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Origin of hydrothermal deposits related to the Emeishan magmatism

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ABSTRACT

In the western Yangtze Block, southwest China, there are many hydrothermal native copper ore deposits and Zn–Pb ore deposits. All of these hydrothermal ore deposits are spatially associated with the Permian Emeishan flood basalts (EFBs), although they are much younger than the EFB. The maximum time interval between the hydrothermal ore deposits and the EFB is over 100 Ma. During this time interval, there is no documented magmatism in this region, and many studies indicate that magmatic fluids played important roles in the formations of these deposits. Thus, the origin of these hydrothermal deposits has long been controversial. In this study, we present a model that considers the underplated Emeishan basalts at the base of the crust as the main source of the ore-forming metals and fluids and present thermal simulation results of the evolution of the underplated Emeishan basalt. The results indicate that the underplated basalts begin to release metal-bearing fluid at 30 Ma after the onset of the underplating, consistent with age data of the oldest hydrothermal deposits in this region, such as the Huize Pb–Zn and native Cu ore deposits. The simulation results also indicate that the releasing ore-forming fluid from the crystallising underplated basalts can last over 100 Ma, which almost covers the entire age data available for the hydrothermal deposits, and thus successfully demonstrates the lack of temporal association between the hydrothermal deposits and the EFB. The model is developed primarily for the origin of the hydrothermal mineralisation in the SYG province, but it has general applicability to other sediment-hosted Pb–Zn deposits around the world.

1. Introduction

In the western Yangtze Block (Fig. 1), southwest China, there are many hydrothermal native copper ore deposits (Bing-Quan et al., 2007) and Zn–Pb ore deposits (Liu and Lin, 1999), including the world-class Huize Zn–Pb deposit with 7 million tons (Mt) of Pb and Zn metals (Han et al., 2007; Huang et al., 2004). These Zn–Pb ore deposits, which form the important Sichuan–Yunnan–Guizhou (SYG) Pb–Zn metallogenic province, contain total Pb and Zn metals of more than 20 Mt at grades of >15% Pb + Zn and have been the major source of base metals in China in the past several decades (Cromie et al., 1996; Liu and Lin, 1999). These native copper and Zn–Pb ore deposits are spatially associated with the Permian Emeishan flood basalts (EFBs) (Fig. 1), and stable isotope studies indicate that magmatic-hydrothermal fluids were involved in the ore-forming processes, as for the native copper ore deposits (Li et al., 2004) and the Zn–Pb deposits (Huang et al., 2004; Zhou et al., 2013b). This has led many workers to suggest that the EFB was an important source of the ore-forming metals and fluids (Bing-Quan et al., 2007; Han et al., 2007; Huang et al., 2004, 2010). However, the Pb–Zn and native copper deposits (132–228 Ma) (Bing-Quan et al., 2007; Li et al., 2007; Zhou et al., 2013c) in the SYG province are much younger than the Permian EFB (259–263 Ma) (He et al., 2007; Zhou et al., 2002) (Table 1). The maximum time interval is over 100 Ma, and during this time interval, there is no documented magmatism in this region (Huang et al., 2004). Thus, the origin of this ore system in the SYG province remains controversial.

In this study, we present a model that considers the underplated Emeishan basalts at the base of the crust as the main source of the ore-forming metals and fluids and present thermal simulation results of the evolution of the underplated Emeishan basalt. The results indicate that the underplated basalts would eventually release metal-bearing fluid after several tens of millions of years and thus successfully interpret the lack of temporal association between the hydrothermal deposits and the EFB. The model is developed primarily for the origin of the hydrothermal mineralisation in the SYG province, but it has general applicability to other regions, such as the Keweenawan native copper deposit in Michigan (Bornhorst et al., 1988; Davis and Paces, 1990) and the giant Broken Hill Pb–Zn deposit (Crawford and Maas, 2009).

2. Geology of the hydrothermal deposits in the SYG province

The Pb–Zn and native copper deposits in the SYG province have an intimately spatial association with the Permian Emeishan flood basalts (Bing-Quan et al., 2007; Han et al., 2007; Huang et al., 2004) (Fig. 1B). The total maximum thickness of basaltic flows is ~5 km located in the

