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Zircon U-Pb Dating and In Situ O Isotopes of the Archean Hongtoushan VMS Cu-Zn Deposit, China

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1 Introduction

The North China Craton (NCC) is well endowed with numerous Precambrian ore deposits, providing an ideal opportunity to understand the relationship between large-scale mineralization and Precambrian evolution of this craton. The Hongtoushan deposit is the largest Archean VMS Cu-Zn deposit in China. Previous works show that the protolith of the VMS-hosting gneiss was mafic-acid volcanic rocks (Zhai et al., 1985) and the Cu-Zn mineralization time was as early as > 2.6 Ga (e.g., Zhang et al., 1984). An understanding of the geochronology and source characteristics through time would offer insight into crustal growth and the mineralization gneiss.

2 Regional and Local Geology

The Hongtoushan VMS Cu-Zn deposit is located in the northeastern margin of the NCC. The NCC is one of the oldest cratons in the world, consists of Archean to Paleoproterozoic metamorphic basement overlain by Mesoproterozoic to Cenozoic unmetamorphosed cover. The NCC is dominated by Neoarchean igneous rocks that were formed during two magmatic events at 2.8–2.7 Ga and 2.55–2.50 Ga (Zhai and Santosh, 2011; Zhao and Cawood, 2012; and references therein), representing two important episodes of crustal growth.

The Qingyuan terrane is dominated by Early Archaean grey gneisses. Several Archean greenstones belts occur along a NE-SW strike within the TTG rocks. These greenstones are generally referred to as the Qingyuan Group, which are further divided into the Jinfengling and Hongtoushan Formations (Zhang et al., 1984; Shen et al., 1994b). The Hongtoushan deposit has metal reserves of 0.5 Mt Cu at grades of 1.5% to 1.8% and 0. 7 Mt Zn at 2.0% to 2.5%. The host rocks of the massive sulfide ores have been metamorphosed to upper amphibolite facies. The main orebodies, although intensely deformed, are stratiform and were stratigraphically controlled by the 'rhythmic member' in the upper part of the Hongtoushan Formation. This thin layer is composed of rhythmic interbeds of biotite plagioclase gneisses and amphibolite gneisses (Gu et al., 2007).

3 Zircon U-Pb Age and O isotopes

All the samples were collected at the underground mining level of -827 m, including host metamorphic rocks of amphibolite gneiss and biotite plagioclase gneiss and disseminated, massive, banded Cu-Zn ores. The zircons from amphibolite gneiss sample were measured by LA-ICP -MS and the rest grains were by Cameca 1280IMS; *In situ* zircon O isotopic analyses were conducted on zircons that were previously dated using Cameca 1280IMS.

3.1 Zircon U-Pb ages

In the amphibolite gneiss, based on the CL images and zircon U-Pb analyses, two groups of zircon are distinguished and interpreted to be all detrital origin (Fig. 1). (1) The old group, with Th/U ratios ranging from 0.09 to 0.72, yields two imprecise age of 3106 +20/–10 Ma and 2626+29/–3 Ma, respectively, indicating the existence of ancient supercrustal rocks in this area as old as ~2.63-3.11 Ga. (2) The magmatic zircons, with Th/U ratios ranging from 0.17 to 1.87, yield an age of 2570 +2/–1 Ma, most likely representing an earlier magmatic event. The zircons from the biotite plagioclase gneiss are igneous origin, with Th/U ratios ranging from 0.21 to 0.48, and define a weighted mean $^{207}Pb/^{206}Pb$ age of 2507 +4/–1 Ma, which precisely determine the formation age of the VMS-hosting, interbedded volcanic rocks.

In the Cu-Zn ores, most zircon grains have typical core-rim structure. The core domains have Th/U ratios ranging

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from 0.31 to 0.69 and yield a weighted mean $^{207}Pb/^{206}Pb$ age of 2568±5 Ma (not shown). The rim domains are hydrothermal origin, with Th/U ratios ranging from 0.01 to 0.34, and define a hydrothermal event at ca. 2507 Ma. It indicates that the Cu-Zn mineralization has a genetic relationship with later felsic volcanism.

Therefore, the ages of the Hongtoushan VMS-hosting volcanics and Cu-Zn mineralization are defined at ca. 2507 Ma and the volcanism played an important role in the processed of the Hongtoushan Cu-Zn mineralization.

3.2 Oxygen isotopes

The *in situ* O-isotope analyses were conducted on the same zircon zones used for U-Pb analysis. The $\delta^{18}O$ values of magmatic zircons from the biotite plagioclase gneiss range from 5.3 to 5.8 ‰ (averaging 5.5 ‰), similar to modern mantle $\delta^{18}O$ value ($\delta^{18}O$ =5.3 ± 0.6 ‰; Valley et al., 1998; Cavosie et al., 2009). The zircons from disseminated ore have a homogenous O isotopic composition, with $\delta^{18}O$ ranging from 7.0 ‰ to 7.7 ‰ (averaging 7.4 ‰) except one anomalous value of 6.7 ‰. The $\delta^{18}O$ values of zircons from the massive sulfide ore and the banded ore occur as two groups according to their core-rim structure. The values of cores have a typical characteristic of modern mantle ranging from 5.3 ‰ to 5.8 ‰ (averaging 5.5 ‰), whereas the values of rims range from 5.6 ‰ to 7.0 ‰ (averaging 6.2 ‰), indicating a metamorphic or hydrothermal origin. A higher $\delta^{18}O$ in the rim than its core demonstrates input of O-enriched materials during overgrowth. The successive elevation of $\delta^{18}O$ indicates increasing input of high-$\delta^{18}O$ materials under high-temperature during evolution of the magmatic hydrothermal convective system.

4 Conclusions

On the basis of the zircon geochronology and *in situ* oxygen isotopic analyses, we can conclude the following.

(1) The amphibolite and biotite plagioclase gneisses hosting the Hongtoushan deposit formed at ca. 2510 Ma.

(2) The Hongtoushan Cu-Zn mineralization occurred at ~2510 Ma and has a genetic relationship with the felsic volcanism.

(3) The hydrothermal fluid of Cu-Zn mineralization is sourced from O-enriched post-magmatic hydrothermal solution.

(4) The protoliths of the gneisses have mantle-like source, likely indicating an intensively extensional setting related to the rift or mantle plume that formed the large scale volcanogenic massive sulfide Cu-Zn mineralization at Hongtoushan.

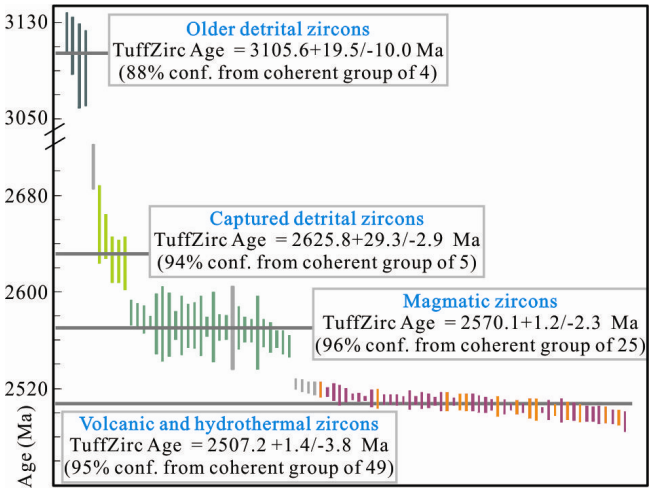

Fig. 1. Zircon U-Pb analysis results in the Hongtoushan VMS Cu-Zn deposit.

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