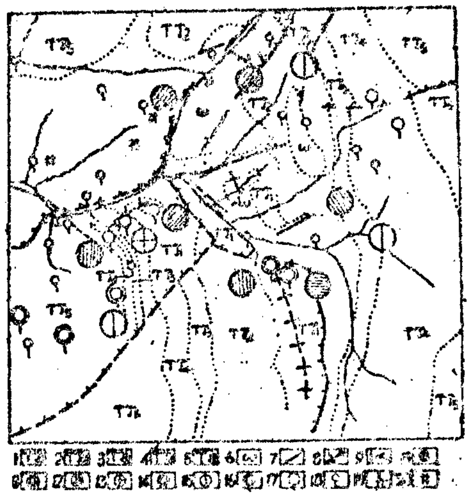

Figure 1 Hydro-Geological Conditions of the Mining Area

1. Quartzite--some of the crevasses contain a rich water stratum;
2. Purple-red shale--an extremely low water stratum;
3. Quartz felspar sandstone--the structural crevasses form a rich water stratum;
4. Sandy shale composite fold--weathering crevasse, very low water stratum;
5. Assorted color shale--the structural crevasses between the strata form a rich water stratum;
6. Porphyritic syenite, principally a water-filtering shear zone, a very low water stratum;
7. Faulting zone;
8. Axis of anticline;
9. Water network;
10. Water contains bicarbonates of sodium sulfate and calcium sulfate;
11. Water contains bicarbonates of sodium sulfate;
12. Water contains bicarbonates of sodium sulfate and magnesium sulfate;
13. Water contains bicarbonates of calcium, sodium and magnesium;
14. Water contains bicarbonates of calcium, and magnesium;
15. Water contains bicarbonates of sodium and calcium;
16. Amount of flow of descending spring is $>$ 5 liters per second;
17. Amount of flow of descending spring is $>$ 1 liter per second;
18. Amount of flow of descending spring is $<$ 1 liter per second;
19. Ascending spring; 20. Amount of flow of well is $>$ 1 liter per second.

calcium bicarbonates, with a relatively strong alkalinity, enabling the neutral and weak acidic water that contains a small amount of metallic element to produce a more obvious hydrological abnormality.

II. Hydrological Characteristics of the Mining District and Geological Effects of Hydrological Survey

(1) According to the study of a simple hydrological analysis and the results of an analysis of the micro-elements in the water, it has been assumed that the underground water in this mining district possesses the following characteristics:

A. The mining district's background water and mineralized water (the abnormal water induced by the ore deposit) show an obvious difference in chemical composition. Especially the mineralized water shows an obvious increase of lead ion and sulfate ion, and a relative increase in the specific value contained in sulfate ion and chlorine ion and a relative decrease of PH value. The increase and decrease of chlorine ion is not very obvious. It has been assumed that this is affected by the depth of the underground water and that the amount of chlorine ion is greater in underground water of greater depth than that in the underground water of lesser depth. The average chemical combination of mineralized water and background water is shown in Table 2.

Table 2

Quantity / Type of Water	Pb^{++} Value Avg.	Max.	Min.	SO_4^{--} Value Avg.	Max.	Min.
Mineralized	96.8	200.0	30.0	0.86	3.72	0.20
Background	0	0	0	0.80	0.20	0

(2nd half of table)	SO_4^{--}/Cl^- Value Avg.	Max.	Min.	pH Value Avg.	Max.	Min.
Mineralized	27.05	92.00	5.0	7.10	8.00	5.80
Background	1.78	5.00	0	8.81	10.00	8.00

Note: Unit for PH^{++} is gram/liter; unit for SO_4^{-} is milligram equivalent/liter.

B. (a) From the chemical analysis in this mining district, the neutral and weak acidic water, belonging to the mineralized water, besides the ovbious increase of lead ion, have an obvious abnormality in the other auxiliary prospecting indications. This shows a definite relationship between the amount of lead ion and the abnormality. It is clearly shown that the abnormal amount is caused by the influence of ore deposit. Then, it is possible to use hydrological survey as a means to prospect lead mines in this district.

