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**Geological characteristics and analysis of the zinc-fluorite ore deposit prospecting in
Naoyangping-Damogou mine at Pingli County, southeastern Shaanxi, China**

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Abstract

The Naoyangping-Damogou zinc-fluorite mining area is located in the Caledonian fold belt of the east wing of Pingli Anticlinorium in the North Dabashan Mountains. The region is located within the Qinling fold belt, which was formed during intense activity in the late Paleozoic. The belt has a north-north-west orientation and consists of a system of anticlines, synclines, thrust faults, shear strike slip faults and ductile shear zone. Two dominant fault structures and other small faults sets appear closely associated with zinc-fluorite mineralization within the region, with several deposits commonly occurring along these faults. Based on analysis of geological background and geological characteristics of the zinc-fluorite mineralization in the region, the ore-controlling factors and the genesis of the zinc-fluorite ore deposit have indicated that the geological conditions for prospecting a large-scale deposit are existing in the Naoyangping-Damogou mining area. It also establish the metallogenic favorable locations prediction of the zinc-fluorite deposit in this area.

Keywords: Naoyangping-Damogou, zinc-fluorite ore deposit, geological characteristics, prospecting prospect, North Dabashan belt.

Introduction

The Naoyangping-Damogou zinc-fluorite ore deposit, is one of the small-scale zinc-fluorite ore deposit, and it's a significant source base of fluorite and zinc in Shaanxi Province, and contains about 2 million tons of fluorite ore. The Naoyangping-Damogou zinc-fluorite deposit is located in the east wing Pingli Anticlinorium of North Dabashan Caledonian fold belt. Geotectonically, the Naoyangping-Damogou Zn-CaF₂ ore deposit is located in the South Qinling orogen belt and North Dabashan belt contact zone. However, the metallogenesis of zinc-fluorite ore deposit is closely related to the northern Dabashan Mountain side. Ore bodies are hosted to the North Dabashan Caledonian fold belt in the East wing of Pingli Anticlinorium (Zhang Guowei et al., 1997; TU Huaikui, 1997; 1999 Wei D., et al. 2009). The deposit is characterized by the large broad veins large ore body in scale and simple form. This study report results of investigations of its geological characteristics, ore-forming and ore-controlling structures of zinc (Sphalerite) and fluorite, orebody characteristics and existing states of zinc and fluorite at Pingli County of Shaanxi Province. Although zinc-fluorite is found in alkali trachyte and limestone rocks contact fault zone,

both minerals are generally hydrothermal magmatic in origin and are closely related to fault structure. The deposits described herein represent the only known occurrence of fluorite in alkali trachyte rock. It also discusses the metallogenic regularity and analysis of prospecting prospect of the zinc-fluorite in the study area. The ore deposit approximately belonging to the Lower Permian ---Upper Triassic. The formation model of the ore deposit has great guiding significance in prospecting the large-scale zinc-fluorite deposit in the North Dabashan belt of the South Qinling belt.

Regional Metallogenic Backgrounds

Characteristics of the Regional Structures

The Naoyangping mine is located in the North Dabashan Caledonian fold belt area of the South Qinling belt. The south and west of the study area is neighboring with the arcuate fault zones and Yangtze block of north Dabashan Mountain and the north of the research area is neighboring with the Indosinian fold belts of the South Qinling belt (Zhang Guowei et al, 1997; Tu Huaikui 1997-1999) (Fig.1). Since the middle and the late Proterozoic Era, the north Dabashan Mountain area has undergone

complex and superimposed geologic processes, including tectonics, volcanic activity, and magmatic activity. Therefore, the geological structure is complicated and the magmatism is active in the area. Unique regional tectonic framework has been formed in different tectonic evolution stages of tectonic system development process. PingLi Anticlinorium, Pingli-ZhongFengguan fault, Song Shan-he fault, Jinshi-ShuiPingba fault have formed the major tectonic framework in the region (Geological Survey of Shaanxi Province, 1989).

