



**INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH
TECHNOLOGY**

**Ore-Forming and Ore-Controlling Structures of the Naoyangping-Damogou Zn
(CaF₂) ore deposit, Shaanxi Province, China**

Moussounda Kounga Claude^{*1}, ZHENG Youye², YANG³ and Zhang Wen Gao²

^{*1}School of Earth Resources, China University of Geosciences, Wuhan 430074, PR China

²School of Earth Resources, China University of Geosciences, Wuhan 430074, PR China

State Key laboratory of Geological Processes and Mineral Resources, China University of Geosciences,
Wuhan 430074

³Key Laboratory of Western China's Mineral Resources and Geological Engineering, Ministry of
Education Chang'an University, 126 Yanta Road, Xi'an, 710054, PR China

²Structural Geology, Chang'an University, 126 Yanta Road, Xi'an, 710054, PR China

koungamouk@yahoo.fr

Abstract

The Naoyangping-Damogou Zn (CaF₂) ore deposit at Pingli, Shaanxi Province, is a currently proven small-sized Zn (CaF₂) polymetallic ore deposit and it is located in the North Dabashan Caledonian fold belt, in the east wing Pingli Anticlinorium. Metallogenesis is controlled by F7 fault structure and other relevant fault structure systems and closely related to the trachyte side. This study, in conjunction with the most recent exploration data, analyzed the geological background of metallogenesis of this deposit, summarized the geological characteristics of typical ore deposits, determined the alteration zonation of the deposit, investigated regional metallogenesis and the genesis of typical ore deposits, discussed the regional ore-forming and ore-controlling structures.

Keywords: Metallogenesis; ore-forming and ore-controlling structures; ore genesis; Pingli County, Shaanxi Province.

Introduction

The Naoyangping-Damogou zinc-fluorite ore deposit, is one of the small-scale Zn-(CaF₂) ore deposit, and it's a significant source base of CaF₂ and Zn in Shaanxi Province, and contains about 2 million tons of ore CaF₂. The Naoyangping-Damogou zinc-fluorite deposit is located in the North Dabashan Caledonian fold belt, in the east wing Pingli Anticlinorium. 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. Previous studies have focused on ore geology and prospecting prospect (Wei Dong et al., 2009). In recent years, detailed investigations in combination with deep-seated ore prospecting have been conducted, revealing that the ore-forming parent rock of this

deposit is a subvolcanic rocks (alkali trachyte and limestone), and Zn and CaF₂ mineralizations are mainly controlled by fault structure. It has been proven that the zinc and fluorite are closely resources associated with hydrothermal activity and belonging to the hydrothermal magmatic ore deposit. In this paper we focus on ore-forming and ore-controlling structures from different parts in the Naoyangping-Damogou zinc-fluorite ore deposit so as investigated regional metallogenesis and the genesis of typical ore deposits, discussed the regional ore-forming and ore-controlling structures.

**Regional Geological Structural
Characteristics**

The Naoyangping-Damogou area 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; Xu Huaikui 1997-1999) (Fig.1).

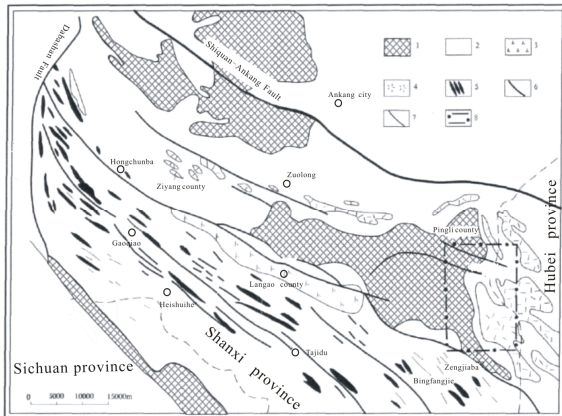


Fig.1 Regional geological tectonic sketch map of North Dabashan Mountain and study area location (Modified after Wei Dong et al., 2009)

- 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.

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-Zhong Fengguan fault, Song Shanhe fault, Jinshi-Shui Pingba fault have formed the major tectonic framework in the region (Geological Survey of Shaanxi Province, 1989).

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).

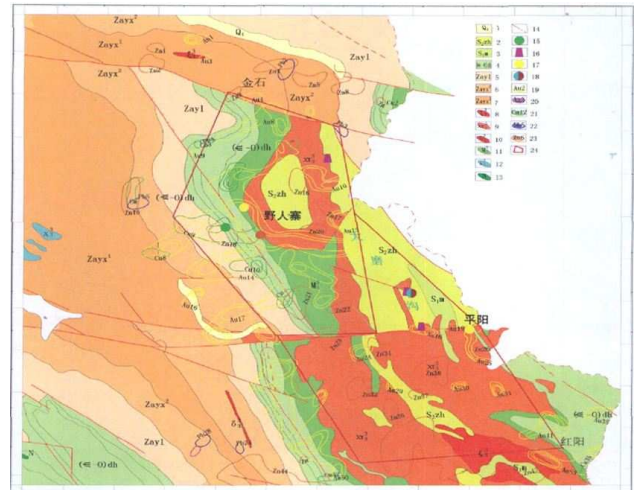


Fig.2 Regional geological sketch map of the Naoyangping-Damogou orefield (After Wei Dong et al., 2009)

- 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 Yaoling-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.

