Geological characteristics of the Yindonggou Ag-Au-Pb deposit and its mineralization model, East Qinling

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Abstract. The Yindonggou Ag-Au-Pb deposit, located in the Erlangping Group of Palaeozoic age in the East Qinling orogen, south-western Henan, is a recently discovered, large structural alteration-type deposit. Its main veins are ca. two thousands meters long and extend to several hundreds meters at depth. It has an average grade of 333 g/t silver and contains multiple paragenetic metallic minerals. It may be the economically most potential deposit type in the area. In this paper we briefly describe the geological characteristics, ore-controlling factors, and propose a mineralization model.

Keywords. Geological characteristics, mineralization model, Yindonggou, Erlangping, East Qinling

1 Introduction

The Yindonggou deposit is located 100 km northwest of the Nanyang city in south-western Henan. It occurs in the Erlangping terrane of the East Qinling west of the Nanyang basin (Fig. 1). The Erlangping Group consist of a set of volcanic-sedimentary associations up to several thousand meters thick. In the last century, several small to medium-sized porphyry and explosive breccia type Cu-Mo deposits and VMS type Cu-Zn deposits and disseminated Au deposits were discovered in the terrane. The recent discovery of the large Yindonggou Ag-Au-Pb deposit by No. 3 Geological Party of the Henan Bureau of Nonferrous Metals Exploration suggests that the area has good prospects for further finding hydrothermal mineral deposits.

2 Geological setting

The strata exposed in the area are mainly the Erlangping Group, which is distributed at Xixia, Neixiang, and Nanzhao counties, Henan Province, and is separated from the Qinling Group by the Zhuxia deep fault on the south and from the Kuanping Group by the Waxuezi-Qiaoduan deep fault on the north. Many geologists (Ren et al. 1980; Xu et al. 1986; Hu et al. 1988; Zhang et al. 2001) have argued that the fault hosts ophiolites and is closely related to the subduction of the Yangtze plate beneath the North China plate and their collision has great significance for the tectonic evolution of the East Qinling orogen.

Although there are different views about the age of the Erlangping Group, most geologists assign it to Early Palaeozoic. In the area, this group can be divided into three formations; they are in ascending order the Damiao, Huoshenmiao, and Xiaozai formations. The Damiao Formation is composed mainly of siliceous slate, marble, metamorphosed tuffaceous sandstone, and quartz keratophyre with a thickness of 1134–1990 m. Its protoliths are an acid volcanic-terrestrial clastic sequence. The Huoshenmiao Formation consists predominantly of spilite and quartz keratophyre with lenses of carbonaceous and siliceous rocks and marble, with a thickness of 2004–5530 m. The ore deposits occurring in the formation are the Shuidongling and Xizhuanghe VMS Cu-Zn deposits, Xuyiaogou Au deposits, and some orebodies of the Yindonggou Ag-Au-Pb deposit. The Xiaozhai Formation is a thick association of carbonaceous sericite schist and sericite-quartz schist intercalated with volcanic rocks, having a thickness of 1617–2269 m. Its protoliths are sandstone and claystone, belonging to abyssal and bathyal turbidity current deposits with flysch characters (Luo et al. 1992). The main part of the Yindonggou deposit occurs in it.

To the south of the Erlangping Group occurs the Palaeoproterozoic Qinling Group complex (Shi et al. 2004), whose protoliths are mainly neritic carbonate rocks with calcareous pelite. They formed in a short time in the continental-margin and rift environment and afterwards they underwent several strong metamorphism-deformation and thermal events (Zhang et al. 1994).