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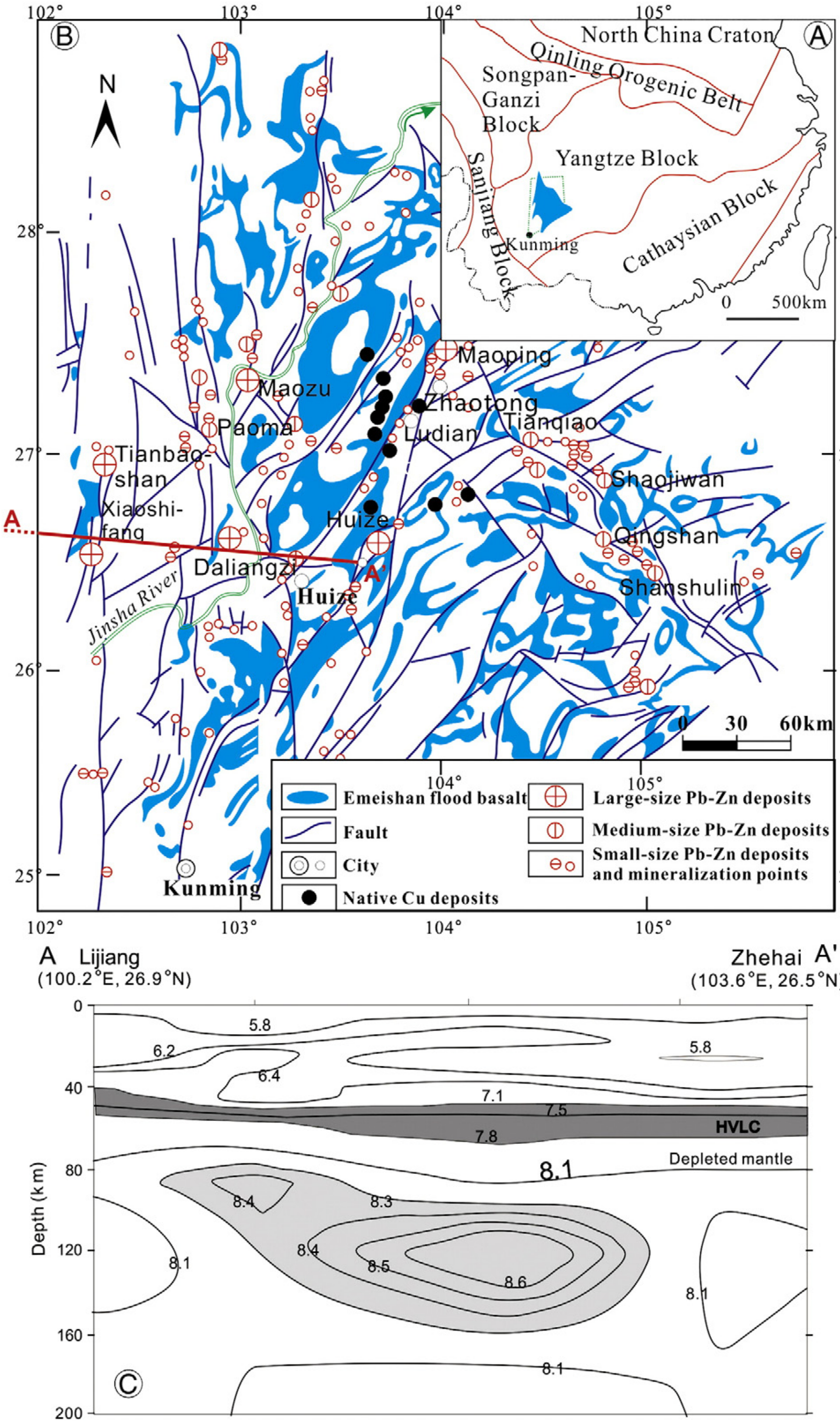

Fig. 1. Regional geological and geophysical maps. Panel A: Tectonic geological sketch; panel B: Regional geological map of the SYG Pb–Zn and native Cu metallogenic province, SW China, showing the distribution of the Permian Emeishan flood basalts, Pb–Zn and native Cu deposits, modified from Bing-Quan et al. (2007) and Huang et al. (2010)). Panel C: The seismic tomographic velocity structure of the crust and upper mantle beneath the ELIP, modified from Liu et al. (2001). The location of the seismic profile from Lijiang to Zhehai (line A–A′) is shown in panel B. HVLC — high-velocity lower crust.

western portion (i.e. Yunnan) of the Emeishan large igneous province (ELIP), whereas in the eastern portion (i.e. Guizhou) total flow thickness is only a few hundred metres (Pirajno, 2013; Shellnutt, 2013; Xu et al., 2001). The EFB is overlain by the Upper Permian Xuanwei Formation, a terrestrial coal-bearing clastic sequence (including silicalite, conglomerate, sandstone and coal beds), and is underlain by the Early Permian Maokou Formation, which consists of carbonates. The overlying Lower Triassic Feixianguan Formation consists of terrestrial sandstones and