Geological Characters of the Ore Deposit

The Zn (CaF₂) deposit is of the vein type. If it is, together with the adjacent related ore deposits, taken into consideration, they would constitute a three-in-one Zn-CaF₂ ore deposit orefield consisting of the massive sulfide-type Zn-(CaF₂) hydrothermal-type CaF₂-hydrothermal-type Zn- Pb deposits. There is a close genetic relationship among them. Therefore, those deposits can be regarded as a typical metallogenic series.

As viewed from the metallogenic series, developed in the area are the massive sulfide-type Zn ore deposit (e.g. Damogou K1), the hydrothermal vein-type Zn-Pb deposits (e.g. K2, K4, K5, KH7, etc.), the hydrothermal CaF₂ deposits (e.g. Naoyangping K3 and K8) (Fig.3). More than 7 ore bodies have been delineated, which are distributed in the Middle Silurian Zhuxi Formation slate and Alkali trachyte fault rock contact zone, closely related to trachyte side, and related structure — the vein belt and are generally developed in the stratiform and

banding pattern along the main tectonic line. There is a close genetic relationship among them.

The K1 orebody (Damogou zinc ore deposit)

The 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 CaF₂ grade ranges of 0.00-31.00%. The average CaF₂ grade is 11.95%. Orebody average attitude of 71° < 64°. The orebody outcrop levels of 1142-1212 m.

The K2 orebody

The K2 orebody is located around Shamuping fault area, with the massive, and disseminated sphalerite are mainly developed, exposed lenticular, bean shaped output, with the thickness and deepening are over change more large. From the surface trench of TC2-0, TC2-1, TC2-3 and TC2-8 controlling, the surface elevation of ore is 1190 m. The middle deep from PD2 addit 3 middle section (1066 middle section, 1046 middle section, and 1015 middle section) and drilling (ZK301, ZK001, ZK401, and ZK801) engineering control verified, which in the PD2 addit middle see the blind orebody K2-2, K2-3, K2-1; three bands orebody developed edge away side present forms of distribution, with the distance between orebody is 8-18 m. The orebody average Zn grade is 10, 25 %, with average thickness of 3.18 m.

The K3 orebody (Naoyangping fluorite ore deposit)

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 400 m 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°-72° < 20°- 48°, with a southeastern side, plunging dipping angle of 20° - 34°, 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° < 42°. The orebodies exhibit bedded on the strata locally showed the branch complex phenomena. 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 CaF₂ grade is 30.22- 50.94%, with an average of 41.98%. The CaF₂ coefficient of variation of grade is 20.25%, with the changes uniform. Lead and zinc content is very low, within Pb grade is 0.00-0.01% and Zn grade is 0.00-0.02%.

The K4 orebody

The K4 orebody is distributed around Miaoergou, with disseminated sphalerite and star (satellite) punctuate galena mainly are developed. The visible few amount of chalcopyrite and malachite showed similar bedded, with the orebody in the trend is more stable. The surface of trench are TC4-1, TC4-2, TC4-3 and TC4-4 holes controlling, with surface see of ore elevation about 1157-1160 m, the orebody trenching engineering controlling about 240 m in length, with the engineering controlling thickness of 0.37-3.00 m. The Pb grade is 0.63-9.10%, with an average of 1.25%. The Zn grade is 3.26-13.93%, with an average of 5.04%, and with the average thickness is 1.40 m. The central part has PD5 addit of two middle sections controlling (1120 and 1050). The average orebody occurrence of 68° < 44°. In the orebody south delay, the number 12 prospecting line engineering ZK1201 hole is more than 400 m. Not lead, zinc and fluorite mineralization occurs in this part.

The K5 orebody

The K5 orebody is located in Jinsha River-Zhaojiacao area. The orebody occur in the alkali trachyte rock, breccias trachyte quartz vein system, with the vein and disseminated sphalerite mainly in the form, the surface of orebody trend small extension, and in the quartz vein system common outcrop two layer sphalerite. The surface of BT1 controlling see ore elevation of 948 m, the Pb grade is 0.01% and Zn grade is 1.57-3.13%. The exposed length about 150 m, 0.7-3.0 m in controlling thickness. The attitude of orebody is 40-60° < 75-90°, the middle-shallow part by ZK5001 drilling controlled, the drilling see ore elevation of 915 m, 0.90 m in controlling thickness, the Zn grade is 7.51%, and axis angle is about 43°. K5 orebody

along trend direction southward more than 80m, ZK5201 hole is being stress construction system of 112-115 m see sphalerite localization, the mineralization is good, and the visual estimation Zn grade is about 2-3%.

