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Structure Analysis and Its Control over Gold and Lead-Zinc Mineralization in the Fengtai Ore Cluster, West Qinling, China

CHEN Shaocong[1], WANG Yitian[1], HU Qiaoqing[1], LIU Xielu[1], ZHANG Juan[1], WEI Ran[1], WANG Ruiting[2], WEN Shenwen[3] and LIU Wei[4]

1 *MLR Key Laboratory of Metallogeny and Mineral Assessment, Institute of Mineral Resources, Chinese Academy of Geol ogical Sciences, Beijing 100037, China*
2 *Northwest Geological Exploration and Mining Bureau for Nonferrous Metals, Xi'an 710054, China*
3 *No. 717 Geological Party, Northwest Geological Exploration and Mining Bureau for Nonferrous, Baoji 721004, China*
4 *Shaanxi Fengxian Sifang Golden Co. Ltd, Baoji 721004, China*

1 Introduction

The Fengxian-Taibai (abbr. Fengtai) ore cluster in Shaanxi Provence, a very important part of the polymetallic ore forming zone in the West Qinling Orogen (WQO), is located in the east of WQO between the North and South China (Yangtze) cratons. The Fengtai ore cluster is a rhombic-shaped area confined by the Xiangzihe-Huangbaiyuan Fault to the north part of the Shangdan Suture and the Jiudianliang-Jiangkou Fault to the south. Regional exposed strata in the Fengtai ore cluster are predominantly comprised of middle to late Devonian low-metamorphosed fine clastic sedimentary and carbonate rocks. The Xiba intermediate-acid intrusive pluton is the biggest one in this area, including granodiorite, biotite ganite, monzonitic granite, quartz monzodiorite, etc. In addition, widespread dikes can also be found in this area, such as diorite-porphyrite, granite-porphyry and lamprophyre.

There are various mineral deposits, of which minerals like lead, zinc and gold are more pronounced in the Fengtai ore cluster. The lead-zinc deposits and gold deposits in the Fengtai ore cluster distributes clearly along the NWW-trending belts, consistent with the direction of the regional tectonic line. Lead-zinc deposits controlled mainly by the NWW-trending fold structures, commonly occurred in the crushed zone between the Gudaoling Formation of Middle Devonian and the Xinghongpu Formation of Upper Devonian and in the collapsed space of the anticlines, like the Bafangshan-Erlihe deposit, the Yinmusi deposit, the Yindongliang deposit, the Qiandongshan-Dongtangzi deposit, etc. There are many gold deposits and occurrences explored and ascertained in the Fengtai ore cluster, including the Buaguamiao deposit, the Shuangwang deposit, the Pangjiahe deposit, etc. The gold ore bodies of the deposits mentioned above occurred in, and are controlled by the NWW-trending brittle-ductile shear zone.

2 Structures in the Fengtai Ore Cluster

The faults and folds are extremely developed in the Fengtai ore cluster, and so do the joints, the lineations and the cleavages. This area is generally an NWW-trending synclinorium as a whole, which is called Guchahe-Yinjiaba synclinorium. A series of tight and linear secondary folds in parallel are present on both limbs of the synclinorium. Similarly, major faults commonly trend in a NWW direction, forming the regional structural framework together with the NWW-trending folds.

Field investigation and structure analysis show that most of the folds in the Fengtai ore cluster are top-thick or isopach folds, whose axial planes strike NW-SE and dip SSW or NNE. The relationship between the dip directions of the limbs and the axial planes suggests that the folds are inclined folds and overturned ones. And through the interlimb angles, we can find that they belong to closed folds and tight ones. Moreover, hinges of the folds and B-type lineations like rodding structure and crenulations lineation plunge shallowly to SEE-SE direction. All above indicate that the folds and the B-type lineation were

* Corresponding author. E-mail: shaocong0211@163.com

formed by the NE-SW compression. In addition, widespread development of the kink structures and rootless, corrugated quartz veins near the core of Guchahe-Yinjiaba anticlinorium also indicate that the Fengtai ore cluster has undergone strong tectonic compression.

Faults in the Fengtai ore cluster can be divided into three major groups: NWW-trending, NW-trending and NE-trending. The mutually interlaced NWW-trending faults and NE-trending ones have cut the Fengtai ore cluster to appear rhombus shapes. Most of the NWW-trending faults are reverse faults parallel or subparallel to bedding and some reverse faults are formed with a dip direction contrary to the dip direction of the strata. Both groups of faults are resulted from one of the X-shaped shear fracture planes. Most of the former are distributed at the limbs close to the core of the folds, which may be caused by interlayer sliding under the continuous compression during the late stage of folding. Two groups of the NWW-trending reverse faults show that the primary stress direction is NE-SW together. The widespread NE-trending and the NW-trending faults are both wrench faults, offsetting the NWW-trending faults. In addition, some of the NE-trending faults are filled with dikes.

