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In-situ sulfur isotope analysis of pyrite from the Pangjiahe gold deposit: Implications for variable sulfur sources in the north and south gold belt of the South Qinling orogen

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ABSTRACT

The sedimentary- and granite porphyry-hosted Pangjiahe gold deposit is located in the north belt of the South Qinling Orogen, with a proven reserve of 38 t Au at 6.3 g/t. A total of 26 samples, from various rock types and locations from the Panjiahe deposit, were taken in order to determine the paragenesis, sulfur source and absolute age of mineralization. Magmatic activities of ca. 240 Ma occurred around the whole study area, which is common in the northwest part of the West Qinling orogen. Field observations confirm that the emplacement of granite porphyry dykes is earlier than the gold mineralization, because they were both altered and mineralized. Moreover, post ore stage diabase dykes, which cut cross the ore bodies, display an age of ca. 220 Ma. Zircons from strongly mineralized granite porphyry samples show typical hydrothermal trace element characteristics. Theses zircons return a concordia age at ca. 230 Ma. Therefore, we infer that the ore-forming age of the Pangjiahe deposit is at ca. 230 Ma.

Optical microscopy, EMPA and LA-(MC)-ICPMS have been used to determine the physical and chemical features of pyrite. Five stages of pyrite have been identified in mineralized phyllite and granite porphyry rocks. Diagenetic pyrite in phyllite, Py1-P, displays a wide range of $\delta^{34}S$ (−1.5% to +9.4%). The magmatic pyrite in the granite porphyry, Py1-G, display relatively narrow range of $\delta^{34}S$ (+2% to +5%) consistent with magmatic sulfur. The main ore stage pyrite in both rocks, Py2 (Py2-P and Py2-G), is the most common sulfide in the deposit. Py2 grains predominantly show oscillatory zoning and either replace or overgrown the Py1-P and Py1-G, or occur as individual fine grains. Arsenopyrite is typically associated with Py2. Pyrite grains in late stage quartz (Qz) veins that cross cut phyllite and granite, Py-Qz, display weak oscillatory zoning. Native gold is commonly observed as inclusions in the Py-Qz grains or within/proximal to quartz veins. Py3 pyrite (Py3-P and Py3-G), which also belong to the later ore stage and can be distinguished by the native gold inclusions in them, all occur as the outer rims that overgrown or replace on Py2. The ore stage Py2, Apy, Py-Qz and Py3 have a similar narrow range in sulfur isotopic composition, from +8% to +10%. This range is slightly lower than the age equivalent SEDEX Pb-Zn deposits situated in graben basins to the East, but totally different from the earlier Py1-P and Py1-G. EMPA element mapping and spot analyses, and in-situ sulfur isotope analyses indicate that the ore stage pyrites in both phyllite and granite rocks have similar major element chemistry and sulfur isotopic composition, indicating that they are likely sourced from the same ore fluids. Therefore, we propose that prograde metamorphism of the underlying Devonian sedimentary sequences during the seafloor exhalation, which are thought to be enriched in Au, As, Sb, B, F and S, may have released H_2S that forming these auriferous sulfides.

Gold mineralization in the south belt of the South Qinling orogen shows the same mineralization style as observed in the North belt. However, mineralization is younger and the $\delta^{34}S$ values of the hydrothermal ore stage sulfide are consistent with magmatic sulfur, which is consistent with intense magmatic activities within the South Qinling orogen. The $\delta^{34}S$ values in the South Belt are distinctly different from those of gold deposits in the north belt. We propose that the source of the sulfur and gold in north belt came from the Devonian graben basins,

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and in the south belt came from a deep magmatic source. More focused studies of the gold and Devonian graben basin hosted SEDEX Pb-Zn deposits are required to further prove or develop this hypothesis.

1. Introduction

Orogenic gold deposit is a widely-accepted term to describe gold deposits that are formed during accretionary and collisional orogens, and are located in a metamorphosed fore-arc or back-arc environment (Groves et al., 1998). Even though we can clearly describe geologic and

