

The relationship between stratabound Pb–Zn–Ag and porphyry–skarn Mo mineralization in the Laochang deposit, southwestern China: Constraints from pyrite Re–Os isotope, sulfur isotope, and trace element data



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ABSTRACT

The Laochang polymetallic deposit is located in the Sanjiang Tethyan metallogenic province of southwestern China. This deposit contains stratabound (and locally vein-type) Pb–Zn–Ag mineralization and underlying porphyry–skarn Mo mineralization. The stratabound Pb–Zn–Ag mineralization is characterized by massive sulfide ores composed mainly of pyrite, sphalerite, galena, and minor chalcocopyrite, whereas the underlying porphyry–skarn Mo mineralization is characterized by quartz–sulfide veins comprising mainly pyrite, chalcocopyrite, molybdenite, and minor sphalerite and galena. The age and origin of the stratabound Pb–Zn–Ag mineralization has long been debated, and its relationship to the porphyry–skarn Mo mineralization remains unknown. Integrated pyrite Re–Os isotope, sulfur isotope, and in situ trace element data are used here to constrain the age and origin of both types of mineralization and their genetic relationships.

Pyrite related to porphyry–skarn Mo mineralization yields a Re–Os isochron age of 47.3 ± 4.8 Ma, which is consistent with a previous molybdenite Re–Os age of the quartz–sulfide ores and zircon U–Pb ages of the granite porphyry (~ 44 – 50 Ma). Pyrite from the stratabound Pb–Zn–Ag mineralization failed to yield a geologically meaningful age, but associated sphalerite and galena have a Re–Os isochron age of 308 ± 25 Ma (Liu et al., 2015), which is consistent with the Carboniferous age of the host basalts. Pyrite, sphalerite, galena, and chalcocopyrite from the stratabound Pb–Zn–Ag mineralization have $\delta^{34}\text{S}$ values (-2.1 to 0.5% ; average 0.48%) indistinguishable from those of sulfides from the porphyry–skarn Mo mineralization (-4 to 1.9% ; average 0.52%). Initial Os isotope ratios indicate a mainly crustal origin for both types of mineralization. The calculated $(\text{Se}/\text{S})_{\text{fluid}}$ and Co/Ni values of pyrite from the stratabound Pb–Zn–Ag mineralization indicate a mixed sedimentary and hydrothermal origin, with a significant magmatic contribution. The identification of a magmatic component, Eocene sulfide mineralization, and phyllic and propylitization alteration in stratabound Pb–Zn–Ag ores indicates that the magmatic–hydrothermal component reflects the overprinting of Carboniferous volcanogenic massive sulfide mineralization by magmatic–hydrothermal fluids derived from an Eocene granite porphyry.

1. Introduction

The Sanjiang Tethyan metallogenic province (STMP) in the eastern Tibetan Plateau is an important part of the giant eastern Tethyan metallogenic belt (Fig. 1a; Hou et al., 2007). Numerous porphyry Cu, Cu–Mo, and Cu–Au deposits define two sub-parallel porphyry belts in the STMP (Fig. 1a; Hou et al., 2006; Deng et al., 2014; Mao et al., 2014). These porphyry deposits are dated at 33–40 Ma (molybdenite Re–Os age) and are related to India–Eurasia continental collision (Wang et al., 2005; Hou et al., 2006; Deng et al., 2014). To the southwest of the two

porphyry zones, numerous stratabound and minor vein and metasomatic polymetallic deposits occur within the Changning–Menglian back-arc basin (CMBB), including the Laochang Pb–Zn–Ag, Tongchangjie Cu, and Dapingzhang Cu–Zn deposits (Zaw et al., 2007; Wang et al., 2010). Recent exploration at the Laochang deposit has revealed porphyry–skarn Mo mineralization is underlying the stratabound Pb–Zn–Ag orebodies. This discovery has led to more controversy over the origin of the Laochang deposit because of the unknown relationship between the two types of mineralization. Two contrasting viewpoints have been proposed for the formation of the stratabound Pb–Zn–Ag