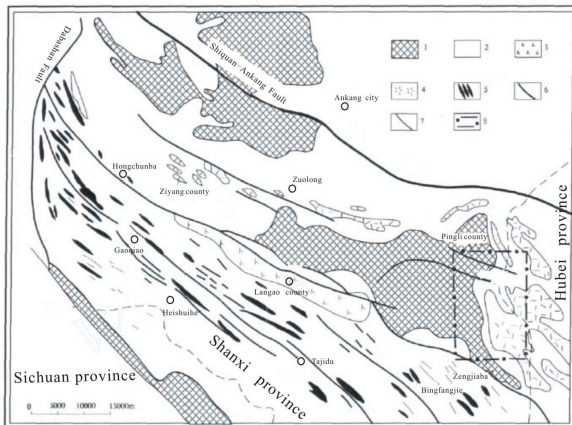


Fig.1 Regional geological tectonic sketch map of North Dabashan Mountain and study area location (Modified after Wei Dong et al., 2009)

- 1: Precambrian; 2: Early Paleozoic; 3: Basic overflow rocks; 4: intermediate-basic rocks; 5: Basic-ultrabasic rocks vein; 6: Main fault; 7: Secondary fault; 8: The range (scope) study area

The regional stratigraphy of the area belongs to Ziyang-Pingli District of South Qinling belt (Geological Survey of Shaanxi Province, 1989). The emergence stratum is mainly a set metamorphic pyroclastic rock and clay clastic rock of Proterozoic Yunxi Group, Yaoling-he Group and Dong-he Group and of Paleozoic Ordovician and Silurian sediments. The magmatic rocks are mainly distributed on the two sides of the HongChunba-Zengjiaba fault and the vast south area. Most of the magmatic rocks are ultrabasic rocks, basic rocks and acid rocks of early Paleozoic era, and the second most rocks are intermediate magmatic rocks. The trachyte is mainly distributed on the North Dabashan Mountain, to be specific, along the two sides of the Luohe- Songshan-he fault, to the east of Caledonian fold belt and PingLi Anticlinorium (Fig.2).

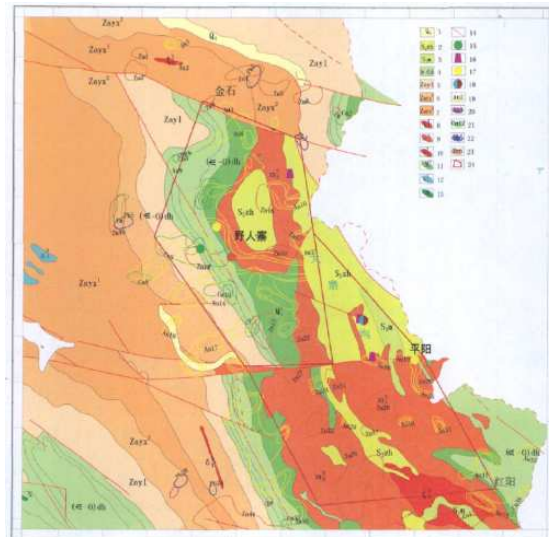


Fig.2 Regional geological sketch map of the Damogou zinc-fluorite deposits at Pingli County (After Wei Dong et al., 2009)

- 1. Quaternary gravel layer, sand and sandy loam; 2. Middle Silurian Zhuxi Formation rock group; 3. Lower Silurian Meiziya rock Group; 4. Cambrian-Ordovician Dong-he Formation rock Group; 5. Lower Sinian Yao-ling-he Group; 6. Upper Lower Sinian Yunxi Group; 7. Lower Sinian Yunxi Group; 8. Syenite porphyry; 9. Alkali trachyte porphyry; 10. Diorite (porphyrite) rock; 11. Gabbro porphyrite, volcanic breccia; 12. Lamprophyre; 13. Basic dyke (diabase); 14. Fault; 15. Ta and Nb ore occurrence; 16. Fluorite deposit (occurrence); 17. Gold occurrence; 18. Pb and Zn deposit (occurrence); 19. Au anomaly; 20. Ag anomaly; 21. Cu anomaly; 22. Zn anomaly; 23. Pb anomaly; 24. Prospecting area.