The KH7orebody

The KH7 is distributed around Damogou East slope. The mineralization is mainly exposed to disseminated sphalerite, star punctuate galena in the form, occurred in a silicification quartz vein system, thickness change unstable, and locally tools expansion phenomenon. The surface of trench TC7-1 and TC7-2 is controlled and the ore discovery is more than 1081 m in elevation. The analysis results shows that the Pb grade is 0.00% and the Zn grade is 1.24% , 2.85 m in thickness and 100 m in length of the orebody controlled.

The K8 orebody

The K8 orebody is distributed around Naoyangping. The mineralization is occurred in the Zhuxi Group limestone lenses edge (margin) within the fault zone. The orebody is lens body produced in the limestone or limestone edge of the crushing zone system. Only fluorite ore occur in K8 with the grade of orbod and orebody attitude are not available.

Research on the Ore-Forming and Ore-Controlling Structures

The Naoyangping-Damogou Zn-(CaF₂) deposit is occurs in small scale and has varying mineral species. Its ore-forming and ore-controlling structures are also relatively complicated. The ore-forming and ore-controlling structures of the Naoyangping -Damogou mining area are located in the North Dabashan Caledonian tectonic belt (Fig.1). There is also great potential of ore prospecting both at deep levels and on the peripheries. Therefore, the dissection of typical orefield structures is of great significance in informing both theory and practical in directing in ore prospecting.

Analysis of the ore-forming and ore-controlling structures

As viewed from regional structures, The Naoyangping-Damogou orefield is located in south Qinling belt and north Dabashan contact zone, where the mineralization is closely related to the north Dabashan side. The concrete regional strata are controlled mainly by the Naoyangping-Damogou-Jinsha River fault normal- thrust-reverse basin where there exist residual Middle Silurian Zhuxi Group phyllite (limestone and argillaceous slate) and alkali trachyte rocks.

The Naoyangping-Damogou Zn-(CaF₂) orefield is controlled by the Naoyangping-Damogou-Jinsha River fault. The structures within the region are

dominated by fault structures and alkali trachyte rocks.

The fault structures are dominated by nearly EW-, NW-SE, NWW-SEE and NE-SW-striking fault structures group, with the NWW-SEE fault structures being dominant. Most of the fault structures are characterized by multi-episodes activities.

The main ore-controlling structure of the orefield is the F7 fault. This fault is located around Damogou in the central part of the mining area. F7 is the main ore-controlling structure zinc ore body of the mining area. The fault in the southern part is developed between alkali trachyte rock and Middle Silurian Zhuxi Group contact zone, while the northern part is mainly developed in the Silurian Zhuxi Formation argillite (argillaceous slate) and alkali trachyte rock system. The fault is 5000 m in length, striking NW-SE and plunging NWW-SEE, with the dipping angle of about 60° - 80° \angle 55° - 70° . Fault crushed zones are well developed, consisting of fault gravels, fault gouge and others tectonites. The F7 fault strike NNW-SSE direction. In the area, the fault outcrop is more than nearly 5000 m in length from southward cross (intersection) to F1 fault and is extended NNW toward delay to Jinsha-he area. Due to Jinsha-he, Damogou two both sides local part of Quaternary system broken (dilapidation) deposit cover, the fault position only depend on presumed roughly determined. The fault zones are different in width, varying from 2 to 8 m with an average of 12 m.

The Zn-Pb mineralization and CaF₂ mineralization are closely related to the hydrothermal activities. The metallogenic materials are derived from the Middle Silurian Zhuxi Group strata and alkali trachyte rocks. They may also be derived from 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 and in favorable places precipitation of metallogenic. They are developed in the Middle Silurian Zhuxi limestone, argillaceous slate and alkali trachyte rocks as cover strata, by which the Naoyangping, Damogou, and other ore deposits (ore runs) are controlled. Due to being cut by F1 and F2, the F7 fault is divided into two parts along strike. The alkali trachyte rock is located around Damogou on the central part, and in the

southeast part of the mining area, associated with the fault structures.

Magmatic activity

Magmatic activity in the Naoyangping-Damogou zinc-fluorite mining area is strong and is a part of multi-time activity of the Caledonian period into the strata. The main rock types in the orefield formed as a result of regional magmatic activities and can be divided into two main types: The first main type is basic-ultrabasic rock with low SiO₂ and the second consist of the neutral—intermediate-acidic—acidic rock with high SiO₂ (trachyte).

Metallogenesis is closely related to the trachyte rock side and developed in the Naoyangping-Damogou-Jinshahe fault, and other small fault systems, which is regarded as the main ore-forming parent rock of the Naoyangping-Damogou orefield. The magmatic rocks are developed in the orefield; in space, microstructure (glass). There are two main types of magmatic rocks found in this orefield: that is: pyroxenite which is mainly located in the western part of the orefield, above the Dong-he Group, while the trachyte is to the east of microstructure (glass) pyroxenite; but to the west of Zhuxi Group. This type of distribution indicates that both microstructure (glass) pyroxenite and trachyte are stratiform feature in space. Chronologically speaking, microstructure (glass) pyroxenite is much older, while the trachyte is comparatively younger and both of them originated in early Silurian.