(b) In this district, the underground water is both igneous and sedimentary rocks shows different values of abnormality and background of chemical composition. The different values are shown in Table 3.

Water Type	Mine Type	Pb^{++} Avg	Max	Min	SO— Avg	Max	Min	SO_4—/Cl— Avg	Max	Min	pH Avg	Max	Min
Mineralized	Igneous Rock	112.00	200.00	60.00	1.09	3.72	0.42	30.21	92.00	9.00	6.56	7.80	5.80
	Sandy Shale	81.70	120.00	30.00	0.63	1.08	0.20	23.90	48.00	5.00	7.55	8.00	7.00
Background	Igneous Rock	0	0	0	0.09	0.16	0	1.95	5.00	0	8.45	9.00	3.00
	Sandy Shale	0	0	0	0.07	0.20	0	1.61	5.00	0	9.24	10.00	8.00

From the data shown above, the amount of PH^{++}, SO_4-/Cl- contained by mineralized water and background water in igneous rocks is greater than that in sedimentary rocks, while the PH values for igneous rocks are lower than that in sedimentary rocks. All these characteristics are closely related to the physical and chemical properties of the igneous and sedimentary rocks, the geological conditions of hydrology as well as the mode of occurence of ore deposit.

(2) Variation of ore deposit water in the mining area:

1. Lead ion: The lead ion contained in underground water in this district comes from lead ore deposit. But the amount of lead ion contained in the mineralized water either in igneous or sedimentary rocks is generally lower than the values in the lead-zinc mine ($1x10^{3}$-$1x10^{-2}$ gr/l). Generally, the amount of lead ion is only $5x10^{-5}$-$2x10^{-4}$ gr/l, which is low abnormality, but it can form an abnormal amount.

2. Sulfate ion: The amount of sulfate ion is proportional to the increase of PH^{++} in water and is related to the increased value of SO_4-/Cl-. This explains that sulfate ion comes from pyrite and galena. As galena associates with pyrite in this district, the presence of abnormality of sulfate ion can be used as an important auxiliary indication fro prospecting of lead ore deposit.

3. PH value: In this mining district, the Ph value is inversely proportional to the amount of lead ion in the ore deposit water and it ranges from 5.8-8. It is higher in sedimentary rocks than that in igneous rocks, but both are weak-acidic and neutral waters because the rocks in this district are themselves of a higher alkalinity. The lower PH value in ore deposit water is the principal reason for the lead ion not moving very far and of low value.

(3) Geological effect of hydrological survey in the mining area:

The geological effect of hydrological survey for prospecting of lead mine in this district is very good. The result of a hydrological survey map of a scale of 1:50,000 figures out not only the formation of the already known mining area, which basically conforms with the hydrological abnormal area, but also discovers some new areas of abnormality. As shown in Figure 2, in the experimental district, there are discovered six abnormal areas; among them Nos. II, VI, V are new mining areas discovered through the use of the hydrological survey method. Owing to the lack of detailed geological survey and engineering investigation data, the relation between ore deposit and abnormality has not yet been clearly known.

No. I abnormal area principally reflects the hydrological abnormality of the largest ore deposit in the mining district. The abnormal water spots are scattered along the contact shear zone between the igneous and sedimentary rocks. Because the formation of the abnormal area basically conforms with the formation of the ore deposit and because the water spots are scattered in the igneous rocks, the amount contained in principal and auxiliary prospecting indications are good and normal.

No. III abnormal area reflects the hydrological abnormal conditions of the principal vein-shape lead mine within the district. The existing formation of the abnormal area is quite similar to that of both the known ore deposit and the structural zone. Because the surrounding rocks are mainly sandstone and sandy shale that contain rich water originating from the structural crevasses, the underground water has a stronger replacement reaction. The ore deposit shows a higher degree of dip angle, and the amount of lead ion is similar. Some of the water that contains a strong dilution, though it flows directly to the ore deposit, shows no existence of lead ion, but only the auxiliary prospecting indications show out clearly, forming many lead normal areas, which are as spot-like vacant areas inside the lead abnormal area.