Regional Geochemical Characteristics

The mining area belongs to Pingli County Jinshi village - Zhenping County Niutoudian Au, Ag, Cu, Pb, Zn, As, Zr, La geochemical region of Pingli County Jinshi village - Zhenping County Hongshi village Au, Ag, Cu, Pb, Zn, As, Zr, La geochemical subregion. Au, As elements showed a high background zonal distribution; Cu, Pb, and Zn elements exposed high background, local lower anomalies distribution; Ag element in the Dong-he Group distribution area showed the high background uniform distribution. Anomaly with a NW-SE striking faults and magmatic rocks between closely, the compositions NW-SE faults, magmatic rocks-geochemical anomalies belt; La, Zr such rare earth elements in the alkali trachyte system significantly enriched.

According to 1:200.000 geochemical prospecting and 1:50000 water system sediments

measurement data; in the area, the geochemical exploration anomaly is dense, with an anomaly is high, the element combination (assemblage) have completed by good enrichment center. With Au, Zn is mainly dominated of the polymetallic combination anomaly belt along sub volcanic rocks body distribution. After anomaly inspection, we found that gold and zinc ore have occurrences.

Fluorine elements in the Cambrian system strata and the alkali trachyte rock system are relatively enriched. Its concentration Clarke value is $1.11-1.15 \times 10^{-6}$. While in other strata or rock body system, the average contents showed lower or close to the background value (622.81×10^{-9}). Fluorine elements showed high abundance characteristics, alkali rocks have a better fluoride of metallogenic specialization. Based on geochemical characteristics, showed that in this area have a better fluoride of metallogenic specialization. Based on geochemical characteristics, showed that in this area have better good of lead, zinc and fluorite ore prospecting prospects.

Geological Characteristics of Zinc-Fluorite Ore Deposit

Geological Characteristics of Zinc-Fluorite Ore Bodies

The Naoyangping-Damogou zinc-fluorite mining area is located in the Caledonian fold belt of North Dabashan at the east wing Pingli Anticlinorium (Fig.1). Regionally, the Naoyangping-Damogou mining area is located in the north side of ZengJiabaHongchunba large fault of the same group fault of Luohe-Songshanhe fault in the north side. Geographically, it is situated in Damogounao-Songshan-he area (Geological survey of Shaanxi Province 1989, 2008; Wei Dong et al., 2009). The ore bodies occurs in the NNW-SSE trending in the Middle Silurian Zhuxi Group slate and alkali trachyte surface rock fault contact zone, with there are closely related to the alkali trachyte side. Orebody occurs in stratiform bedding. The orebody thickness is more stable and dipping angle large such as characteristics. As viewed from the metallogenesis series (Geological Survey of Shaanxi Province, 2008) and the results of our investigation, more than 8 orebodies have been delineated on the orefield, including K1, K2, K3, K4, K5, KH7 and K8, which sphalerite ore bodies are K1, K2, K4, K5 and KH7. Those of fluorite ore of K3 and K8 (Fig.3). There ore bodies in the region are distributed in the Middle Silurian Zhuxi Formation slate and Alkali trachyte fault rock contact zone, closely related to trachyte side, and related structure to the vein belt and are

generally developed in the stratiform and banding pattern along the fault structures. This distribution of the orebodies on the orefield was according to the already delineation of fluorite ore weight new sampling analysis of Zn and Pb. The Zn grade of 0.04-0.12% and Pb grade of 0.00% with the content is lower, can only ring out fluorite orebody. This study focus on K1 and K3 ore bodies were the zinc and fluorite ore deposit are a close genetic relationship among them and have the potential of becoming large-sized deposits, with good prospecting potential.

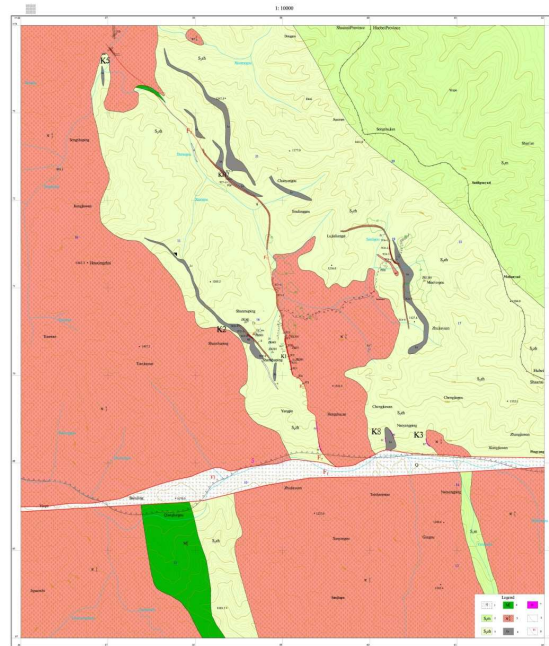


Fig.3 Geological sketch map of distribution schemes of the Naoyangping-Damogou zinc-fluorite ore deposit

