

# Analysis of the Geological Characteristics and Metallogenic Mechanism of Baini lead-zinc deposit in Hezhang county, Guizhou Province

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**Abstract.** Based on review of previous researches, the Baini lead-zinc deposit of Hezhang county is studied through various measures such as field geological survey, microscopic observation and geochemical analysis. The results show that the distribution of lead-zinc ore is determined by the structure, and it experienced the hydrothermal mineralization period and epigenetic oxidation enrichment stage during the formation of deposit. The prospecting indicators mainly include rock structure, structure, mineralization and stratigraphic markers.

**Keywords:** Lead-Zinc Ore; Geological Characteristics; Metallogenic Mechanism; Hezhang.

## 1. Introduction

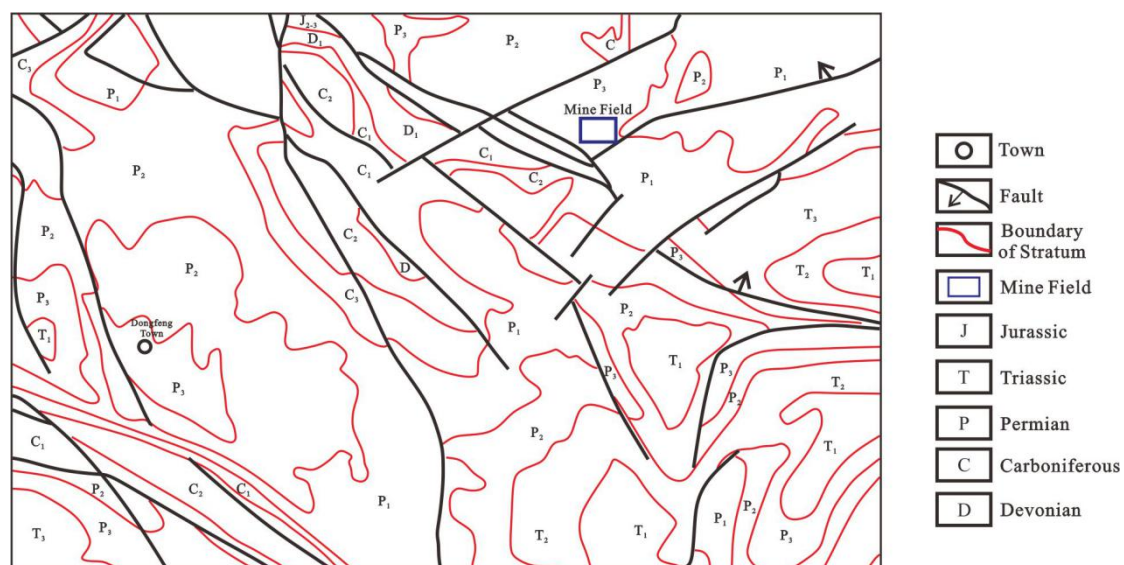
Guizhou Province has abundant lead-zinc resources, and there are rich lead-zinc resources in the western, northwestern and southwestern areas of Guizhou. Many experts and scholars have studied the lead-zinc resources in Guizhou (Tu, 2000; Huang et al., 2001; Liu, 2002; Gao, 2002; Zhang, 2005; Li, 2012; Yang, 2014; Zhang, 2016; Qi, 2016), and many results have been achieved. This paper chooses the lead-zinc resources of Hezhang White Mud Factory in West Guizhou as the research object and studies its geological characteristics and metallogenic mechanism. The research data of lead-zinc deposits in the northwest region are also supplemented, which has certain significance to further explore the lead-zinc resources in this area.

## 2. Geological Background

There are many lead-zinc deposits in the northwestern area of Guizhou Province, and the Baini lead-zinc deposit of Hezhang county is one of them. The Baini lead-zinc deposit in Zhijie Township, Hezhang County is located at the east side of South Hezhang County, which has a diameter of around 25km and an area of around 2.29km<sup>2</sup>, and it is under the jurisdiction of Zhijie Yi and Miao Ethnic Township, Hezhang County. The rural road from Zhijie to Xingfa passes through the working area, which can provide convenient transportation. Through mineral survey of this area, lead-zinc ore, limestone (for construction), limonite etc. have been found.