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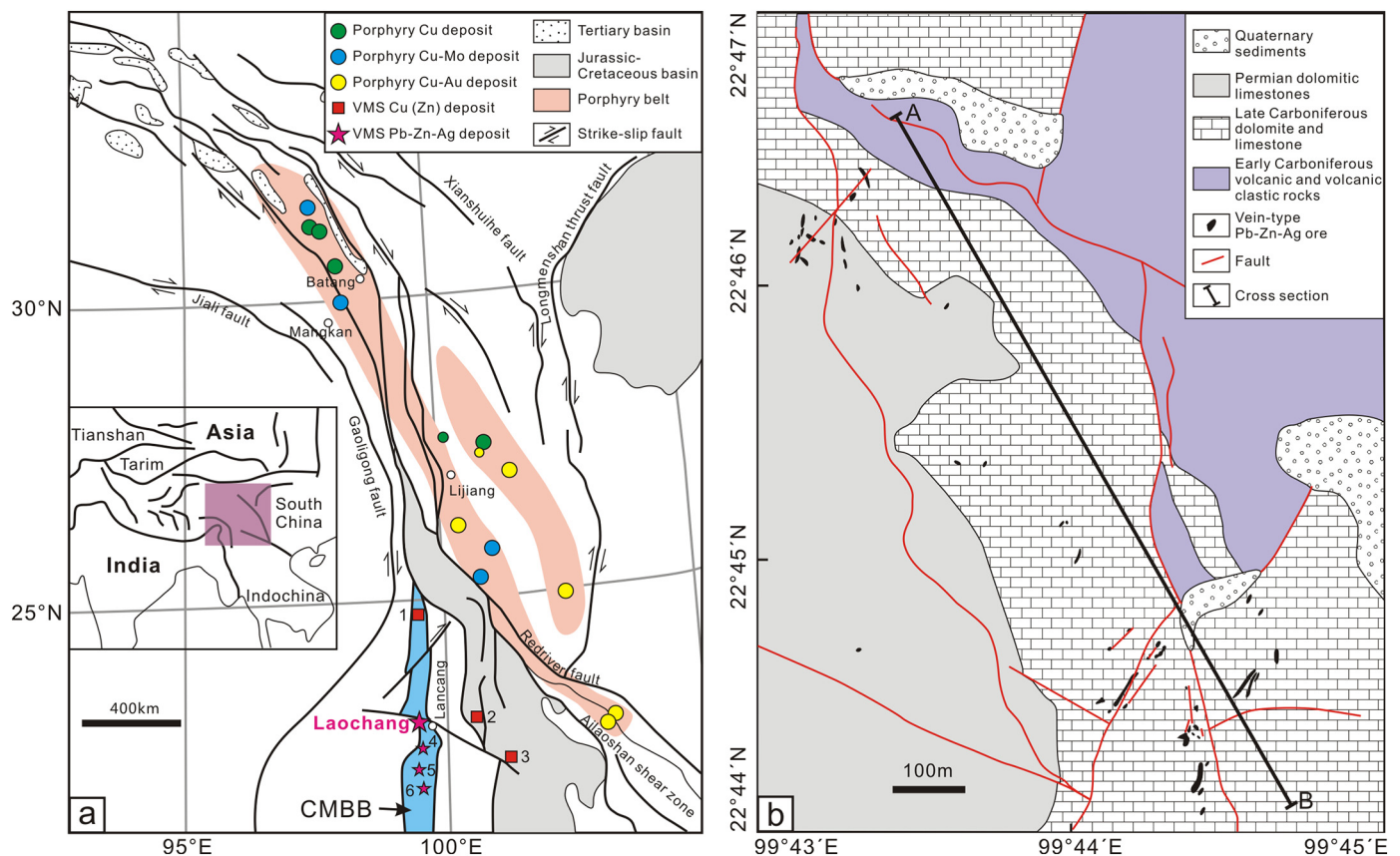


Fig. 1. (a) Simplified geological map showing the tectonic framework of the Sanjiang Tethyan metallogenic province and the distribution of Pb–Zn–Ag and porphyry deposits. Numbers 1, 2, and 3 represent the Tongchangjie, Dapingzhang, and Sandashan Cu ± Zn ± Pb polymetallic deposits, respectively, whereas 4, 5, and 6 represent the smaller Bansha, Nanya, and Padi Pb–Zn–Ag deposits, respectively. (b) Geological map of the Laochang deposit showing the distribution of orebodies and location of the cross-section in Fig. 2 (after Li et al., 2010a). CMBB = Changning–Menglian back-arc basin.