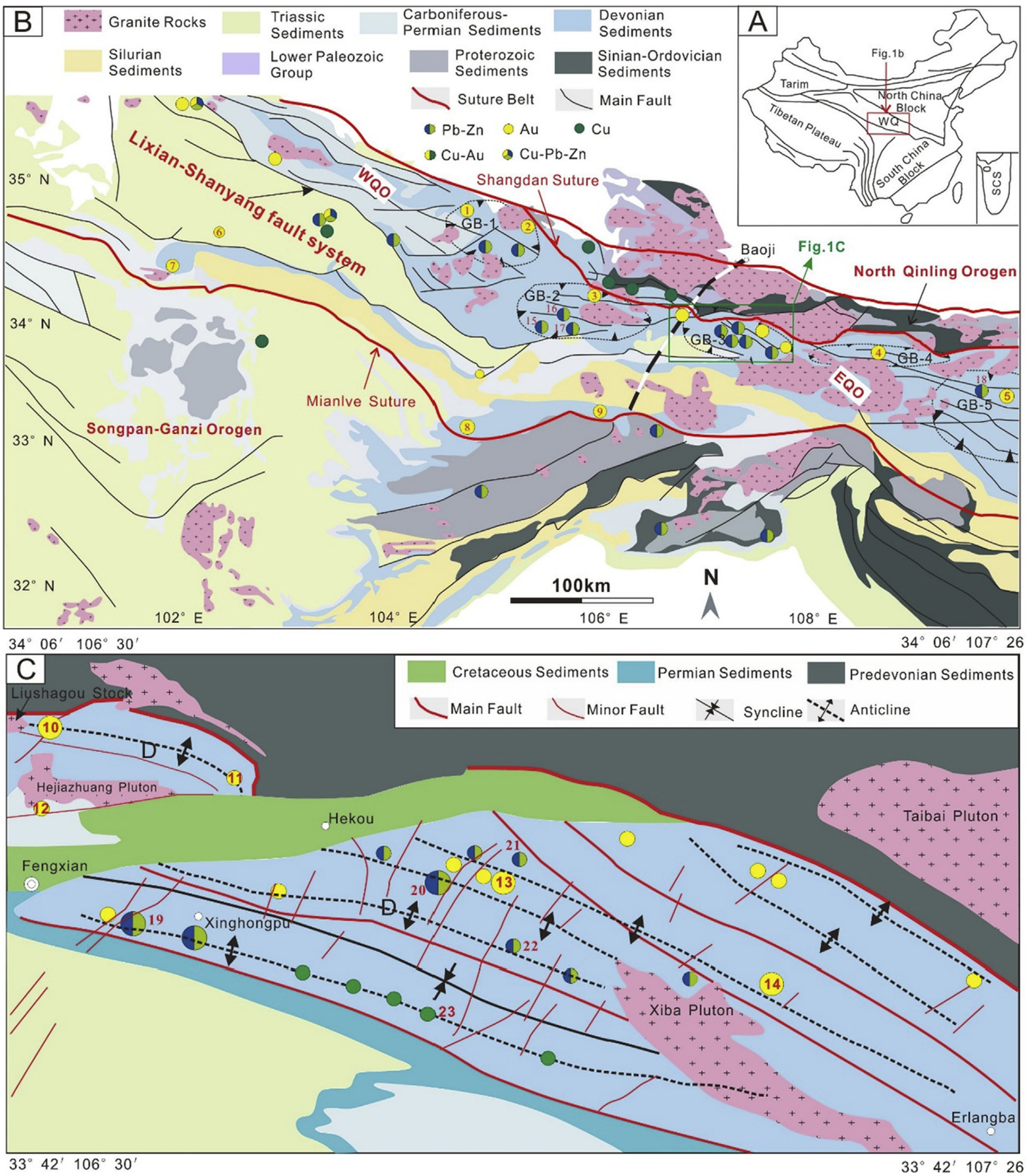

Fig. 1. A) Simplified geological map showing major tectonic units of China. B) Simplified map showing geological distribution of the Qinling orogeny and its neighboring (after Luo et al., 2012; Liu, 2001; Mao et al., 2012). C) Geological map of the Fengxian-taibai graben basin, West Qinling (after Hu, 2015). GB-1 = Mengxianlixian graben basin, GB-2 = Xihe-chengxian graben basin, GB-3 = Fengxian-taibaixian graben basin, GB-4 = Bansha graben basin, GB-5 = Shanyang-zhashui graben basin (Liu, 2001; Ji et al., 2014). Gold deposits: 1 = Zhaishang, 2 = Liba, 3 = Liziyuan, 4 = Ma'anqiao, 5 = Qiuling, 6 = La'erma, 7 = Dashui, 8 = Yangshan, 9 = Huachanggou, 10 = Pangjiahe, 11 = Matigou, 12 = Zuojiazhuang, 13 = Baguamiao, 14 = Shuangwang; Lead-Zinc deposits: 15 = Dengjiashan, 16 = Changba, 17 = Bijiashan, 18 = Yingdongzi, 19 = Qiandongshan-Dongtangzi, 20 = Bafangshan-Erlihe, 21 = Yingdongshan, 22 = Yingmusi-Guanmengou; Copper deposit: 23 = Jiuzigou. Abbrevations: Western Qinling orogen (WQO), Eastern Qinling orogen (EQO).