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Geochronological and geochemical constraints on the genesis of the Huanren skarn Cu–Zn deposit, northeast China

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ABSTRACT

The Huanren skarn Cu–Zn deposit is located in southeastern Liaoning on the eastern edge of the North China Craton (NCC). In this paper, we present a study on the geochronologic, geochemical and Sr–Nd–Hf and S isotopic data for the magmatic rocks and sulfide minerals exposed in the deposit. Laser ablation inductively coupled plasma mass spectrometry (LA–ICP–MS) dating of zircon grains from two mining pits in the monzodiorite yields ages of 128.2 ± 1.1 Ma and 128.6 ± 1.5 Ma; these results indicate that the magmatism in the Huanren Cu–Zn deposit might have occurred in the Early Cretaceous. Geochemically, the Huanren monzodiorite belongs to the high-K calc-alkaline and shoshonitic series, is enriched in Rb, Ba, and K and is depleted in Nb, Ta, and Ti. The rocks also have relatively high ($^{87}Sr/^{86}Sr)_i$ (0.7091–0.7099) and low εNd(t) (−13.2 to − 10.3) and εHf(t) values (−14.3 to − 7.8). The Sr–Nd–Hf isotopic data for the monzodiorite indicate that the magma may be derived from mixed sources of the crust and mantle. The $\delta^{34}S$ values of chalcopyrite, galena and pyrite range from 4.4‰ to 5.8‰, with an average of 5.1‰, indicating that the sulfur in the deposit was mainly derived from a magmatic source. The Huanren Cu–Zn deposit resulted from the magmatism and mineralization induced by the rollback of the Paleo-Pacific Plate.

1. Introduction

The southeastern section of Liaoning Province forms part of Northeast China and lies along the eastern edge of the North China Craton (NCC), an area that hosts numerous Cu, Au, and Pb–Zn deposits comprising VMS, porphyry and associated skarn deposits, including the Hongtoushan, Shujigou, Huatong, Wanbaoyuan, Xiaowanggou, Sanjiazi, and Huanren Cu (Zn) deposits, the Qingchengzi Pb–Zn–Au polymetallic ore district, the Maoling and Wulong Au deposits, and the Cu–Mo mineralization formed during the Archean, Jurassic, and Cretaceous (Zhang et al., 2016). In comparison, the porphyry and skarn Cu mineralization formed mainly during the Cretaceous in the east-central part of Jilin Province (Zhang et al., 2015). However, known Cu deposits and proven reserves are far fewer and smaller than those of Au and Pb–Zn deposits, and this apparent dichotomy has attracted much research interest.

The Huanren deposit is an important Cu–Zn polymetallic deposit that is located in southeastern Liaoning and abounds in lead, zinc, copper and iron, which have been mined for more than 100 years. Many studies have focused on the geology (Zhang, 2009), geochemistry (Zhang, 2009; Leng, 2013), ore genesis and predictive models (Song, 2010; Hu et al., 2008), although the timing of formation, the source region of the magmas and the tectonic setting of the deposit remain unclear. Previously, the timing of mineralization has been inferred using whole-rock K–Ar ages of 116–133 Ma (Zhang, 1992; Song, 2010), as well as zircon U–Pb ages of 123–126 Ma and 124–129 Ma for the igneous rocks in the Huanren area (Lei et al., 2014; Zhao, 2015). In addition, Zhang (1992, 2009) used the geochemical composition of mineralization-related rocks associated with the Huanren deposit to suggest that the magmas that formed these intrusions were derived from the mantle. Other geologists argued that the ore-forming minerals were associated with the sedimentary strata (Leng, 2013). However, despite extensive study, the timing and processes that formed the deposit remain unclear, primarily due to a lack of precise geochemistry and geochronology for this deposit. Here, we present zircon U–Pb geochronology, geochemical, Sr–Nd–Hf and S isotopic data for mineralization-associated monzodiorite and sulfide minerals. Based on geochronological and geochemical data, we discuss the timing of the crystallization age of the monzodiorite, the characteristics of the source region of the magmas and ore-forming minerals and the geodynamic setting.