No. IV abnormal area: The abnormality of the water in this area is proved to be normal by the known conditions of ore deposit. The formation of the abnormal area follows the curves of the ore deposit and structure, forming the shape of " ".

III. Field and Indoor Working Methods and Data Compilation in Hydrological Survey

1. Method of water sampling and dense concentration of sampling in field work:

In this mining district, the scale used for hydrological survey is 1:50,000. Because it is keypoint testing and the geological structure of the area is complicated, water sampling is taken from not less than two points per square kilometer, which is slightly higher than general requirement. But judging from the stand point that in this district the amount of lead ion is not great, lead ion cannot move far and the geological structure is complicated, the number of points for water sampling in the 1:50,000 scale for hydrological investigation, should be increased to 3-3.6 water samplings per square kilometer.

Principles for water sampling points selection and distribution:

(1) Water sample is mainly taken from underground water(from drilling, pit, well and spring), another source is surface water. It is preferred that the sampel is obtained from surface water which is closely originating from underground water. Generally, most of the samples are taken from the intersection of streams where amount and rate of flow are not very great.

(2) Uniform distribution of water points is necessary since it is essential for accurate locating of the abnormal area. But the water sample should be taken from the most important geological contact area or rock areas which contain certain amounts of minerals so that the results of water sample analysis may be fully utilized.

Field water sampling, according to the different items of analysis, can be classified into two kinds as follows:

(1) Samples for simple analysis of water characteristics: Items to be determined for this kind of samples are SO_4^{--}, Cl, Ph value, and the degree of mineralization. Only 100 Cc of water sample is needed for the determination of PH value

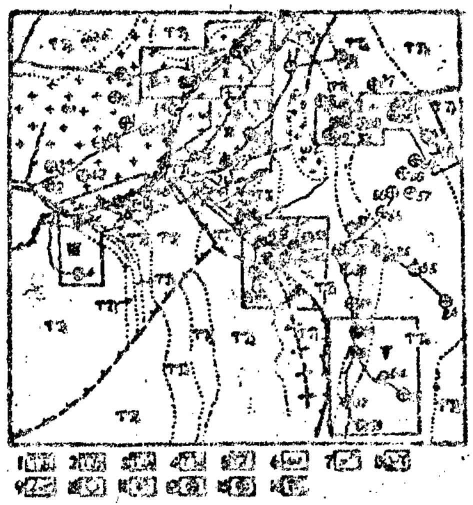

Figure 2 General Map of Mining District
Hydrological Survey

1. Sericite-quartz sandstone;
2. Purple-red slate shale;
3. Quartz feldspar sandstone;
4. Inter-bedded purple-red sandy shale;
5. Assorted color shale;
6. Porphyritic syenite and potassium alkaline volcanic rocks;
7. Fault structural line;
8. Axis of anticline;
9. Water network;
10. Water sampling point and sampling number;
11. Background water;
12. Mineralized water induced by pyrite;
13. Mineralized water induced by lead ore deposit and pyrite;
14. Hydrological abnormal area and compilation number.

and Cl^- in field work. Determination of SO_4^{--} is performed in the laboratory.

(2) Samples for the determination of small amount of heavy metal: Elements such as Cu, Pb, and Zn are determined by chemical method, the determination for Mo, V, Co, Ni, Ag, and Sn are performed through the use of spectrum technique. The amount of samples required for the determination of Cu, Pb and Zn is recommended at a volume of 1,000 CC while that for spectrum analysis will be of 2,000 CC.

