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Recognition of Yanshanian magmatic-hydrothermal gold and polymetallic gold mineralization in the Laowan gold metallogenic belt, Tongbai Mountains: New evidence from structural controls, geochronology and geochemistry

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A B S T R A C T

The Laowan metallogenic belt in China is an important metallogenic belt within the Tongbai orogenic belt, and contains the medium-sized Laowan and Shangshanghe gold deposits, the small Huangzhuyuan lead–zinc–silver–gold deposit and some gold and Cu–Pb occurrences. These deposits are hosted in Mesoproterozoic plagioclase amphibolite (or schist) and mica-quartz schist. The gold ores are mainly quartz veins and veinlets and disseminated altered ores. Subordinate ore types include massive sulfides and breccias. The Laowan gold deposit is characterized by three right-stepping en-echelon fracture-controlled alteration zones that dip gently to the south and includes disseminated, sheeted and stockwork ores. These lodes were formed by the interaction of ore-forming fluid with foliated-to laminated cataclasite within the transpressional faults. The Shangshanghe gold deposit is characterized by parallel ore lodes that dip steeply to the north, and includes quartz veins and breccias in addition to ores in altered wallrocks. These lodes were formed by focusing of fluids into transtensional faults. These ore controlling faults displaced early barren quartz veins 10 m horizontally with a dextral sense of motion. The ore-hosting structures at the Laowan and Shangshanghe deposits correspond to the P and R-type shears of a brittle dextral strike-slip fault system, respectively, which make angles of about 15° and −15° to the Laowan and Songpa boundary faults. The ore-controlling fault system post-dated formation of a ductile shear zone, and peak regional metamorphism. This precludes a genetic relationship between hydrothermal mineralization and regional metamorphism and ductile shear deformation. These gold deposits are not typical orogenic gold deposits. The metallogenic belt displays district-scale-zoning of Mo → Cu–Pb–Zn–Ag → Au relative to Songpa granite porphyry dike zone, suggesting the mineralization may be closely related to the granite porphyry. Measured $\delta^{34}S$ of sulfides and $\delta^{18}O$ and δD of fluid inclusion waters in auriferous quartz also are consistent with a magmatic source for sulfur and ore fluids. The similarity of Pb isotope ratios between the ores and Yanshanian granitoids suggests a similar source. As the age (139 ± 3 Ma) of granite porphyry obtained by zircon U–Pb isotope overlaps the mineralization age (138 ± 1 Ma: Zhang et al., 2008a), the gold and polymetallic metallogenesis of the Laowan gold belt has close spatial, temporal and possibly genetic relationships with Yanshanian high level magmatism.

1. Introduction

It is widely accepted that orogenic gold deposits form a distinctive class of deposits that are usually hosted in metamorphic terranes and are structurally controlled (Groves et al., 1998). These orogenic deposits formed in a range of structural setting in collisional orogenic belts through geological time (Goldfarb et al., 2001; Groves et al., 2003), and are closely related to greenschist to amphibolite facies metamorphism during compressional to transpressional deformation in accretionary or collisional orogens of Archean and younger ages (Kerrich and Cassidy, 1994; Groves et al., 1998; Goldfarb et al., 2001; Salier et al., 2005). The Late Archean and Paleoproterozoic were extremely favorable for orogenic gold mineralization (Goldfarb et al., 2001, and references therein; Groves et al., 2003; Salier et al., 2005).

The Tongbai collisional orogen contains numerous gold and silver deposits, mostly concentrated in the Mesoproterozoic Erlangping terrane which contains the large Yindongpo gold deposit, the giant Poshan silver deposit, and the large Yindongling silver-dominated polymetallic deposit (J. Zhang et al., 2008), and the Laowan gold belt in Gui-Mei shear

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zone (Fig. 1). The Laowan gold belt is an important gold and polymetallic metallogenic belt in the northern Tongbai orogenic belt, and the ore-hosting geological units form a narrow zone, nearly 20 km long from east to west, 1.5–2.5 km wide from north to south. In the early 1980s, mineral exploration in this area identified the medium sized Laowan gold deposit and some gold bodies at the surface at Shangshanghe, as well as small lead–zinc–silver–gold deposits (e.g. Huangzhuyuan). Several gold occurrences (Jiuguan and Doupoyan) were subsequently discovered. Mining of the Laowan gold deposit commenced in the 1980s. The elevation range from +250 m above sea level to −40 m below sea level has mined out, with the deepest workings to −80 m below sea level. A small amount of Mo ores has been mined in Jiangzhuang-Caijiaao area in the northern Laowan gold deposit, close to the granite porphyry dike zone. The Shangshanghe gold deposit is currently being mined and has been mined from about 220 m above sea level to −400 m below sea level, and it becomes a medium sized gold deposit. Mineral exploration continues at the Huangzhuyuan lead–zinc–silver–gold deposit. Since 2000, the Laowan gold belt has become an important area for research again, and there is ongoing near-mine exploration. The geology of gold deposits in the Laowan gold belt has been briefly described (e.g. Liu et al., 2003; Xie et al., 2001; Z.H. Zhang et al., 2002; Chen et al., 2009), but the lead–zinc–silver–gold polymetallic deposits are poorly described and ore-controlling structures have received relatively little attention (e.g. Liu et al., 2003). Consequently, because early exploration drilling in the Shangshanghe district was designed according to characteristics of gold bodies at Laowan, gold ore bodies at depth were not discovered due to the misunderstandings about the nature of the ore-controlling structures. Furthermore, details regarding the mineralization features, ore fluids, and genesis are not available. To address this knowledge gap, this paper will focus on determining (1) the kinematics and evolution of ore-controlling structures and their relationship to mineralization, and (2) the zoning of ore and related element assemblages and its relation to Yanshanian magmatism. We also present a high precision U–Pb age of granite porphyry dykes (high-level equivalents of the granitoid plutons) which occur widely in the Laowan gold belt, and compare this age with published $^{39}Ar/^{40}Ar$ ages on gold-related alteration minerals to demonstrate that there is a direct temporal link between gold-polymetallic mineralization and the Yanshanian high level granite porphyry intrusion, rather than the earlier Laowan granite. We finally use H–O, S and Pb isotopes of gold and lead–zinc–silver–gold deposits to provide information about the ore fluids, sulfur source, and genesis of these deposits. These data allow us to test the relationship of gold deposits of Laowan gold belt to magmatism and assess the applicability of typical orogenic gold models to this belt.