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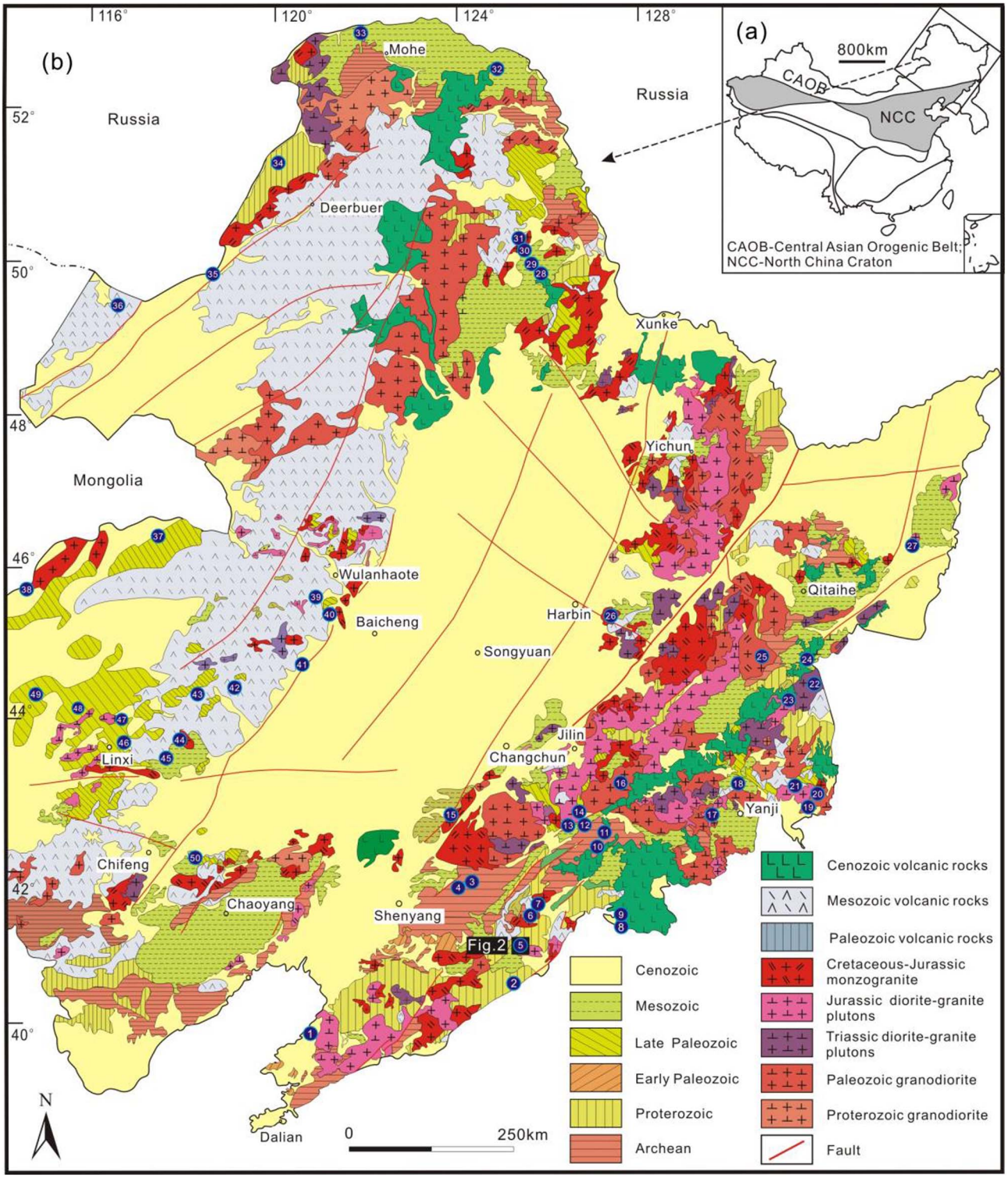

Fig. 1. Map showing the distribution of Cu deposits in northeast China. Data sources and deposit numbers are listed in Table 1.

2. Geological setting and Huanren Cu–Zn deposit characteristics

The NCC is one of the oldest cratons in the world (Liu et al., 1992), which has undergone very complicated evolution history and has recorded almost all the important geological events (Zhai, 2010; Qiu et al., 2016a). The southeastern part of Liaoning province is located on the eastern edge of the NCC (Fig. 1a). The tectonic evolution of this region was affected by the development of a Proterozoic rift, the evolution of the Paleo-Asian Ocean, the Xing'an–Mongolia Orogeny and subduction of the Paleo-Pacific Plate. Therefore, various genetic types of Cu, Au, Mo, and Pb–Zn deposits were developed in the area. The study area is located in the southeastern part of the Liaoning Paleoproterozoic rift. The exposed rocks in study area include the Paleoproterozoic Liaohe Group and the Neoproterozoic Sinian, Early Paleozoic Cambrian and Ordovician, Late Paleozoic Carboniferous and Permian, Mesozoic Jurassic and Cretaceous, and Quaternary rocks (Fig. 1b). The structure of the area is dominated by the NW-trending Xinbin–Yahe fault, the NE Yalu River deep-fracture zone and the