The distribution of related stratigraphic units shows that the two sets of igneous rocks folded simultaneously. One the other hand, the distribution of some rock units shows the incursive feature such as the sub-trachyte in Damogou, which is proved to be subvolcanic rock based on its petrology features and field investigation. According to the present data, some rocks which are the feature of subvolcanic rock can be found in the microstructure (glass) pyroxenite. Whence, the two sets of igneous rocks are of volcanic-rock feature. Each set of the rock contains lava, subvolcanic rock and metamorphic pyroclastic rock which are closely related to metamorphosed pyroclastic element. Due to the causes of different lithology in each set of rock and the connection in space, it has formed the “horizon” features.

From the basic-ultrabasic rocks, the rock is dark green pyroxene porphyrite. The rock schistosity is mostly developed by phenocrysts of pyroxene, showed tabular and prismatic crystal. The rock metamorphism is strong with alteration zone more of sericite, ouralite (pale green amphibole resulting from the change of some pyroxenes) replaced the

matrix of pyroxene microcrystalline because of strong alteration, it is dominated by chlorite replacement. It is distributed mainly in Naoyangping western part of the working area. Moreover, in the Middle Silurian Zhuxi Group system, they developed lenticular and banding texture.

The intermediate sub-volcanic rocks ($\chi\tau^3_3$) are mainly developed banding distribution on the west side of the Shanshuping detailed survey area and Hongshacao-Lujialianzi area, with the thickness of about 600-1400 m. Concordant layer in Zhuxi Group among them or along the basic subvolcanic rocks (M^3_3) contact zone intrusive. The lithology is dominated by alkali trachyte, trachyte breccia and trachyte porphyry.

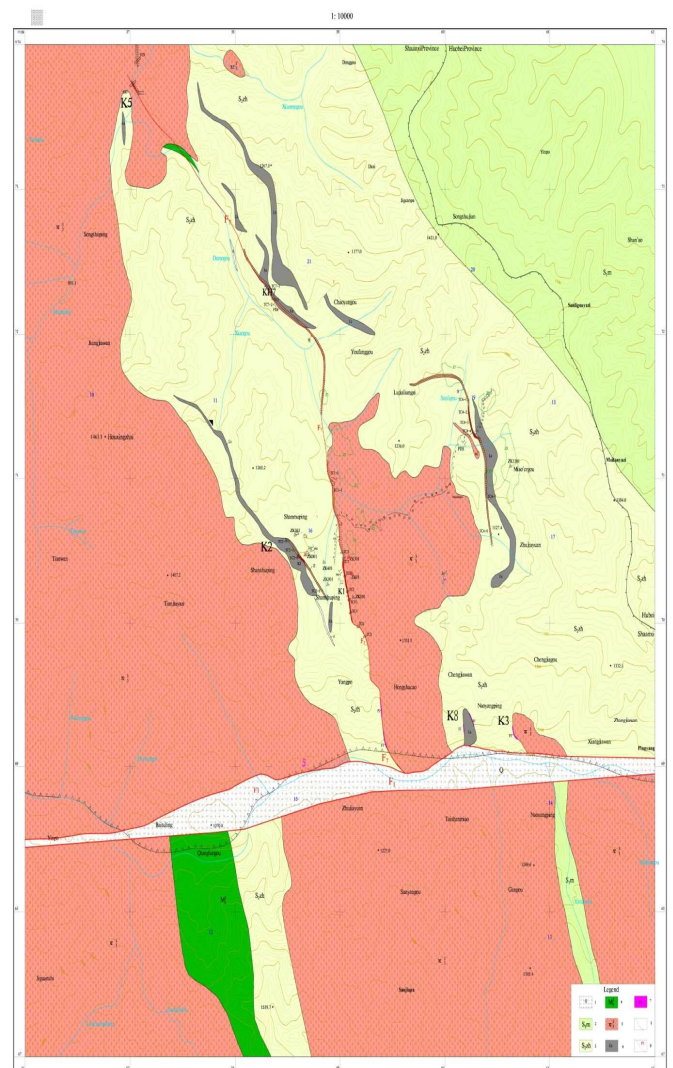


Fig.3 Geological sketch map of distribution schemes of the Naoyangping-Damogou zinc-fluorite ore deposit

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

The strata

The strata in the region are dominated by the Middle Silurian Zhuxi Group (S_{2zh}) and Middle-Lower Silurian Meiziya Formation (S_{1m}), with the Lower Silurian Meiziya Formation strata is clay slate, sandy slate, carbonate-containing banded clay slate, sandy limestone and tuff sandstone. The Middle Silurian Zhuxi Group and Lower Silurian Meiziya Formation rocks are mostly distributed in the form of fault blocks because they were cut by faults and eroded and reworked by magmatic rocks. Regionally, a large area of alkali trachyte rocks is exposed in the east wing of Pingli Anticlinorium which always serve as the main ore-hosting country rocks for minerals and having an important significance in prospecting. There is generally no metallogenic control, but rocks in the Naoyangping-Damogou orefield