To the north of the Erlangping Group there occurs the Mesoproterozoic Kuanping Group, which is composed mainly of two-mica-quartz schist and two-mica schist, with minor plagioclase-amphibole schist and carbonaceous mica-quartz schist. The protoliths are mainly a sequence of volcanic and terrigenous clastic rocks. The former was derived from the depleted mantle, while the latter from the Qinling Group to the south and Taihua Group to the north (Zhang et al. 1994; Zhang et al. 2002). The lineament in the area generally strikes NWW, and

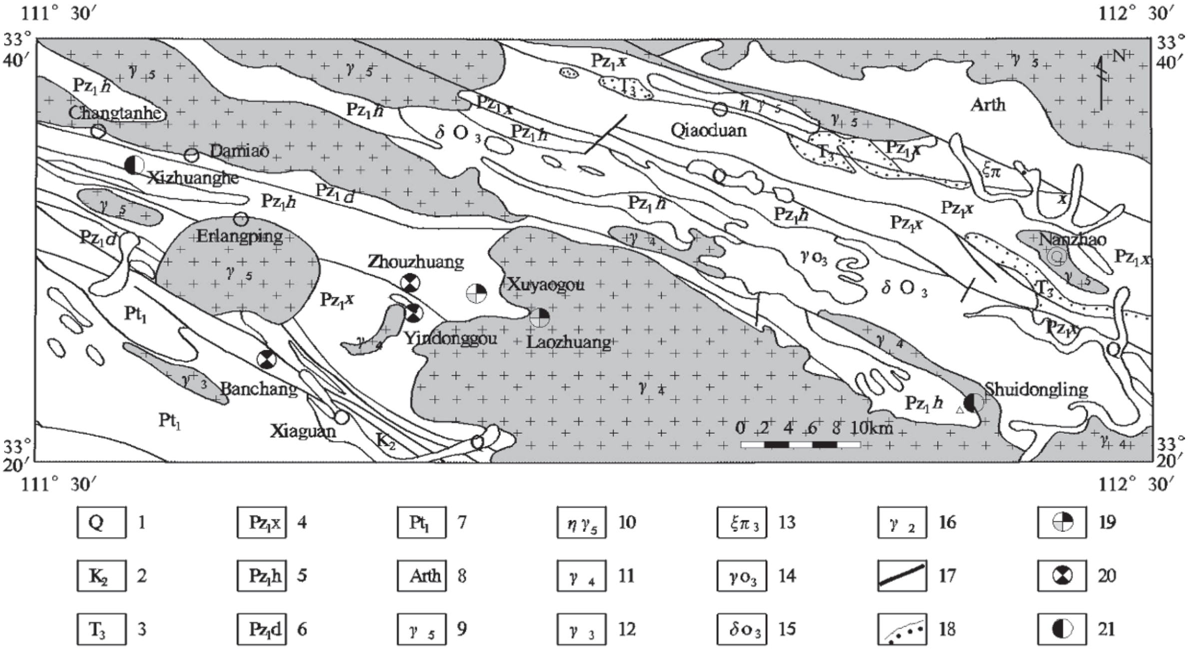

Figure 1: Regional geological map of the Nanzhao-Neixiang district, southwestern Henan. 1. Quaternary sediments; 2. Upper Cretaceous continental sedimentary rocks and volcanic rocks; 3. Triassic continental argillo-arenaceous and shale; 4. Biotite-quartz schist, two-mica-uartz schist, and metasandstone of the Xiaozhai Formation of the Erlangping Group; 5. Spilite, Keratophyre, and quartz keratophyre of the Huoshenmiao Formation of the Erlangping Group; 6. Ribbon mable, palgioclase-hornblende schist, and sericite-quartz schist of the Damiao Formation of the Erlangping Group; 7. Dolomite marble, graphite-bearing marble and plagioclase gneiss of the Qinling Group; 8. Archean metamorphic rock; 9. Late Mesozoic Yanshanian granite; 10. Late Mesozoic Yanshanian monzogranite; 11. Late Palaeozoic Hecynian granite; 12. Early Palaeozoic Caledonian granite; 13. Caledonian syenite; 14. Caledonian plagiogranite; 15. Caledonian qrartz diorite; 16. Proterozoic Ningjinian granite; 17. Fault; 18. Unconformity; 19. Gold deposit; 20. Ag-polymetallic deposit; 21. Copper-zink deposit.

from north to south there occur the Waxuzi-Qiaoduan fault, Zhuyangguan-Xiaguan fault, and Zhengping fault successively. These faults are large in scale and have a long-active history. On both sides of these faults secondary faults occur, which are generally up to several kilometres wide. Due to the influence of regional faulting, NW- and NE-trending secondary faults are developed. They occur in swarms, extending nearly linearly, parallelly and discontinuously, and intersect with NWW-trending faults to form a network. All these faults exert a controlling effect on magmatic activities and mineralization in the area.