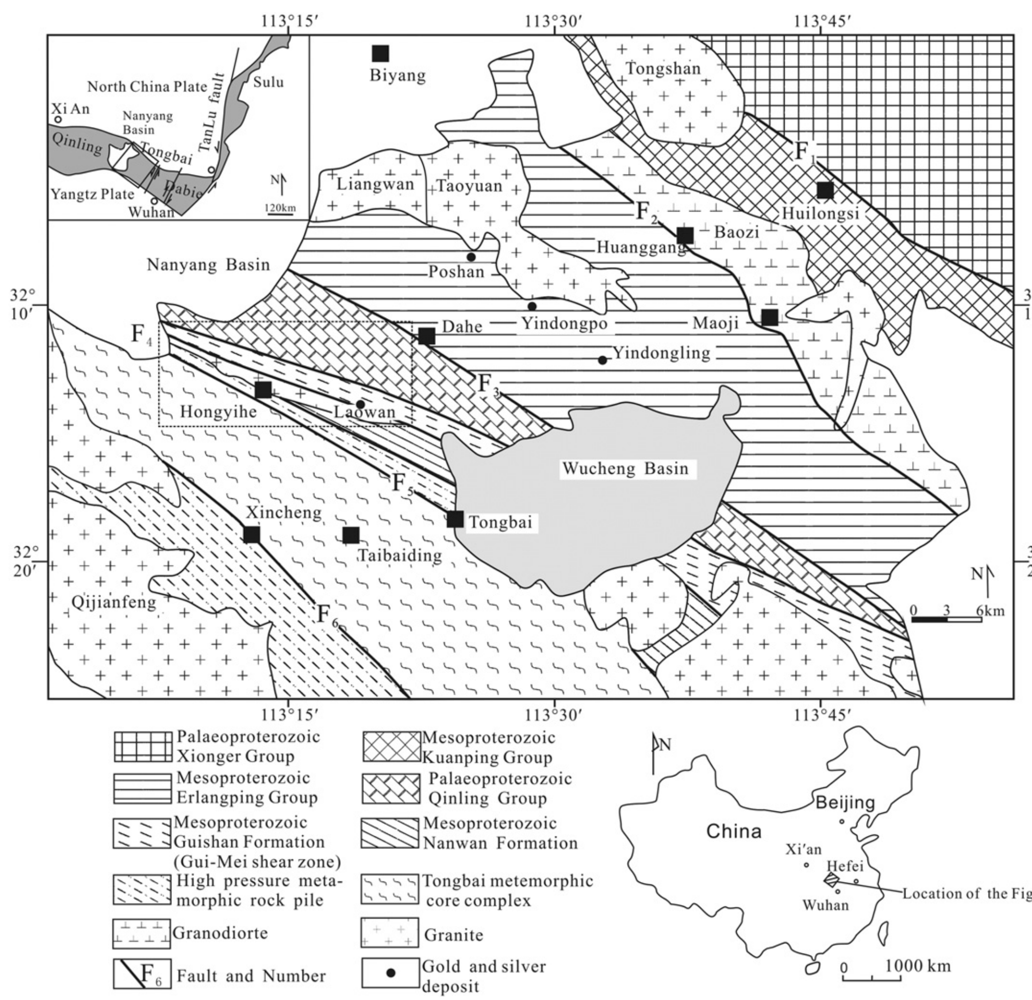

Fig. 1. Geological map showing the Tongbai orogen and the Laowan gold belt, modified from Third Geological Survey Team, Henan Bureau of Geo-exploration and Mineral Development (1991[1]

[1] Third Geological Survey Team, Henan Bureau of Geo-exploration and Mineral Development, 1990. Report of large scale gold metallogenic prediction, Tongbai county, Henan Province.) and Liu et al. (2011a). Also shown are the major gold–silver districts in the Tongbai orogen. The inset on the top left corner shows the location of Fig. 1. The inset on the bottom right corner shows the location of Fig. 1 on map of China. The dashed box shows the location of Fig. 2. F_1—Youfangzhuang fault, F_2—Waxiezi fault, F_3—Zhuxia fault, F_4—Gui-Mei fault (Laowan-Songpa fault), F_5—Tongbai-Shangcheng fault, F_6—Xincheng-Huangpi fault.