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Ore-forming conditions and genesis of the Huogeqi Cu–Pb–Zn–Fe deposit in the northern margin of the North China Craton: Evidence from ore petrologic characteristics

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ABSTRACT

The Huogeqi Cu–Pb–Zn–Fe deposit is located in the Langshan district in the western segment of the northern margin of the North China Craton. The deposit is hosted by upper greenschist-lower amphibolite facies (550–650 °C) rocks of the Langshan Group. Most orebodies are hosted in a shear zone that developed in parallel with the sedimentary bedding of the Langshan Group. Fe was precipitated coeval with the deposition of the host rocks (i.e., a syngenetic origin), whereas Cu, Pb and Zn were precipitated in hydrothermal systems postdating formation of the host rocks (i.e., an epigenetic origin). The hydrothermal mineralization process can be subdivided into two stages: 1, a main stage with predominant Cu–Pb–Zn mineralization stage where ore-forming structures are characterized by brittle–ductile and brittle-shear deformation. The main stage sulfide veins cut the mylonite fabrics of the host rocks. Mineral paragenesis and compositions indicate that main-stage Cu mineralization took place at 330–440 °C and 3.4–3.9 kbar. This pressure–temperature (P–T) condition is consistent with that of the brittle–ductile transition zone but lower than that of the peak metamorphism of the host rocks. Compared with Cu mineralization, the main stage Pb–Zn mineralization took place at relatively lower temperature and pressure. The syngenetically formed Fe orebodies and iron formations in the Huogeqi deposit were favorable sites for epigenetic Cu precipitation. The H_2S-rich Cu fluids would have reacted with Fe in the host rocks when flowing through Fe orebodies and iron-formations. Such a reaction would have led to a reduction in $_{H_2S}$ of the ore-forming fluids and consequently Cu precipitation; 2, the late stage Cu-mineralization is of less economic importance, characterized by open-space filling textures and a low-temperature mineral assemblage that constrains the ore-forming temperature as lower than 330 °C. This late stage mineralization took place in an epithermal-like hydrothermal system at a shallower crustal depth.

1. Introduction

Discriminating between metamorphogenic and metamorphosed deposits in metamorphic terranes is sometimes a difficult task but it is essential for proposing and confirming genetic models. Metamorphogenic deposits are epigenetic hydrothermal deposits that formed in a metamorphic environment. In contrast, metamorphosed deposits are formed prior to regional metamorphism and many are of syngenetic origin (Cartwright and Oliver, 2000). An appropriate model is important because it provides insights into the geological processes involved in mineralization, and provides a basis for exploration methods.

The Huogeqi deposit is an example of a Cu–Pb–Zn–Fe polymetallic deposit hosted in a greenschist–amphibolite facies terrane. It is regarded as a base-metal deposit typical of the Langshan district, which is one of the most important Cu–Pb–Zn polymetallic ore belts in the northern margin of the North China Craton (NCC). A Mesoproterozoic exhalative-sedimentary (i.e., syngenetic) model is the most popular genetic model proposed for the Huogeqi deposit (Cao, 2002; Fei et al., 2004; Geng, 1997; Huang et al., 2001; Peng and Zhai, 2004; Peng et al., 2006, 2007; Zhai et al., 2008). This model stresses that the deposit was deposited simultaneously with its host rocks and later underwent metamorphism, deformation and a limited degree of syn-metamorphic remobilization. The syngenetic, metamorphosed model is supported by macroscopic and mesoscopic features (e.g., the host rift sequences, the stratiform appearance of the orebodies, the lithological control on mineralization, laminated and banded appearances of ores) and geochemical characteristics (e.g., the Co and Ni contents of pyrite and S- and Pb-isotope signatures) (Cao, 2002; Chen, 2009; Fei et al., 2004; Geng, 1997; Huang et al., 2001; Peng and Zhai, 2004; Peng et al., 2006, 2007; Zhai et al., 2008). However, the macroscopic and mesoscopic features can be

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alternatively interpreted within an epigenetic genetic model, a hypothesis that will be discussed in this paper. The geochemical data are very difficult to interpret due to their complexity. Therefore they are always interpreted as the result of superimposition of more than one geological event. An alternative genetic model, first proposed by Zhang and Wang (2001, 2002), hypothesized that the Huogeqi deposit was genetically controlled by a shear zone. Based on structural studies, it was proposed that the host rocks were strongly mylonitized and that mineralization was controlled by shearing. However, some of the basic features necessary for a shear zone-controlled epigenetic deposit model remain equivocal, such as the relative timing of regional metamorphism, tectonic deformation and mineralization, the ore-forming physicochemical conditions and the mechanisms of metal precipitation. Additionally, the Cu–Pb–Zn orebodies in the Huogeqi deposit are accompanied by some Fe orebodies, which are currently being exploited for iron. These are similar in geometry to the Cu–Pb–Zn orebodies and the two types are closely spatially associated with one other. A syngenetic origin is widely accepted for the Fe orebodies, thus the coexistence and similarity between the different orebodies in the Huogeqi deposit have evoked some researchers to consider that both types of orebodies are of syngenetic origin. Therefore, any epigenetic model needs to also account for the coexistence of Fe and Cu–Pb–Zn orebodies within the Huogeqi deposit.