- 1: Quaternary system (Q_4), 2: Meiziya Group (S_{1m}), 3: Middle Silurian Zhuxi Group (S_{2zh}), 4: Basic sub-volcanic rock (M_3 = Diabase and Gabbro), 5: Intermediate sub-volcanic rock ($\chi\tau_3$), 6: Limestone (Ls), 7: Fluorite orebody (Fl), 8: Geological boundary, 9: F1: F1 fault

1. The K1 orebody (The Damogou zinc ore)

K1 orebody (Zn ore) is located in the northern part of the mining area around Damogou area. The present orebody occurs in the Middle Silurian Zhuxi Formation slate rock and alkali trachyte rock fault contact zone, with zinc orebody is closely related to alkali trachyte rock side. The present controlled orebody is more than 0.82-11.97m in thickness. The orebody average thickness is more than 3.42 m with a change coefficient of 85.67%, a type coefficient of 0.4 and thicknesses is stable. The Zn grade is 2.36- 19.20% with an average of

10.57% and the Zn variation coefficient in grade is 66.23%. The variation grade is uniform; engineering orebody associated with a CaF_2 grade ranges of 0.00-31.00%. The average CaF_2 grade is 11.95%. Orebody average attitude of $71^\circ \angle 64^\circ$. The orebody outcrop levels of 1142-1212 m.

2. The K3 orebody (The Naoyangping fluorite orebody)

The Naoyangping fluorite deposit (K3 orebody) is developed in the southern part of Songshan River in the north side of F1 fault (Guangfosi-Naoyangping) zone. Orebody is mainly hosted in the alkali trachyte system, along secondary F1 fault controlled side. The fault is 400m in length, and 12 m in width. The ore bodies are controlled mainly by secondary F1 fault structure and they occur in F1 fault structure and the ductile-shear zone. Orebodies are distributed around the Naoyangping in the southeastern part of the mining area. The orebody strike is generally from NW-SE, in the south part of F1 fault. The orebody is developed mainly on the line 36 and its two both sides, where the outcrops elevation of about 989-1049 m and on line 40 north sides, it is also fragmentary in outcrop. The thick of the orebody is generally dipping angle about $61^\circ\text{-}72^\circ \angle 20^\circ\text{-}48^\circ$, with a southeastern side, plunging dipping angle of $20^\circ\text{-}34^\circ$, from the northwestern side. The dipping angle maximum of about 48° , with the whole orebody striking and dipping NW-trending and which strike on the northern plunging of trend. The orebodies average occurrence of $71^\circ \angle 42^\circ$. The orebodies exhibit bedded on the strata locally showed the branch complex phenomena. The fluorite is mainly fluorite vein, quartz-fluorite vein and calcite-fluorite vein, formed by hydrothermal solution, and is dark purple, white, pink, lilac or light green in colors. The typical fluorite ore texture are automorphic-granular, hypidiomorphic granular, xenomorphic granular, metasomatic, poikilitic, cataclastic. The fluorite ore structures are vein, banded, massive, disseminated, and brecciated. The present controlled orebody is 2.22-23.35 m in thickness, with an average of 10.87m. The thickness coefficient of about 65.32% and the thickness change system, etc. The average CaF_2 grade is 30.22- 50.94% with an average of 41.98%. The CaF_2 coefficient of variation of grade is 20.25%, with the changes uniform. Lead and zinc content is very low, within Pb grade of 0.00-0.01% and Zn grade of about 0.00-0.02%.