Researches on the metamorphism and wall rock alteration

Most of rocks in the ore field have experienced regional metamorphism, but metamorphism is relatively weak as a whole. The low level medium-shallow metamorphic rocks mainly are argillaceous slate, schist, meta-volcanite, and metamorphic crystalline limestone, which are the production of regional dynamo thermal flow metamorphism. The metamorphic grade is low green schist facies and the metamorphic minerals are sericite and chlorite

Based on the outdoors survey, the metamorphism degree and the alliteration rule in the ore field can be concluded as follows:

First, in the south-north direction, the alliteration close to the fault (F1) is more developed, and superposition of different types of alliteration can be found in the area. While, to the north of the fault (F1), the alliteration is gradually becoming weaker and weaker. And in the north part of the ore field, only sericitization is found.

Secondly, the alliteration degree in the ore field is clearly influenced in by the northwest-southeast fault. Along the northwest fracture zone, the alteration of all kinds of rocks is growing stronger and stronger. Three

alteration zones may be marked out in the ore field.

The first zone extends along the fractured zone F7, from the ore K1 to Jinshahe. The second zone situates in the west of the fractured zone F7, from Zhujiayuan to ore K4 to Lujialiangzi. The third zone situates in the east of the fractured zone F7, and extends from Shanmuping to Xiaogou to Damogou. All the three alteration zones extend from northwest to southeast. And the distribution of the zones is almost parallel.

The wall-rock alteration characteristics

Influenced by the fault structure, 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 hydrothermal alteration zones are silicification, carbonatization, fluorite mineralization, 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.

Discussion on the Metallogenesis

Metallogenesis is very complicated and involves a variety of controlling factors, so it is a key subject of scientific research in the field of ore deposits, especially the ore-forming material sources are an issue of hot debate. Some scholars considered

that the ore-forming materials were extracted from ore-bearing wall rocks, and more scholars thought that the ore-forming materials were derived mainly from the deep interior, that mantle plume activities were the main driving force of crustal movement and also the driving force of plate tectonic movement (Maruyama, 1994; Gorczyk et al., 2007; Meriaux et al., 2011), and that the ore-forming materials are of core-mantle source through mantle plume multi-stage evolution (Niu Shuyin et al., 2002; Wang Denghong, 1998; Wang Baode et al., 2010; Sun Aiqun et al., 2006, 2011), and under a special geotectonic environment and in a relatively special tectonic dilatation zone the ore-forming materials were unloaded as ores, forming large-scale ore-concentration zones or large-superlarge ore deposits (Mao Jingwen et al., 2010).

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-Nd isochron (dating fluorite) and SHRIMP U-Pb (dating zinc) (fig.5.3) 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 mineralization age approximately belonging to the Upper Triassic.

Source of ore-forming materials

Current discussion on the source of ore-forming materials is mainly dependent on the isotope geochemical research. Studies have indicated that the ore-forming materials of the magmatic hydrothermal-type ore deposits in the Naoyangping-Damogou region are of deep origin.

Sulfur isotopes

Results of the isotopic determination of pyrite, sphalerite and other sulfides from different types of ore deposits Naoyangping-Damogou mining area indicated that the $\delta^{34}\text{S}$ values of the pyrite of the sulfides from the fluorite deposits in the mining area are within the range of 14.5‰ –17.5‰, those of sphalerite are 11.5‰ –17.5‰ close to -3.5‰. These $\delta^{34}\text{S}$ values are distributed in the tower form as shown in the frequency histogram (fig.4.1), showing the characteristics of pyrite from a single deep-source magma, and sphalerite from a complex deep-source magma. It is possible that some sedimentary sulfur would be involved in the sulfur from late-stage hydrothermal Zn ores.

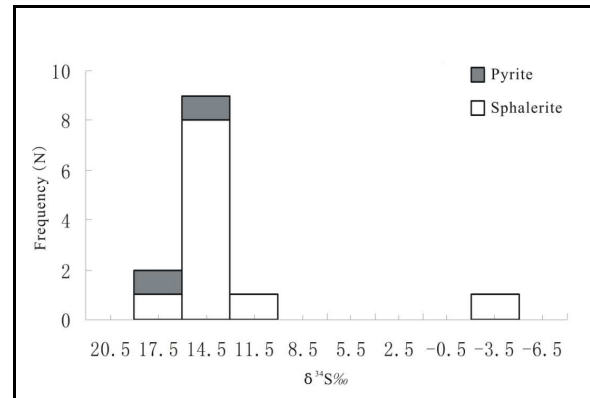


Fig.4. Histogram of the isotopic determination of Pyrite and Sphalerite from Naoyangping-Damogou mining area (After: Geological Survey of Shaanxi Province, 2009).