Large-scale volcanic eruption and magmatic intrusion at different levels have occurred in the area. The Erlangping volcanic rocks are a suite of calc-alkaline basalts to alkaline tholeiite, which is considered to be the product of eruption and sedimentation in the back-arc basin (Zhang et al. 2002). The magmatic intrusion mainly took place in the Palaeozoic and Mesozoic, forming acid rocks (batholiths or large rock bodies) distributed in a nearly E-W-trending zone. Mesozoic magmatism generally occurred at the intersection sites of the NWW- and NE-trending faults and controls vein type mineralization surrounding them. For example, the Yindonggou Ag-Au-Pb deposit is controlled by a hidden rock body.

3 Geological characteristics of the Deposit

The ore district is divided into the Yindonggou ore block, Zhouzhuan ore block and Tumuya ore block (Fig. 1). There are a total of 53 veins in the deposit, all of which occur in fractured zones surrounding the concealed rock body. The host rocks are sericite-quartz schist and metasandstone of the Xiaozhai Formation and metaspilite, spilite tuff and granite of the Huoshenmiao Formation. There are two groups of veins: the nearly N-S group and the NW group, with the former predominating. The veins are several hundred to several thousand meters long and thin and uniform with an average thickness of 0.73 m (Table 1). They contain many and rich useful components. The average grades are Ag 333 g/t, Au 4 g/t, Pb 2.78%, and Zn 1.90% and the ore reserves are Ag 1700 t, Au 12 t, and Pb+Zn 430,000 t.

So far only the Yindonggou ore block has had a relatively high level of exploration and a small mine has been operated there; therefore the characteristics of the orebodies are clearer.

The Yindonggou ore block is located in the eastern part of the deposit (Fig. 2), including 13 veins. The ore reserves are Ag 1250 t, Au 10 t, Pb 100,000 t, and Zn 50,000

t. The host rocks are carbonaceous fine clastic rocks of the Xiaozhai Formation, marine mafic volcanic rocks of the Huoshenmiao Formation, and the late Palaeozoic Hercynian Lujiaping granite. The orebodies are not complex and mainly occur in bedded, bed-like, and podiform shapes. Polymetallic sulphide quartz veins occur (0.2-1.2 m thick generally) at the centre of the orebodies and grade into Ag-Au polymetallic sulphides and pyritized-sericitized rocks towards two sides, but the boundary of orebodies cannot be recognized before chemical analyses.

The main orebody Y1, 2300 m long, occurs in carbonaceous fine clastic rocks of the Xiaozhai Formation and Hercynian Lujiaping biotite granite. The shapes of the orebody are simple, mainly bedded, bed-like or podiform. They strike N10°E and dip west at ~30° at the surface, and dip more steeply toward the depth. The thickness is generally about 0.6 to 0.9 m, with an average of 0.65 m. The averaging grades are Ag 466 g/t, Au 5.3 g/t, Pb 2.1%, and Zn 1.9%. The thickness and grade of the orebody increase at depth.

The main metallic minerals include electrum, argentite, gold, galena, sphalerite, pyrite, chalcopyrite, and pyrrhotite; the gangue minerals include quartz, feldspar, sericite, chlorite and calcite. The ore exhibits euhedral to anhedral granular texture, cataclastic, interstitial, poikilitic, and replacement corrosion textures and spotted, disseminated, massive, banded, network, and breccia structures.