Ore Mineral Characteristics

The K1 orebody is mainly primary sulphide ore, with can be seen a small amount of oxidized ore, which is scattered on the surface, and associated with fluorite ore. The other orebody mainly is dominated by fluorite ore. The Metal minerals mainly are dominated by Sphalerite, and followed by chalcopyrite, pyrite, ilmenite and other minerals group system. The ore minerals are Sphalerite, chalcopyrite, pyrite and ilmenite. The chalcopyrite is accreted with Sphalerite and it can be found on the edge of and even in the micro cracks of the sphalerite ore. It indicates the crystallization of the chalcopyrite is occurred in the late period of the sphalerite mineralization. The crystal of chalcopyrite ore and magnetite ore is automorphic crystal, which is wrapped up in the gangue mineral and sphalerite and is formed in the early stage. The gangue mineral are mainly dominated by quartz, calcite, and fluorite, and followed by chlorite, sericite and feldspar. The quartz vein, feldspar-quartz vein and quartz carbonate vein are formed by hydrothermal solution. The color of silicified quartz vein is smoky grey or grey, and the vein is distributed as sucrosic complex. In the oxidation zone were developed smithsonite, calamine, zincite, almagrerite (zinc sulfate heptahydrate), and other minerals. The zinc ore are dominated mainly by allotriomorphic-automorphic granular, crumb textures and followed by metasomatic (replacement) texture. The typical ore structures are mainly disseminated, massive, brecciated, and banded structures, and followed by vein structure. The gangue minerals of zinc ore are dominated mainly by quartz, calcite and fluorite, and followed by chlorite, sericite, feldspar.

The fluorite is mainly of fluorite vein, quartz fluorite vein and calcite fluorite vein, formed by hydrothermal solution. The ore is dark purple, white, pink and its colors are mulberry, white, pink, and light green in color, with crystal larger coarse. The gangue minerals are dominated mainly by quartz, and followed by clayey mineral, chlorite, sericite, feldspar, calcite, etc. The typical fluorite ore texture are automorphic-granular, hypidiomorphic granular, xenomorphic granular, metasomatic, poikilitic, cataclastic, etc. Fluorite ore showed aggregate and irregular clusters massive hosted in the wall-rock or the alteration vein system. The fluorite ore structures are vein, banded, massive, disseminated, and brecciated.

According to the macroscopic observation, ore mineral species are simple. It is composed by non-metallic minerals and metallic minerals. The

non-metallic minerals are mainly dominated by fluorite (40%), ferrodolomite (19%), plagioclase (15%) and quartz (10%), followed by muscovite, sericite (4%), K-feldspar (5%), calcite (2%), phlogopite, chlorite, zircon (small amount), zircon and apatite (trace element). Whereas, the metallic minerals are mainly dominated by pyrite (5%), and followed by magnetite and limonite.

The wall-Rock Alteration Characteristics

The wall-rock alteration within the region generally with metasomatism is mainly dominated, but the metasomatism uneven strength (intensity). The wall-rock in the zone is mainly banded (or linear). The alteration system post-magmatic hydrothermal fluid along rock strata fissure rise (increased) migration process surface rock strata suffer intrusive metamorphism formed. The wall-rock alteration are silicification, carbonatization, fluoritization, chloritization, sericitization, pyritization, marbleization, and other planar alterations.

The wall-rock in the zone is mainly banded (or linear). The major wall-rock alteration in the ore field includes silicification, carbonatization, fluoritization and pyritization, and the minor alteration consists of sericitization and chloritization. The wall rock alteration zone is extended in the shape of ribbon pattern or filiform pattern. And the width of the zone is about 3~8m and it is as wide as 12 m. The silicification is strong in the zinc-fluorite mineralization zone, with metasomatic filling of hydrothermal quartz of different times, lightening the color of the wall rock light and strengthening the hardness of the wall rock, showing the feature of color-fading.

Under the microscope, 25%~30% of the quartz particles in the rock is enlarged, showing the output with the massive, striped, streak and wormlike shape, with a clear feature of the formation of late period. Fluoritization is often associated with silicification and carbonatization, and it is emerged with the form of fluorite vein, fluorite-quartz vein fluorite-calcite. The fluorite is output with the form of irregular crumb, vein and composite vein.