Hydrogen and oxygen isotopes

Oxygen and hydrogen isotopes analysis data were carried out by Geological survey of Shaanxi Province in the mining area is showed in the Fig.4.2. This figure illustrates the relative positions in Craig's diagram of H/O-isotopic of various fluid inclusions in fluorite from the Naoyangping-Damogou mining area. For comparison, there are also shown the analytical results for fluorite and quartz occurring in magmatic rocks from the same locality. From this figure we can see:

The fluids phase of inclusions in all fluorites occurring in magmatic rocks shows relatively large negative δD (fluid inclusions hosted by fluorites range between -115‰ and -95‰) and small positives $\delta^{18}\text{O}$ values (fluid inclusions hosted by fluorites range between 5‰ to 11‰). The relevant data points fall around the magmatic water line in Craig's diagram, suggesting that these fluorites, in spite of their occurrence in magmatic rocks, resulted from the magmatic water at the late stage.

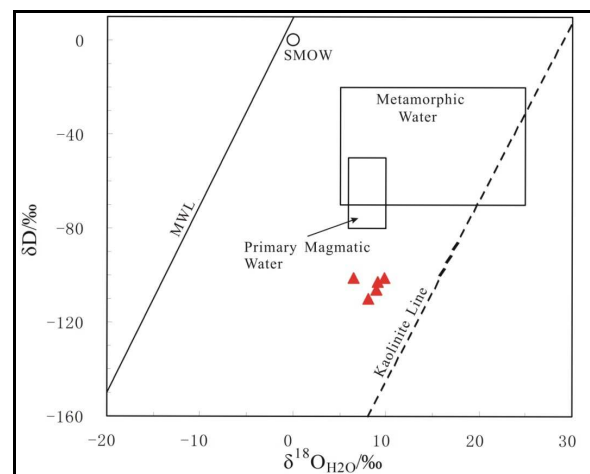


Fig. 4. δD - $\delta^{18}O$ characteristics of the fluid inclusion water at Naoyangping-Damogou zinc-fluorite deposit (After Geological Survey of Shaanxi Province, 2009).

From the Taylor (1974) δD - $\delta^{18}O$ isotopic diagram (Fig.4), can be seen that the δD values of fluid inclusions hosted in fluorite deposits ranges between -100‰ and -115‰ and those of $\delta^{18}O$ ranges between 5‰ and 10‰, the relevant points of ore-forming materials were derived mainly from deep-source magmas which had been brought about the alkali trachyte and Middle Silurian Zhuxi group from the deep interior. This indicates that for the hot-water sedimentary fluorite deposits of the ore-forming fluids were predominantly formation water or mixed water. It appears that while volcanism furnished abundant F for the formation of hot-water sedimentary fluorite deposits, volcanic hydrothermal solutions were also involved in the fluorite formation. As for the genetic type, the Naoyangping-Damogou is a strata-bound sedimentary-hydrothermal fluorite deposits associated with zinc-lead deposit.

Tb/Ca vs. Tb/La cross plot of fluorites

Fluorite occurs in various mineral deposits and host rocks and has distinct geochemical patterns indicative of the type of mineral deposit and host rock (Richardson and Holland, 1979; Strong et al., 1984; Ekambaram et al., 1986; Constantopoulos, 1988; Eppinger, 1988; Eppinger and Closs, 1990; Subias and Fernandez-Nieto, 1995; Hill et al., 2000; Andrade et al., 1999; Buhn et al., 2002; Bosze and Rakovan, 2002; Monecke et al., 2002). The Tb/Ca and Tb/La ratios of Naoyangping-Damogou fluorite indicate origins and depositional histories. These Tb/La - Tb/Ca ratios of fluorites indicate that the Naoyangping-Damogou fluorite cross plot mainly in the "magmatic" or "high-hydrothermal" field of the diagram of Möller et al., (1976) (Fig.4.7) with the characteristics of primary crystallization and remobilization trends. The ratios can be used to classify the fluorites according to their conditions of formation (Moller et al., 1976; Moller and Morteani, 1983). The Tb/La ratios of the Naoyangping-Damogou fluorites are quite low and high, and show that they are the products of early stage crystallization as explained by Constantopoulos (1988). Naoyangping-Damogou fluorites plot in the hydrothermal field, whereas fluorites from the plot entirely in the magmatic fields (Fig.5).

According to the analysis result of Geological Survey of Shaanxi Province, (2009) of fluorites in the Naoyangping-Damogou orefield, there exist purple-white fluorites in Naoyangping-Damogou district which bear sedimentary

characteristics of limestone and trachyte-like fluorites and have different stages. These results indicate that the fluorite in hot-water sedimentary deposits were formed at higher temperatures of Tb/La and low temperatures with Tb/Ca. Within fluorite in hot-water hydrothermal deposits were formed at at higher temperatures of Tb/Ca and low temperatures with Tb/La.