Measurement and Analysis of joints show that nearly all the joints have a high-angle dip and they break into two types of dominant joint sets: the first set is NE-trending and the second set is NWW-NW-trending. Most of the NWW-trending joints with characteristics of tension joints are commonly filled with quartz carbonate veins and distributed at or nearby the core of the NWW-trending folds, which indicate that they may be the longitudinal joints formed during the folding period. However, the NE-trending joints with straight surface, small opening degree and long extended distance show the characteristics of the shear joints. Within the Baguamiao gold deposit, NE-trending joints are more concentrated, which can be subdivided into two sets: NEE-trending and NNE-trending ones and most of them are filled with gold-bearing quartz veins. We suggest that the two sets of joints are formed from the "Riedel" fractures under the background of the left lateral strike-slipping under the compression of NE-SW primary stress.

3 Structural Deformation Sequence

Based on the relationship among the structures in field and observation of the microstructures, structural deformations in the Fengtai ore cluster can be divided into three periods:

1) Deposition of the Devonian strata formed the bedding (S_0). The later greenschist facies metamorphism and deformation (D_1) forced the schistose minerals like muscovite to arrange directionally, called phyllitic foliation (S_1) parallel or subparallel to S_0.

2) NWW-trending tight folds and the B-type lineations were formed by NE-SW strong compression ($D_{2\text{-}1}$), and the NWW-trending thrust faults formed afterward. On the micro scale, the common crenulation cleavage (S_2) overlaid on S_1.

3) Till the late period of D_2, the NE-SW compression turned to left lateral shear-slipping ($D_{2\text{-}2}$). The NEE-trending and NNE-trending shear joints might formed by $D_{2\text{-}2}$. Continuous shearing induced strike-slip movement of the joints, forming the NE-trending faults.

4) The faults trending NW and faults trending NE and dipping SE, offsetting the NE-trending joints and faults, may indicate a later deformation period (D_3).

All in all, two left lateral strike-slipping faults limited the Fengtai ore cluster as the boundaries to the north and the south. NW-trending multiple folds, SEE-plunging B-type lineation, NWW-trending and NE-trending strike-slipping faults are extensively developed in the Cluster. The whole Fengtai ore cluster appears to be a strike-slip duplex under a primary stress orienting NE-SW (Wang et al., 2009).

4 Characteristics and Mechanism of Ore-controlling Structures

The formation and distribution of the deposits in the Fengtai ore cluster are closely related to the following structures:

1) Most of the polymetallic deposits distribute along NWW direction and the ore bodies are produced in the core and inverted limb of the folds or nearby the brittle-ductile shear zone.

2) The stretching direction of single ore body in lead-zinc and gold deposits is consistent with that of the tectonic lineament—NWW-SEE direction, and the lead-zinc ore bodies appears as saddled or layered shape, closely related to the anticlines.

3) NE-trending joints veins contribute to the gold mineralization and the rich gold mineralization commonly occurs in the overlapped part of the NEE-trending and NWW-trending structures.

4) The post-mineralization faults play a role in ore destruction.

Geophysical and geochemical barrier often form in the boundaries of physical and chemical environment (Lu et

al., 2001). In such locations, plenty of minerals deposit because of the sudden change of the physical and chemical properties of the water-rock system (Zhai and Lu, 2002). The mineralization mechanism of the main lead-zinc deposits might be that the competencies of the strata are different, causing interlayer sliding and the core collapsing under the folding. And the partial sudden releasing of the stress aroused the importing of the ore fluid and the ore deposition by pumping function. This mechanism also played an important role in the gold mineralization in Fengtai ore cluster. Phylite of the Xinghongpu Formation folded at the ductile-brittle transition level under the NE-SW compression. Cracks and fractures formed along the interlayer, across the bedding and at the core of the folds. Au-bearing fluid filled and precipitated in these cracks and with the metasomatic alteration of the phylite, i.e., the quartz vein type mineralization and the altered rock type mineralization occurred. Afterwards, during the changing to left lateral strike-slipping from the compression in a NE-SW orientation, NE-trending shear joints began to form, forming the geophysical and geochemical barrier. Au-bearing fluid was sucked in the tension-shear joints, causing gold mineralization superposing on the former mineralization.

5 Conclusion

There are various structural styles in the Fengtai ore cluster. Plenty of NWW-trending folds and thrust faults, NE-trending faults, SEE-plunging lineation, foliation and cleavage are developed under the early NE-SW compression and later left lateral strike-slipping, forming the strike-slip duplex. Structures provided the path and driving force for the fluid migration and the space of the ore deposit. The anticline and contact zone between the Gudaoling Formation and the Xinghongpu Formation play a significant role in the forming of lead-zinc deposits, while the gold deposits are mainly controlled by the NWW-trending brittle-ductile shear zone, and the hydrothermal activity controlled mainly by NE-trending joints superposed and enriched the former mineraliztion.

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