The Baini lead-zinc deposit in Zhijie Township, Hezhang County is located at the northeast wing of the syncline of White Mud Factory at the southeast section of the Yadu- Mangdong fold fault zone (Fig.1). The emergence strata in the area include: gray and light gray thick-massive limestone of Upper Mapping Formation of carboniferous system ( $C_{2mp}$ ); gray & gray-black mudstone, carbon mudstone, gray-yellow and gray-white quartz sandstone of Middle Liangshan Formation of Permian System ( $P_{2l}$ ); gray, dark grey and gray-black medium-to-heavy limestone of Qixia Formation ( $P_{2q}$ ); clay, sub clay and pebbly clay sparsely distributed in the quaternary system, which are not integrated on the above strata in different angles. The fault structure was mainly developed in the  $F_1$  normal faults and the  $F_2$  reverse fault in the northwest-west and northwest direction. The lead-zinc deposits in the area are output near the lower plate of the fracture zone of  $F_2$  fault. The minerals in this area include lead-zinc, pyrite, limestone, etc.



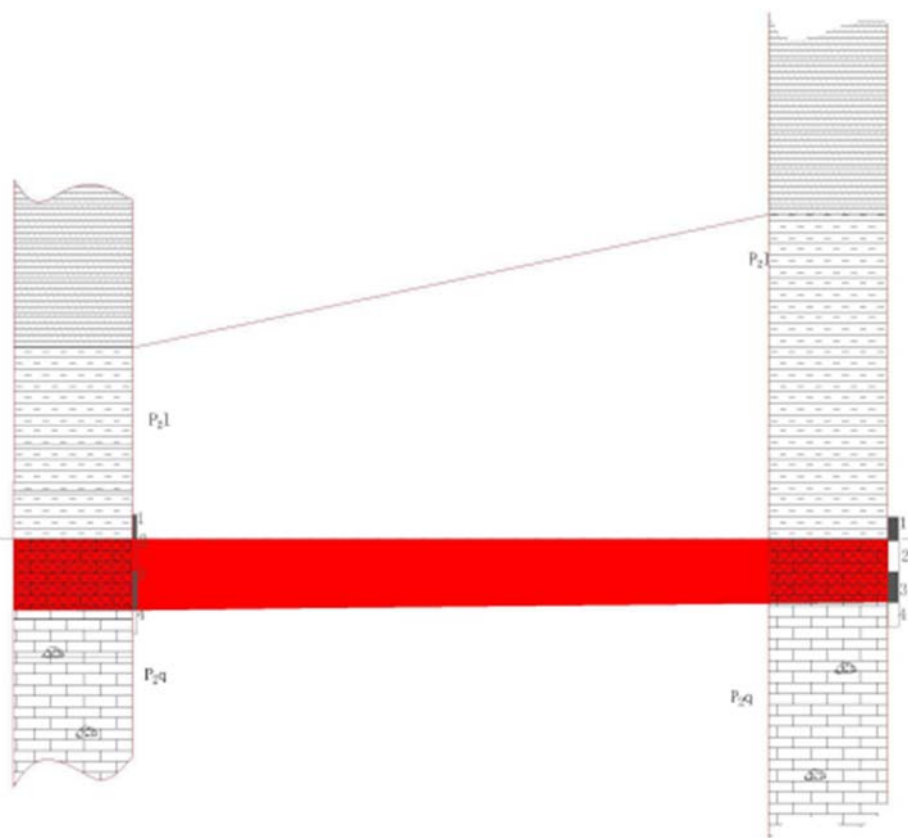
**Fig.1.** Geological map of the study area

### 3. Characteristics of Ore Body

The lead-zinc deposit in Guizhou mainly consists of lead-zinc sulfide ore, galena ore and blende ore, accounting for 59.5% and 54.9% of the province's total lead and zinc reserves respectively; followed by lead-zinc oxide ore (mostly placer), accounting for 39.6% and 37.8% of the total reserves in the province. The minerals are often associated with other usable minerals, such as silver, antimony, cadmium, tellurium and tellurium. Among them, Hezhang Zhangkoudong- Xiaokuangshan and Maomaochang are famous, with high ore grade and large scale. The lead-zinc mine can cover the entire northwestern area of Guizhou Province, which can also extend to Yunnan Province. It enters Yunnan from Yemachuan-Magu Town-Dongfeng Town-Jinzhong Town-Yangjie Town, which continues for more than 100 kilometers. The Baini lead-zinc deposit of Hezhang is located in this area, and it has great ore-searching prospects.