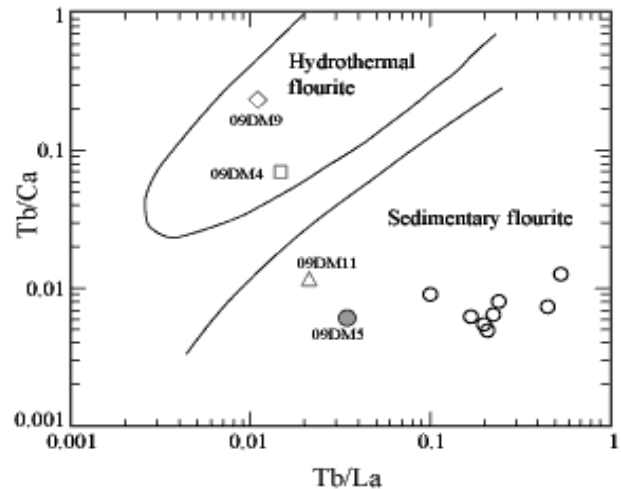


Fig.5 Cross Plot of the Naoyangping-Damogou fluorites on a Tb/Ca versus Tb/La variation diagram (After Möller et al. 1976). Trends are taken from Geological Survey of Shaanxi Province, (2009).

Acknowledgements

This study was supported by Resources Planning & Developing Dept. of Shanghai Baosteel Baosteel according to their research project license key (6100000820339) for the Naoyangping-Damogou zinc-fluorite deposit in Pingli County of Shaanxi Province in China.

References

- [1] Andrade, F.R.D., Möller, P., Lüders, V., Dulski, P. and Gilg, H.A. (1999). Hydrothermal rare earth elements mineralization in the Barra do Itapirapuã carbonatite, southern Brazil: behaviour of selected trace elements and stable isotopes (C,O); *Chemical Geology*, Volume 155, pages 91-113.
- [2] Bosze, S., Rakovan, J., 2002. Surface-structure-controlled sectoral zoning of the REEs in fluorite from Long lake, New York, and Bingam, New Mexico, USA. *Geochim. Cosmochim. Acta* 66, 997 - 1009.
- [3] Buhn, B., Rankin, A.H., Schneider, J., Dulski, P., 2002. The nature of

- ortomagmatic, carbonatitic fluids precipitating REE, Sr-rich fluorite: fluid-inclusion evidence from the Okorusu fluorite deposits, Nambia. *Chem. Geol.* 186, 75 - 98.
- [4] Constantopoulos, J., 1988. Fluid inclusion and REE geochemistry of fluorite from south-central Idaho. *Econ. Geol.* 83, 626 - 636.
- [5] Dong Wei, Ximin Chen, and Bangchao Wu (2009). Geological Characteristics and Ore Prospects of Zinc-Fluorite Deposit in Pingli Damogou, Shaanxi. *Northwestern Geology* 46(3), 77-85.
- [6] Dong Wei, Ximin Chen, and Bangchao Wu (2009). Geological Characteristics and Ore Prospects of Zinc-Fluorite Deposit in Pingli Damogou, Shaanxi. *Northwestern Geology* 46(3), 77-85.
- [7] Ekambaram, V., Brookins, D.G., Rosenberg, P.E., Emanuel, K.M., (1986). REE geochemistry of fluorite-carbonate deposits in Western Montana, USA. *Chem. Geol.* 54, 319 - 331.
- [8] Eppinger, G.E., Closs, L.G., (1990). Variation of trace elements and rare earth elements in fluorite: a possible tool for exploration. *Econ. Geol.* 85, 1896 - 1907.
- [9] Eppinger, R.G., (1988). Trace and REE variation in fluorites collected from skarn and epithermal mineral deposits in the Sierra Cuchillo area, south central New Mexico. *US Geol. Surv., Open-File Rept.* 88-0566, 108 p.
- [10] Geological Survey of Shaanxi Province and Mineral Resources Bureau. (1989). *Regional Geology of Shaanxi*. Edit [M]. Geology Press, Beijing.
- [11] Geological Survey of Shaanxi Province and Mineral Resources Bureau. (1989). *Regional Geology of Shaanxi*. Edit [M]. Geology Press, Beijing.
- [12] Geological Survey of Shaanxi Province, (1966). 1:200,000 Geological map of Ziyang sheet (I-49-31) (in Chinese).
- [13] Geological Survey of Shaanxi Province, (1966). 1:200,000 Geological map of Ziyang sheet (I-49-31) (in Chinese).
- [14] Geological Survey of Shaanxi Province, (2008). 1:250,000 Geological map of Ankang sheet (I49C004001) (in Chinese).
- [15] Geological Survey of Shaanxi Province, (2009). Damogou Zn-CaF₂ ore: Structure-Magmatic hydrothermal.
- [16] Gorczyk W., Gerya T.V., Connolly J.A.D. et al. (2007) Growth and mixing dynamics of mantle wedge plumes [J]. *Geology*. 35, 587 - 590 (in Chinese with English abstract)
- [17] Hill, G.T., Campbell, A.R. and Kyle, P.R. (2000): Geochemistry of the southwestern New Mexico fluorite occurrences, implications for precious metals exploration in fluorite-bearing systems; *Journal of Geochemical Exploration*, Volume 68, pages 1-20.
- [18] Mao Jingwen, Zhang Jiandong, and Guo Chunli (2010) Metallogenic model of porphyry copper-epithermal Ag-Pb-Zn-distant contact hydrothermal gold ore deposits: A new ore deposit model as exemplified by the Dexing region [J]. *Journal of Earth Science and Environmental Science*. 32, 1 - 14 (in Chinese with English abstract).
- [19] Maruyama S. (1994) Plume tectonics [J]. *J. Geol. Soc. Japan*. 100, 24 - 49.
- [20] Meriaux C.A., Mansour J.A., Moresi L.N. et al. (2011) On the rise of strongly tilted mantle plume tails [J]. *Physics of the Earth and Planetary Interiors*. 184(1 - 2), 63 - 79.
- [21] Möller, P., Morteani, G., (1983). On the chemical fractionation of REE during the formation of Ca- minerals and its application to problems of the genesis of ore deposits. In: Augustithis, S., (Ed.), *The significance of trace elements in solving petro-genetic problems*: Athens, pp. 747 - 791.
- [22] Möller, P., Parekh, P. P. & Schneider, H.-J. (1976): The application of Tb/Ca - Tb/La abundance ratios to problems of fluor spar genesis. *Mineralium Deposita* 11, 111 - 116.
- [23] Monecke, T., Kempe, U., Monecke, J., Sala, M., Wolf, D., (2002). The tetrad effect in REE distribution patterns: A method of quantification with application to rock and mineral samples from granite-related rare metal deposits. *Geochim. Cosmochim. Acta* 66, 1185 - 1196.
- [24] Niu Shuyin, Li Hongyang, Sun Aiqun et al. (2002) *Mantle Branch Theory and Ore Prospecting Practice* [M]. pp.1 - 243. Seismological Publishing House, Beijing (in Chinese).