To discriminate between metamorphogenic and metamorphosed deposits and to reveal the relative timing of mineralization and relevant geological events, the most effective method is a detailed study of ore fabrics and the mineral paragenesis (Cartwright and Oliver, 2000; Marshall et al., 2000). However, no detailed microscopic study of the Huogeqi deposit had been carried out prior to the present work.

Based on detailed petrographic and mineralogical study, in combination with electron probe microanalysis, geothermobarometry and phase equilibrium calculations, a sustainable epigenetic genetic model can be proposed for the Huogeqi deposit. The genetic model presented below involves an account of the relative timing of mineralization and relevant geological events, the ore-forming physicochemical conditions, the mechanism of mineral precipitation and the ore-controlling factors. Our new genetic model accounts for the observed shear-zone controlled character of the deposit, the macroscopic and mesoscopic features and the relationship between the Fe and Cu–Pb–Zn mineralization.

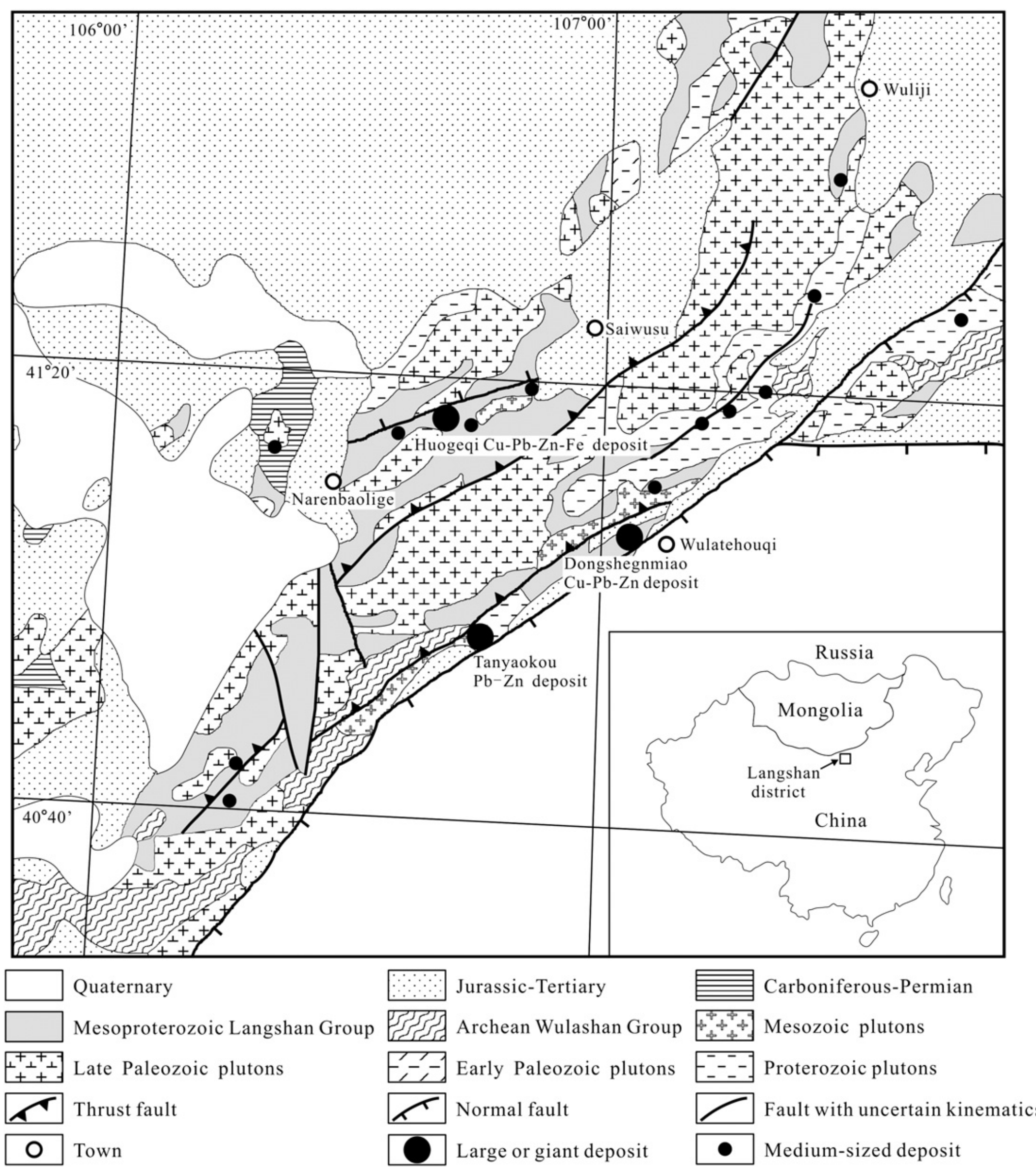

Fig. 1. Regional geology of the Langshan district, northern China (modified from Peng et al., 2007).