The lead-zinc minerals in this area are mainly output in the  $F_2$  fault zone in the northwest direction. The fracture zone mainly consists of limestone breccia. The breccia has poor roundness with angular shape and subangular shape, the joint fissure has developed, many calcite crystals and geodes are visible, and the lead-zinc mines fill the structural fractures with star, fine-veined, irregular shapes. The exposed ore belt on surface has a length of 314.12m, a thickness of 0.8-1.5m, and an average thickness of 1.2m. The roof of the ore body is gray & gray-black mudstone, carbon mudstone, gray-yellow and gray-white quartz sandstone of Middle Liangshan Formation of Permian System ( $P_{2l}$ ); the floor is gray, dark grey and gray-black medium-to-heavy limestone of Qixia Formation of Permian System ( $P_{2q}$ ) (Fig.2).

The ore-bearing layer of this ore body is located at Qixia Formation of Permian System ( $P_2q$ ), the ore-bearing zone is mainly located within the fracture zone at the northeast plate of  $F_2$  fault, and partial mineralized spot or mineralization can be seen in the southwest plate of  $F_2$  fault. However, through sampling and analysis, we found that most of them did not reach the industrial grade, so they were not exploited; no mineralized spot or mineralization was found in the rest area. The main causes for the above-mentioned phenomena include: 1) The ore body is under structural ore control, which is controlled by the northwest  $F_2$  fault, and the ore body is output in the fracture zone of the  $F_2$  fault. The lead-zinc deposit is a hydrothermal polymetallic ore deposit, the ore body in  $F_2$  fault provides a pathway for the migration of ore-forming materials and becomes a space for enrichment of ore-forming materials, and the ore body presents layered output along the fault fracture zone; 2) The deposit is affected by stratigraphic position and lithology, which is output in the gray, dark grey and gray-black medium-to-heavy limestone of Qixia Formation of Permian System ( $P_2q$ ). The morphology, shape and scale of ore body are all controlled by the  $F_2$  ore-bearing fault. The ore body is output in the  $F_2$  fault fracture zone, with a dip of  $233^\circ$  and an inclination of  $65^\circ$ .



**Fig.2.** stratigraphic correlation diagram of ore-bearing rock formation

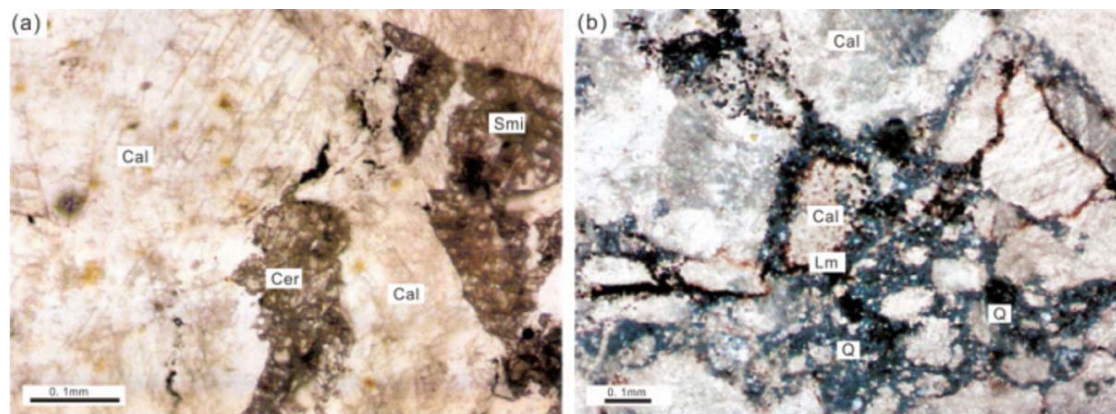
At present, after exposure on shallow surface through projects such as trenching and inclined shaft, 1 layered lead-zinc oxide ore body was found, which was output along the fracture zone of the  $F_2$  fault. For the surface outcrop of ore body, 5 surveillance points were arranged in trial trench with an interval of 80-100m along the strike, 4 surveillance points were arranged in tunnel (inclined shaft) with an interval of 40—50m along the dip, and 2 surveillance points were arranged in drilling project. Among the 11 implemented projects, 9 have exposed the ore-bearing belt. According to the project, the exposed ore body has a length of 314.12m, extending 60m along the dip, which is 0.8-1.5m thick and 1.2m thick on average. The lead-zinc ore body is output along the  $F_2$  fault fracture zone. The occurrence is consistent with the fault occurrence, with a dip of  $233^\circ$  and an inclination of  $65^\circ$ . The ore body is of

medium scale, which has relatively concentrated distribution and shallow burial, and it is suitable for small-scale mining through simultaneous mining and exploiting.