Geological Time of Metallogenesis

Representative samples of the Naoyangping-Damogou zinc and fluorites were collected and dated by the Geological survey of Shaanxi Province, (2009). The isotopic age results of the fluorite ore and zinc ore in the Naoyangping-Damogou mining area by Sm-Ndisochron (dating

fluorite) and SHRIMP U-Pb (dating zinc) are respectively $^{147}\text{Sm}/^{144}\text{Nd}$ (276 ± 47 Ma) (MSWD = 1.04) with fluorite ore and $^{206}\text{Pb}/^{238}\text{U}$ (217 ± 2.6 Ma) ($n=6$, MSWD = 1.3) with zinc ore. These age results showing that the fluorite age is, approximately belonging to the Lower Permian. Whereas, the zinc ore age approximately belonging to the Upper Triassic.

Metallogenic Regularity and Analysis of Prospecting Prospect

Metallogenic Regularity

The strata and lithology conditions

In the mining area, zinc and fluorite ore bodies generally occur in accordance with the ore-bearing conditions. Subsequently, the ore rock combination type can be divided into two types: firstly, the Middle Silurian Zhuxi Group argillaceous slate (argillite) and alkali trachyte contact zone area, and is closely related to the alkali trachyte side (K1 and K3 ore bodies). Secondly the Middle Silurian Zhuxi Group Formation argillaceous slates and crystalline limestone contact zone (K2, K4, K5 and KH7 ore bodies).

Structures conditions

The orebody mainly occur along a NNW-SSE-trending fault crushed zone (e.g. F7) system. The ore bodies are lenticular, layer-shape distribution with the fault attitude changing's in accordance to the site. High measurements were recorded for orebodies thickness and grade. This is evidence of the effect of the fault on controlling the orebody formation process.

Hydrothermal activity

In the study area, the Zn and CaF_2 mineralization are closely related to hydrothermal activities. The metallogenic materials comes from to the Middle Silurian Zhuxi Group strata and alkali trachyte rocks, and also exhibit deep source material. The NW-trending fault activities of mineral activation provide heat energy, and is rich in ores deposit hydrothermal fluid migration provides a path. During the ore-forming fluid migration process system, footwall sandy slate of ore fluid enrichment provides a good barrier bed, along with the physicochemical conditions of changes mineral along the fault, fissure filling metasomatism surrounding rock in favorable places precipitation of metallogenic. Wall-rock alteration is finds zinc ore of obvious criteria.

Analysis of Metallogenic Regularity of Zinc-Fluorite Ore Depositing the Orefield Area

Analysis of field and other research data, led to the conclusion that it is advisable to evaluate the metallogenic regularity and mineralization perspectives of zinc and fluorite ores separately.

The Zn orebody generally exists in the fractured zone as lenses, the extended length is short, and the lenses width changes dramatically. There is visible sphalerite stringer, which fills the calcite veins or the fluorite veins, and breccia resulted from the cementation of the hydrothermal solution of sphalerite is found on the surface. All the features indicate that the deposit type of zinc ores in this area is hydrothermal deposits dominated by fractured zone. This type of zinc ore is different from the Sedex type lead-zinc deposit and the MVT type lead-zinc deposit, and its scale is dominated by the large size of fractured zone. The size of the fractured zone in the ore is not so ideal, and the zinc ore metallogenic prospect is not optimistic.

The fluorite orebody exists in fractured zone in the form of stratoid, while, its extension is stable, with high-grade CaF_2 in the ore. These features are in accordance with the most fluorite metallogenic characteristics in the country, with the ore having two conditions: (1) the fractured one resulted from the volcanism and the thrust nappe, (2) the fluorite ore metallogenic prospect is promising.

Metallogenic Favorable Locations Prediction

Based on analysis of the mineralization control conditions of zinc ore, fluorite ore and the clue for prospecting, three (3) favorable metallogenic alteration zones can be identified for future prospecting orientations. (1) A zone extending along the fractured zone F7, from the ore K1 to Jinsha-he. (2) A zone situated in the west of the fractured zone F7, from Zhujiayuan to ore K4 to Lujialiangzi. (3) A zone situated in the east of the fractured zone F7, and extending from Shamuping to Xiaogou to Damogou. All three alteration zones extend from northwest to southeast and intersect at fractured zone F7. The exploration work can be conducted in the three alteration zones close to the fractured zone F7.

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