mineralization. Some studies have argued that the stratabound Pb–Zn–Ag mineralization is typical volcanogenic massive sulfide mineralization that is independent of porphyry system (Li et al., 1996; Wang et al., 1997; Li et al., 2009b, 2010a; Yang, 2014; Liu et al., 2015), whereas others have considered the mineralization to be a product of a common magmatic–hydrothermal system related to Eocene granitic intrusions (Ouyang and Xu, 1991; Xu and Ouyang, 1991; X.-D. Deng et al., 2016), because distal carbonate-replacement Pb–Zn–Ag deposits can form around intrusion-centered porphyry Cu system (Sillitoe, 2010). The former viewpoint is based mainly on the different mineralization styles, ages, fluid sources, and lack of a clear contact relationship between the two types of mineralization. The latter model is based on the high Cu contents, magma-dominated ore-forming fluids of the stratabound Pb–Zn–Ag ores (Ouyang and Xu, 1991; Xu and Ouyang, 1991), and similar ages (~46 Ma, Long et al., 2008; X.-D. Deng et al., 2016) of the stratabound Pb–Zn–Ag mineralization and granite porphyry. However, due to unknown sample detail, the ~46 Ma sphalerite Rb–Sr age reported by Long et al. (2008) cannot be evaluated. X.-D. Deng et al. (2016) reported ~46 Ma Re–Os isochron age for pyrite from the stratabound Pb–Zn–Ag mineralization. Lacking of other geochemical data to determine the origin of pyrite makes the meaning of pyrite Re–Os age ambiguous. Therefore, the timing and origin of stratabound Pb–Zn–Ag mineralization in the Laochang deposit has been debated and thus its relationship to porphyry–skarn Mo mineralization remains controversial, which limits our understanding of the Laochang hydrothermal system and sulfide mineralization in the STMP.

Conditions of ore forming processes can be reconstructed from trace element and isotope compositions of sulfides. Re–Os dating of sulfides such as pyrite, arsenopyrite, and chalcopyrite has proven to be a robust and direct tool for constraining the age of ore mineralization (e.g., Stein

et al., 2000; Mathur et al., 2002; Morelli et al., 2004; Morelli and Creaser, 2006; Selby et al., 2009; Huang et al., 2013a, 2013b, 2013c; Hnatyshin et al., 2015; X.-H. Deng et al., 2016; Li et al., 2016; Kelley et al., 2017). Initial Os isotope ratios can also be used to trace the source of Os and, by inference, the metals within the sulfide minerals (e.g., Mathur et al., 2000, 2002; Barra et al., 2017). Sulfur isotope studies of sulfides can also be used to infer the sulfur source(s) of ore-forming fluids (e.g., Sakai, 1968). Pyrite, the most common sulfide, can record changes in fluid chemistry during the evolution of the fluid from which it precipitated (Cook et al., 2009; Reich et al., 2013, 2016; Gregory et al., 2014, 2016; Ingham et al., 2014; Tanner et al., 2016; Tardani et al., 2017). Pyrite is characterized by variable trace element compositions in a variety of mineral deposits (Deditius et al., 2008, 2013; Large et al., 2009, 2015; Zwahlen et al., 2014; Revan et al., 2014; Genna and Gaboury, 2015; Gadd et al., 2016; Mukherjee and Large, 2017). Thus, trace element geochemistry of pyrite can be used to trace the fluid source(s). For example, the Co/Ni and Se/S ratios of pyrite are very powerful in discriminating their origins (e.g., Bajwah et al., 1987; Huston et al., 1995a, 1995b; Layton-Matthews et al., 2005; Gregory et al., 2015).

Here we present an integrated study of Re–Os isotopes, sulfur isotopes, and in situ trace elements in pyrite from the stratabound Pb–Zn–Ag and porphyry–skarn Mo mineralization from the Laochang deposit. Combined with previous data (Li et al., 1995, 2015; Zhao et al., 2012; Liang, 2014), this new dataset is used to constrain the timing, origin, and relationships of these two types of mineralization.

2. Geological background

The STMP is composed of a mosaic of accreted terranes and blocks

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