## 4. Ore Characteristics

### 4.1. Characteristics of Mineral Association

The ore is of cerussite-smithsonite type, which is oxidized ore. The mineral association is complex. The ore is brownish yellow, brownish, gray and grayish black, while the main minerals are cerussite and smithsonite. Generally, there are cerussite, smithsonite, pyrite, calcite, etc.; the secondary minerals include anglesite and residual primary boozite, sphalerite, etc. (Fig. 3). Ore grade: Pb 0.60%-1.65%, average 1.09%; Zn 1.60%-1.94%, average 1.73%.



**Fig.3.** Texture of ores: Cal, calcite; Smi, smithsonite; Cer, cerussite; Q, quartz.

### 4.2. Structural Characteristics of Ore

(1) Metasomatism residual structure: The oxidized sphalerite is dissolution metasomatism of smithsonite along its grain edge or cleavable fracture, and its core often contains traces of sphalerite. (2) Fragmentation structure: Aggregates of block and stripped smithsonite and cerussite; they were squeezed, stretched, and crushed to pieces or crumbs of different sizes due to the tectonic action after mineralization; then, it was cemented by hydrothermal pyrite, dolomite, and calcite. (3) Spherulitic structure: Light brown, pale yellow and colorless smithsonite and cerussite form a concentric ring zone, forming a complete or incomplete pellet, and its interior generally has radial colloidal cracks. Some pellets present weak heterogeneity. (4) Anhedral and subhedral grain structure: Anhedral and subhedral smithsonite and cerussite (0.5-2.0mm) grains were unevenly and sparsely distributed between the fractures of residual surrounding rocks, or the corrosion holes and holes of various types of rocks, and they have the ore structures commonly found in ore belts.

The ore structures mainly include: (1) Disseminated structure: Cerussite and smithsonite are filled and distributed along the cracks between the rocks and gravels in the form of anhedral grains, which form rock breccia cement or form netted venation, and it is mainly for filling with weak dissolution metasomatism. (2) Breccia structure: The rock underwent cracking and staggered cracking due to tectonic action, which made the rock present the breccia structure (the size of breccia is around 0.35-2x6mm). The cracks between these breccia fragments are cemented by quartz, chalcedony (Q) and limonite, which made the ore have breccia structure. (3) Granophyric structure: The rock has some cracks due to its tectonic effect, and cerussite and smithsonite are filled in the above micro-cracks in metasomatic distribution and present a granophyric structure.

### 4.3. Tectonic Characteristics of Ore

Based on tectonic characteristics, ore can be divided into the 6 types of disseminated ore, surrounding rock breccia-cemented ore, stripped ore, colloidal ore, massive ore, granophyric ore and lump ore. They



mainly have the following characteristics: (1) Disseminated ore: An ore with an anhedral and subhedral grain structure. The metal minerals are mainly cerussite and smithsonite, with a small amount of pyrite or galena, which can be classified into sparsely disseminated or densely disseminated according to the content of cerussite and smithsonite (with about 10% as the line), or it can be divided into graniphyric, dyke, and micro-dyke disseminated shapes according to the filling pore characteristics, which is the most common type; (2) The surrounding rock breccia is filled with cemented ore: After the ore-bearing carbonate rock is broken by tectonics, its fractions and powder are filled and cemented by hydrothermal sphalerite, pyrite, dolomite, etc.. The hydrothermal minerals have slight dissolution and metasomatism on surrounding rock fragments, and it is also the main ore type; (3) Stripped ore: smithsonite and cerussite concentrate to irregular stip and distributed in crystalline limestone. The strips have a width of about 0.2-2.5mm, which are partially broken and bent. We can see crystallites and fine-grained pyrite fill and cross along cracks, and it is a main ore type; (4) Colloidal ore: They consist of pelletized colloidal cerussite and smithsonite, colloidal pyrite and a small amount of hydrothermal dolomite, only found in agglomerates; (5) Massive ore: It is formed by closely jointing the galenite or smithsonite of equiaxed granular or anhedral irregularly shaped aggregates. The content of galenite or smithsonite is extremely high, with very few remaining voids. Hydrothermal dolomite filling constitutes a rich ore, but the ore belt seldom has output; (6) Graniphyric ore and lump ore: The cerussite or smithsonite aggregates generally present the graniphyric ore and lump shape (1-5mm). sparsely distributed in the large dissolved holes of crystallized limestone. They are the main ore types.