- [25] Richardson, C.K., Holland, H.D., (1979). Fluorite deposition in hydrothermal systems: *Geochem. Et Cosmochim. Acta* 43, 1327 - 1335.
- [26] Strong, D.F., Fryer, B.J., Kerrich, R., (1984). Genesis of the St Lawrence fluorspar deposits as indicated by fluid inclusion, REE, and isotopic data. *Econ. Geol.* 78, 1142 - 1158.
- [27] Subias, I., Fernandez-Nieto, C., (1995). Hydrothermal events in the Valle de Tena (Spanish Western Pyrenees) as evidenced by fluid inclusions and trace-elements distribution from fluorite deposits. *Chem. Geol.* 124, 264 - 282.
- [28] Sun Aiqun, Hu Huabin, Niu Shuyin, Mao Jingwen, Wang Baode, Li Yingping, and Wang Laiming (2006). Characteristics of mantle-branch structure in western Shandong and its roles in minerogenesis and ore-controlling [J]. *Chinese Journal of Geochemistry.* 25, 340 - 353.
- [29] Sun Aiqun, Niu Shuyin, Wang Baode, Han Yuchou, Wei Minhui, Ma Baojun, Zhao Zhiyuan, and Xia Dong (2011) Metallogenic characteristics of the region of Northwest Hebei and analysis of ore prospecting potential in its peripheries [J]. *Chinese Journal of Geochemistry.* 30,1 - 13.
- [30] Taylor, H. P. (1974) The application of oxygen and hydrogen isotope studies to problems of hydrothermal alteration and ore deposition. *Econ. Geol.*, 69, 843 - 883.
- [31] TU Huaikui, (1997). A preliminary discussion on geological setting and ore-forming characteristics of Ankang region, southern Shaanxi [J] *Geology of Shaanxi*, 11 (2): 9-11.
- [32] TU Huaikui, (1999). Crustal evolution and characteristics of gold mineralization in north margin of Yangtze platform [J] *Geological Ore-Prospecting Symposium*, 14 (3) 172241
- [33] Wang Baode, Niu Shuyin, Sun Aiqun, Liu Yaming, Xie Yan, Jiang Xiaoping, Zhao Yongli, Gao Yincang, and Zhao Fuwang (2010) Temporal- spatial distribution and ore-forming material source of gold, copper and silver polymetallic ore deposits in the Fuping mantle structure zone [J]. *Chinese Journal of Geochemistry.* 29, 270 - 277.
- [34] Wang Denghong (1998) *Mantle Plume and Its Metallogenesis* [M], pp.1 - 160. Geological Publishing House, Beijing (in Chinese).
- [35] Zhang, G.W., Meng, Q.R., Yu, Z.P., Sun, Y., Zhou, D.W., Guo, A.L., (1997). Orogenesis and dynamics of the Qinling orogen. *Science in China, Series D* 39, 225 - 234.