The procedure and method for the simple analysis of water characteristics follow general requirements. In the procedure following the direction toward the upper stream, observations should be made over geological and hydrological conditions and a reasonable arrangement of the locations for the water sampling points should be made. Then samples are taken step by step along the direction toward the upper stream. Samples are stored in glass bottles. On the top of each bottle, an air space of 5-10 CC is maintained and the bottles are stopped with rubber or soft-wood plugs. Before taking the samplings, the bottles are washed with clean water three times, next with hydrochlorine acid once, and finally with distilled water once.

The method of sampling for heavy metal micro-analysis is the same as mentioned above. However, in order to facilitate transportation, this brigade used the combined effect of precipitation and dense concentration by adding cadium sulfate and calcium chloride into the sample. The volume of sample after precipitation and dense concentration treatment is measured about 25 CC. The weight of the sample is greatly reduced about 40-80 times. This reduction of weight considerably cuts down the time and labor required for transportation. Obviously, it gives advantage to the work of hydrological survey.

Regarding the manipulation of precipitation and dense concentration of cadium sulfate and calcium chloride, a reference paper "Micro-Determination and Dense Concentration of Metallic Ions in Natural Water" is available (Ti-chih yu K'an-t'an, No. 7, 1959), reported by the Analytical Section, Prospecting Research Department, Geological Ministry.

In field tests, to avoid property change of the sample, this team used calcium carbonate for the precipitating and dense concentration method instead of cadium sulfate and calcium chloride dense concentration method. Meanwhile, when the amount of sodium carbonate was increased in water up to 15 CC, the time required for precipitation is reduced from 30 minutes to 8 and 25 minutes.

2. Method for the analysis of water sample:

The simple analysis of water sample is performed by the ordinary simple analysis method. Heavy metallic elements such as lead, copper and zinc are determined with satisfactory results by the colorimetric method which is recommended by the Analytic Section, Prospecting Department, Geological Ministry.

3. Data collection and compilation:

The work of hydrological prospecting in mining engineering is still in its preliminary stage. Data are collected and compiled on a simplified basis to form a map of hydrological abnormality, only confined to lead ion and some other auxiliary prospecting indications. The items needed for this purpose are shown as follows:

(1) Recording table for water sampling:

Sample No.	Location of Sampling	Type of Water Sample	Time Required for Sampling
1	2	3	4

Condition for Sampling	Hydro-geological Conditions of Hydrous Stratum	Geological Conditions of Water Source	Treatment of Sample
5	6	7	8

This table is designated for collecting records of out-door sampling conditions and the geological conditions of the surrounding rocks. The records made under the items in the table will be used as original data for the formation of a hydrological map. Item No. 5 is used for recording depth, temperature, and other conditions of water source (the amount of dirt and condition of use) and conditions of climate, etc. Item No. 6 is used for recording the name of hydrous stratum, type of underground water, conditions for drainage and relations with hydrous stratum. Item No. 7 is used for recording conditions of ground surface of water source, characteristics of water crevasse and other related geological conditions. Item No. 8 is used for recording weight of water sample, method of dense collection, dense concentration and the weight of the sample after being dried.

(2) Recording table for hydrological analysis:

	Results of Hydrological Analysis													Remarks
	~~Prime~~ Indicators			Spectrum Analysis Results							Aux. Indicators			
No	Cu	Pb	Zn	Mo	Ag	Co	Ni	V			SO_4	SO_4/Cl	pH	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

The records listed on this table will be used as principal comprehensive information for the formation of a hydrological map, based on the comprehensive compilation of analytical results and water sample records. Under item No. 15, name of hydrous stratum, conditions of water source, type of underground water and characteristics of water crevasses are recorded.

The locations and numbers of sampling are marked on the hydrological or geological map and represented by small circles. Within these small circles, draw lines with different colors to indicate the different degrees of abnormality of the chemical composition of principal and auxiliary prospecting indications. According to the characteristics of geological structure and regularity of mineralization, the areas of different degrees of abnormality are marked on the map, offering the information for evaluation of the mine in the future.

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