The ore has the industrial type of carbonate-type lead-zinc deposit. The ore contains oxidized ores and primary ores, and oxidized ores are mainly mined in this area.

## 5. Hydrogeological and Engineering Geological Conditions

### 5.1. Hydrogeological Conditions

According to the hydrogeological characteristics of exposed strata, it can be mainly divided into carbonate fissure karst water and bedrock fissure water. Carbonate fissure karst water: Upper Mapping Formation of carboniferous system (C<sub>2</sub>mp), and the lithology is gray and light gray thick-massive limestone. Karst development: karsts, fissures and pipelines developed in the rocks, the water content was uneven, there were few spring spots exposed, and the water abundance was strong. Qixia Formation (P<sub>2</sub>q) of Permian System: the lithology is gray and light gray medium-to-heavy limestone with a thickness of 135m. Karst development: karsts, fissures and pipelines developed in the rocks, the water content was uneven, there were few spring spots exposed, and the water abundance was strong. Bedrock fissure water: Middle Liangshan Formation of Permian System (P<sub>2</sub>l): the lithology is gray & gray-black mudstone, carbon mudstone, gray-yellow and gray-white quartz sandstone; it has 0-4 layers of coal streak in the middle, and the upper part has thin marlstone occasionally, with a thickness of 98m. Joint fissures developed in the rock, and there were fewer exposed spring spots in the area. It has poor water content and water conductivity, which belongs to bedrock fissure water. Dominated by clastic rock, the rock contains many muddy components, so the rock generally has weak anti-weathering ability. The outcrop area has thicker strong-to-medium weathering belts, and it is easy for massive atmospheric precipitation to penetrate; it contains shallow weathered fissures phreatic water, and in the deep part, the development of rock fissures weakened, while the water content of rock decreased correspondingly.

The water filling sources of deposits (atmospheric precipitation, surface water, groundwater, old kiln water and fault water) are in direct contact with the ore body. The groundwater directly enters the deposit through cracks, pores, and caves, so the deposit is a karst and fissure water-filling deposit. The hydrogeological conditions of this deposit are moderately complex.

### 5.2. Engineering Geological Conditions

The engineering geological formation can be divided into loose formation, soft formation and hard formation. Loose formation: the quaternary system (Q): residual deposit, the lithology is subclay and pebbly clay, which are plastic and thin, mainly distributed in low-lying areas. This formation has poor

physical and mechanical properties and low strength. Soft formation: Middle Liangshan Formation of Permian System (P<sub>2</sub>l): the lithology is gray & gray-black mudstone, carbon mudstone, gray-yellow and gray-white quartz sandstone. Joint fissures developed in the rock, and the rock had weathering resistance. Clay rocks and carbonaceous clay rocks tend to soften in water, lowering the physical and mechanical properties of the rock, and it has poor engineering stability.

Hard formation: Qixia Formation (P<sub>2</sub>q) of Permian System and Upper Mapping Formation of carboniferous system (C<sub>2</sub>mp): the lithology is gray and light gray medium-to-heavy limestone. This type of rock is hard, brittle and exposed on surface, which can resist physical weathering and has high compressive strengths ( $R_c > 60$  MPa). Generally, it presents thicker layer-like structure and the more silicon it contains, the higher compressive strength it has. According to the core statistics, the RQD value in P<sub>2</sub>q + C<sub>2</sub>mp is 0.77-0.97, which indicates that the rock integrity is complete- relatively complete. However, such rocks have weak resistance to chemical weathering and corrosion. The purer the grey material it contains, the easier for it to be corroded. Such rocks can be found in all karst caves in the mining area, especially in the Qixia Formation. At the same time, such rocks are hard and brittle, and they are prone to long-lasting shear joints under the influence of extrusion forces. In short, this kind of rock is hard, with high physical and mechanical strength, strong anti-weathering ability and great engineering stability.