The alteration types include silicification, pyritization, sericitization, chloritization, and carbonisation. The alteration zones, varying in thickness from ~5 to 10 m, generally are thicker in metamorphic rocks of the Erlangping Group and narrow in granite.

There are three mineralization stages: (1) quartz-pyrite stage, which witnessed filling of quartz along cracks and ductile deformation; (2) quartz-polymetallic sulphide stage, which is the crucial mineralization stage; and (3) carbonate stage, in which mineralization was relatively weak.

The mineralization and alteration exhibit apparent vertical zoning: carbonization and weak mineralization are pronounced at the top of the orebodies; pyrite, galena and silver increase in the middle; and at depth sphalerite, chalcopyrite and gold increase but silver decreases.

4 Proposed mineralization model

There is no direct and reliable evidence about the mineralization age so far, but it is inferred that the deposit probably formed in the Mesozoic.

As the veins cut Hercynian granite and occur around the blind Mesozoic granite, the mineralization should occur later than Hercynian granite and even slightly later than Mesozoic granite. In addition, according to an analysis of the geological evolution, the Mesozoic, especially the period of Late Jurassic to Early Cretaceous, is the main mineralization age for most hydrothermal deposits in the East Qinling orogen.

The ore-forming material might be derived from the Xiaozhai Formation. On the basis of dispersion train measurements of the Xiaozhai Formation by the No. 5 Geological Survey Party of the Henan Nonferrous Metals Exploration Bureau in the 1990s, the contents of the ore-forming elements Au, Pb, Zn, As, Sb, Bi, Ba, and F and indictor elements are apparently higher than those in the underlying Damiao and Huoshengmiao formations, and the high contents of volatiles such as Ba and F suggest that the Xiaozhai Formation might be abyssal argillaceous, fine clastic rocks associated with hydrothermal sedimentation.

The nearly N-S- and NE-striking ore-hosting faults exhibit the characteristics of multi-stage activities. They were ductile in the early stage and brittle in the mineralization stage.

The ore-forming fluids are of Cl-Na type with Cl>F and Na>K, being mainly neutral, and became CO32- type in the late stage, showing the subalkaline character. Fluid inclusions show that they contain magmatic water and meteoric water. The variation in composition of the inclusions shows that more and more meteoric water entered into the ore-forming fluids with the evolution of mineralization (Zhang et al. 2004).

The proposed mineralization is as follows: The subduction of the south China plate beneath the North China plate in the Early Palaeozoic resulted in the formation of the very thick Erlangping Group in a back-arc basin environment. The Xiaozhai Formation in this environment became the main ore source because of its high content of ore-forming material and feature of easy remobilisation.

Table 1: Characteristics of the main veins of the Yindonggou deposit

Ore vein	Vein length (m)	Orebody length (m)	Dip width of orebody (m)	Orebody thickness (m)	Average grade			
					Ag (g/t)	Au (g/t)	Pb (%)	Zn (%)
Y1	2300	1800	390	0.6-0.9	466	5.3	2.1	1.9
Y2	1500	1200	100	0.4-1.6	221	10.0	0.6	0.2
Y3	1800	1200	250	0.8-3.0	578	2.8	7.4	3.3
Z1	1200	900	100	0.5-1.6	69	4.0	0.5	
Z2	2100	1200	250	0.8-1.5	234	1.1	1.8	1.2

In the Triassic the North China plate and South China plate collided and were amalgamated, resulting in N-S compression and crustal shortening in the East Qinling (Zhang et al. 2001; Mao et al. 2003, 2005), and the high pressure and high temperature brought about partial melting of the lower crust. In the Late Jurassic to Early Cretaceous (at 140-120 Ma), lithospheric thinning and extension in eastern China resulted in upwelling of the asthenosphere and large-scale magma activities. Under the controls of the tectono-thermal event, magmatism, and magmatic fluids and later in the presence of meteoric water, ore-forming fluids extracted ore substances from the Xiaozhai Formation and unloaded them along the reactivated N-S- and NW-trending faults, thus forming the large Yindongou Ag-Au-Pb deposit.

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