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Zinc, sulfur and lead isotopic variations in carbonate-hosted Pb–Zn sulfide deposits, southwest China

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ABSTRACT

The Sichuan–Yunnan–Guizhou Pb–Zn metallogenic province in the western Yangtze Block, southwest China, contains more than four hundred Pb–Zn deposits with more than 200 million tons of Pb–Zn ores at mean grades of 5 wt.% Pb and 10 wt.% Zn. These deposits are hosted in Sinian (Ediacaran) to Permian carbonate rocks and are structurally controlled by thrust fault–fold structures, and are spatially associated with the late Permian ~ 260 Ma Emeishan flood basalts. Two representative low temperature hydrothermal Pb–Zn sulfide deposits, the Tianqiao and Banbanqiao deposits in the southeastern part of the Sichuan–Yunnan–Guizhou Pb–Zn metallogenic province are selected for Zn–S–Pb isotopic analyses. Sphalerite from the Tianqiao deposit has δ^{66}Zn values ranging from −0.26 to +0.58‰ relative to the JMC 3–0749L zinc isotope standard, whereas δ^{66}Zn values of sphalerite from the Banbanqiao deposit range from +0.07 to +0.71‰. The zinc isotopic composition of sphalerite from both deposits increase from early to final mineralization stage. In addition, sphalerite from the center (near to bottom) part of the No. 1 ore body in the Tianqiao deposit has lower δ^{66}Zn values (−0.01 to +0.43‰) than those (+0.11 to +0.57‰) in the periphery (near to top). Sinian to Permian sedimentary rocks and Permian Emeishan flood basalts, the potential zinc metal source rocks, have δ^{66}Zn values range from −0.24 to +0.17‰ and from +0.32 to +0.44‰, respectively. The majority of the hydrothermal sphalerite has heavier zinc isotope than the country rocks, precluding the mixing of multiple zinc sources as the key factor controlling the spatial and temporal variations of zinc isotope. Therefore, the increased δ^{66}Zn values from the early to late stage and from the center to top could be due to kinetic Raleigh fractionation. Sphalerite from the Tianqiao and Banbanqiao deposits has δ^{34}S values ranging from +10.9 to +14.8‰ and from +3.9 to +9.0‰, respectively, lower than Cambrian to Permian marine sulfates (+15 to +35‰) and sulfate-bearing evaporates (+15 to +28‰) in the Devonian to Permian carbonate host rocks. Sulfur of the Pb–Zn ores from both deposits is interpreted as the result of thermal chemical sulfate reduction of evaporates in the sedimentary rocks, most likely the host rocks. Sphalerite from the Tianqiao deposit has Pb isotope similar to that of age-corrected Devonian to Permian carbonate host rocks, whereas sphalerite from the Banbanqiao deposit has Pb isotope similar to that of age-corrected underlying Precambrian basement rocks. Therefore, at least lead in the Tianqiao and Banbanqiao deposits was mainly originated from the host rocks and the underlying basements, respectively. Zn–S–Pb isotopic studies of sphalerite from both deposits indicate that sources of metals and sulfur in the hydrothermal fluid for the Tianqiao deposit are the Paleozoic carbonate host rocks, whereas for the Banbanqiao deposit the sources are the Precambrian basements and the Paleozoic carbonate host rocks, respectively.

1. Introduction

Recent advances in multiple collector inductively coupled plasma mass spectrometry (MC-ICP-MS) allow the analysis of the isotopic compositions of transition metals (such as Cu, Zn and Fe) from hydrothermal ore deposits (e.g., Fernandez and Borrok, 2009; Fujii et al., 2011; Gagnevin et al., 2012; Haest et al., 2009; Ikeihata and Hirata, 2012; Larson et al., 2003; Maréchal et al., 1999; Markl et al., 2006; Mason et al., 2005; Mathur et al., 2009, 2010, 2012; Rouxel et al., 2004; Wang et al., 2011; Zhu et al., 2000, 2002). Of these, the zinc isotope system has seen an increasing interest as a potential tool for understanding geochemical processes of zinc transportation and deposition in hydrothermal systems (Gagnevin et al., 2012; John et al., 2008; Kelley et al., 2009; Mason et al., 2005; Toutain et al., 2008). Studies suggest that three main processes can be used to explain variations of

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zinc isotope during precipitation: kinetic Raleigh fractionation (Gagnevin et al., 2012; John et al., 2008; Kelley et al., 2009; Maréchal and Sheppard, 2002; Wilkinson et al., 2005), temperature gradient (Mason et al., 2005) and mixing of multiple zinc sources (Wilkinson et al., 2005). However, the evolutions of zinc isotope in hydrothermal deposits and the most important controlling factors are still unclear.