The structural planes in the area are mainly the original sedimentary bedding planes, and weathered joints and fissures developed on shallow surface. The lead-zinc ore body was output along the broken breccia zone of F<sub>2</sub> fault, with loose brecciated grains, loose cementation, and developed structural fractures with poor stability. The joint fissures developed in the two plates of rock, which seriously damaged the stability of the original sedimentary structural plane of the rock in the mining area, which had lowered the physical and mechanical properties of the rock. The hydrogeological engineering geological conditions in the mining area tend to be complicated. It has a great influence on the technical conditions for mining lead-zinc deposits in the deep mining areas.

Evaluation of engineering geological conditions: The lead-zinc ore body in the area is output in the F<sub>2</sub> fault shuttered zone, and the surrounding rock is structural breccia composed of limestone of the Qixia Formation (P<sub>2</sub>q) of Permian System, with joint fissure development, loose structure, and poor stability. The floor of the ore-bearing layer is the limestone of the Qixia Formation (P<sub>2</sub>q) of Permian System, and the roof is mudstone, carbon mudstone and quartz sandstone of Middle Liangshan Formation of Permian System (P<sub>2</sub>l). Under the influence of the F<sub>2</sub> fracture structure, the roof and floor rocks have joint fissure development and poor engineering stability. During the construction and mining process of mines, it tends to cause collapses and landslides, and it is easy to cause geological disasters such as mudslides of slope in the heavy rainy season. In general, the mine has poor engineering geological conditions, which is a medium-complex deposit.

## 6. Metallogenic mechanism and prospecting indicators

### 6.1. Genesis of Mineral Deposit

The surrounding rock of ore body is gray, dark grey and gray-black medium-to-heavy limestone of Qixia Formation (P<sub>2</sub>q). The surrounding rock of ore body has alteration to varying degrees, mainly including petrolysis, fading, dolomitization, and pyrite. The mineralization of the ore body is relatively continuous, and there is generally no horse-stone.

Based on review of previous researches (Chen, 1986; Chen, 1999; Ou, 1996; Zhang, 1999; Han et al., 2001; Chen et al., 2008; Nie et al., 2007; Nie and Kang, 2014; Wang et al., 2013; Liu et al., 2016; Peng et al., 2016; Qin et al., 2016), the following initial conclusion can be drawn according to the aspects of mineral characteristics, mineral composition, ore structure and mineral symbiosis in the mining area: It is believed that the lead-zinc deposit in the region is a hydrothermal polymetallic deposit, and the ore body was output near the limestone of the Qixia Formation and the carbon mudstone of Middle Liangshan Formation of Permian System, which is controlled by the interlamellar fracture and interlaminar weakness formed by the F<sub>2</sub> fault. The cause is preliminarily considered as "hydrothermal

polymetallic deposit" oxidized deposit, which has undergone a tectonic hydrothermal metallogenic period and an epigenetic enrichment stage.

**Tectonic hydrothermal metallogenic period:** Under the regional tectonic stress, an interlaminar fracture zone was formed between the limestone of the Qixia Formation and the carbon mudstone of Middle Liangshan Formation of Permian System, and the ore-forming hydrothermal fluid containing lead and zinc along the fracture zone moved up to generate first-generation pyrite-sphalerite-galena-few quartz combination. According to the microscopic observation, we can see that the pyrite grains are surrounded by sphalerite and galenite, or the galena and sphalerite are dissolved in the pyrite; the galena had dissolution and metasomatism with sphalerite; a small amount of quartz is distributed in the edges or cracks of other mineral particles. It indicates that the generation order of this generation of minerals is pyrite-sphalerite-galena-quartz.

After the main metallogenic stage, there were more than one secondary tectonic hydrothermal metallogenic stages, and a small amount of second-generation mineral combination would be generated: secondary lead minerals - a small amount of quartz. In the secondary metallogenic stage, the first generation of minerals and breccia were severely broken and fragmented due to tectonic action.

**Epigenetic oxidation and enrichment phase:** because the primary minerals were broken up, more complete oxidation occurred during this period, resulting in the formation of smithsonite, cerussite and limonite.

## 6.2. Ore-controlling Factors

The lead-zinc minerals in the area are strictly controlled by the minerogenic fault  $F_2$  in the area, and the fault  $F_2$  is the channel to minerogenic materials provided by the ore body, it became space for enrichment of minerogenic materials, and the ore body had layered output along the fault fracture zone. Secondly, the deposit is strictly controlled by the gray, dark grey and gray-black medium-to-heavy limestone of Qixia Formation ( $P_{2q}$ ).