In the western Yangtze Block, SW China, the Sichuan–Yunnan–Guizhou Pb–Zn metallogenic province hosts over 400 Pb–Zn deposits with more than 200 million tons (Mt) of P–Zn ores grading 5 wt.% Pb and 10 wt.% Zn, making it one of the world's largest Pb–Zn producers (Deng et al., 2000; Hu and Zhou, 2012; Liu and Lin, 1999; Zhou et al., 2013a, 2013b). This metallogenic province contains several world-class deposits, such as the Huize Zn–Pb–Ge–Ag deposit (Han et al., 2007; Zhou et al., 2001) and the Daliangzi Zn–Pb–Cd deposit (Zheng and Wang, 1991). The deposits are hosted in Sinian (Ediacaran) to Permian carbonate rocks and are structurally controlled by thrust fault–fold structures and are spatially associated with the late Permian ~ 260 Ma mantle plume-derived Emeishan flood basalts (Han et al., 2007; Huang et al., 2010; Liu and Lin, 1999; Zhou et al., 2001, 2002a, 2011). Previous studies focused on the geology and origin of these deposits (e.g., Deng et al., 2000; Han et al., 2004, 2007, 2012; Huang et al., 2003, 2010; Li et al., 2007a, 2007b; Zheng and Wang, 1991; Zhou et al., 2001, 2011, 2013a, 2013b, 2013c) demonstrating that those deposits differ from the type of magmatic hydrothermal,

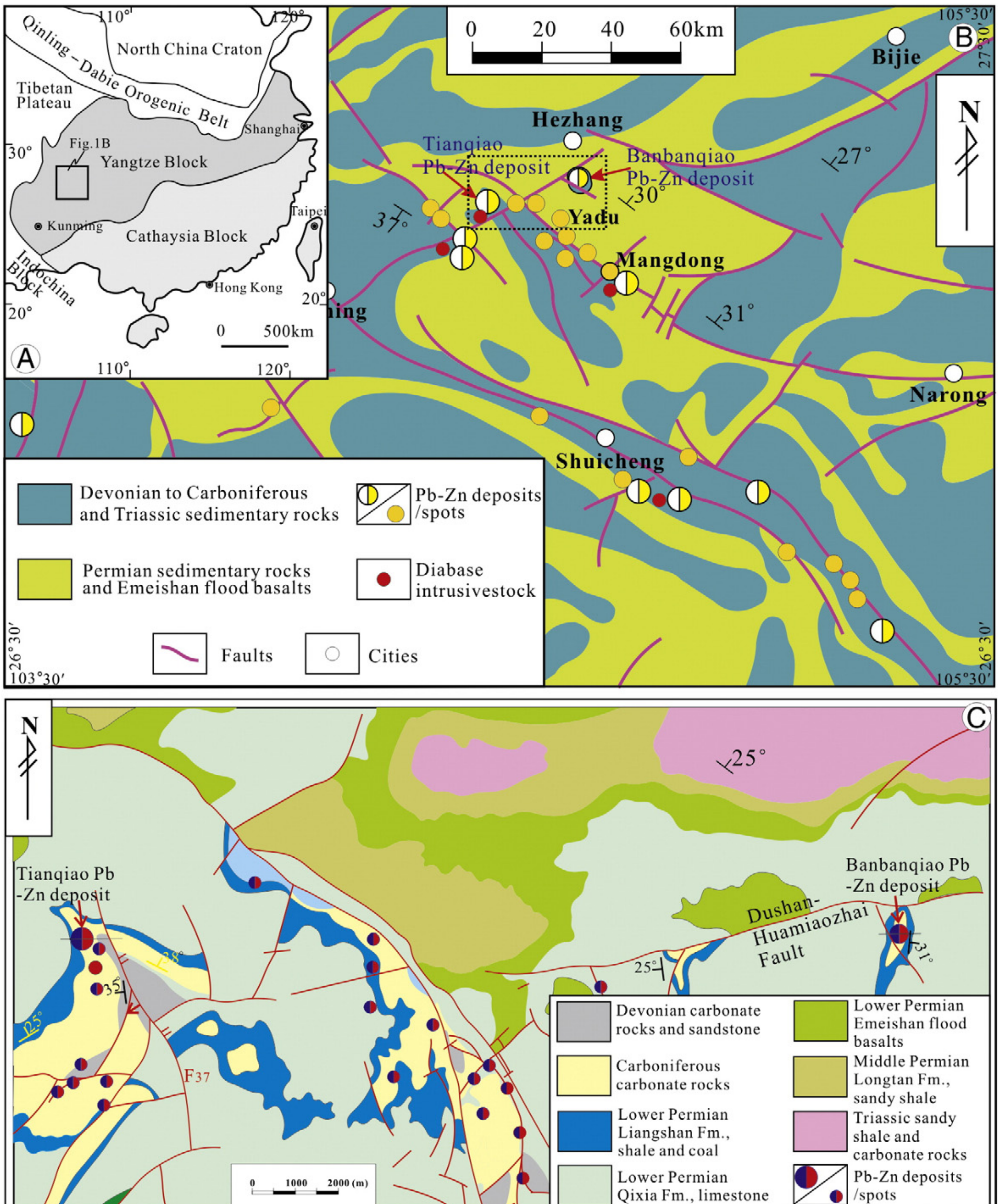

Fig. 1. The Sichuan–Yunnan–Guizhou Pb–Zn metallogeinc province is located in the western Yangtze Block, southwest China (A); geological map of the southeastern part of the Sichuan–Yunnan–Guizhou Pb–Zn metallogeinc province (modified from Zhou et al., 2011) shows the strata, faults and distribution of Pb–Zn deposits (B); geological map of the Tianqiao to Banbanqiao Pb–Zn deposits shows distributions of Devonian to Triassic sedimentary rocks, late Permian Emeishan flood basalts, structures and Pb–Zn deposits (C).