## 6.3. Prospecting Indicators

In the fracture limestone of the Qixia Formation ( $P_{2q}$ ) in the  $F_2$  fault fracture zone in the northwest direction, various degrees of mineralization (calcification, fading, dolomitization, pyritization, etc.) can be seen in the limestone, and the rocks have metasomatic remnant structure, granulated structure, breccia structure, disseminated structure and granophyric structure, the stratum lithology sign is that the lead-zinc ore was mainly output in the contact fracture zone of Qixia Formation ( $P_{2q}$ ) and Liangshan Formation ( $P_{2l}$ ) as well as the thick limestone of Qixia Formation ( $P_{2q}$ ); the geophysical sign is that the gravity contour of this area is gradually increasing from north to south in the northeast-east direction. The polarizability and resistivity of rock (ore) have the following characteristics: 1) In the strata, the stratum containing carbonaceous rock ( $C_{1j}$ ) has significant change in polarizability, which is 0.7%-12.6%, and the polarizability is relatively high, 4.12% on average; the resistivity is 190-874 $\Omega$ .m, 390 $\Omega$ .m on average, which is 3 times higher than that of lead-zinc ore, while other strata have low polarizability, which is 0.8%-1.7%; 2) The polarizability in various rocks is generally low, and the polarizability is 0.8% for limestone, 1.12% for dolomite, 1.4% for sandstone, 1.5% for quartz sandstone, and 1.65% for dolomitic limestone; the resistivity is high, the variation range is 4096-57994 $\Omega$ .m, 20941 $\Omega$ .m on average; 3) In the ore, the pyrite-type lead-zinc ore has extremely high polarizability, between 8.4%-28.2%, 15.99% on average; the pyrite has a very low resistivity, which is 1-7 $\Omega$ .m; the resistivity of lead-zinc ore is 40-300 $\Omega$ .m, 120 $\Omega$ .m on average; 4) The surrounding rock of ore has extremely low polarizability, which is 0.5%-5%, 1.6% on average; 5) The pyrite-type lead-zinc deposits in this area have low resistivity and high polarity; peaty sand shale has low resistance and medium polarity; other rocks have high resistivity and low polarization. The geochemical indicator is that the anomalous combination of stream sediments Pb-Zn-Ag-Sb-As-Ba-Cu, which almost covers the mining area. The anomalous morphology is consistent with the distribution of regional fault structure ( $F_1$ ) and the distribution characteristics of the Pb and Zn mineralized zones. The anomaly intensity is high, and the concentration trend is obvious. The anomaly value range is:  $w(Pb)$  is:  $300 \times 10^{-6}$  -  $5000 \times 10^{-6}$  for  $w(Pb)$ ,

$400 \times 10^{-6}$ -  $3600 \times 10^{-6}$  for w(Zn),  $10 \times 10^{-6}$ -  $60 \times 10^{-6}$  for w(Sb), and  $100 \times 10^{-6}$ -  $500 \times 10^{-6}$  for w(As). Cu, Pb and Zn: all of them are sulfophilic elements, and there are two types of anomalies: one is related to the comprehensive factors of fracture and lithology. There are only two locations with such anomalies. Their strata both belong to Loushanguan Formation of Cambrian system, and most anomalies are related to the faults. The two anomalies also correspond to the lead-zinc mineralization points respectively, which indicates the prospecting significance of such anomalies.

In summary, in addition to rock structure, tectonics and mineralization signs, the main prospecting indicators for lead-zinc deposit in the area include rock lithology, geophysical and geochemical signs.

## 7. Conclusion

Based on comprehensive research on the Baini lead-zinc deposit, the following conclusions can be obtained: 1) The lead-zinc ore body was output in the gray, dark grey and gray-black medium-to-heavy limestone of Qixia Formation of Permian System ( $P_2q$ ), the shape, occurrence and size of ore body were controlled by the F2 ore-bearing fault, which is structural ore-control; 2) The ore presents the color brown yellow, brownish, gray, gray-black, etc., and the main minerals are cerussite and smithsonite; 3) The deposit is "hydrothermal polymetallic deposit" oxidized deposit, which has undergone a tectonic hydrothermal metallogenic period and an epigenetic enrichment stage; 4) In addition to rock structure, tectonics and mineralization signs, the prospecting indicators also include strata lithologic signs, geophysical and geochemical signs.

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