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Geological and geochemical constraints on the genesis of the Huachanggou gold deposit, western Qinling region, Central China

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ABSTRACT

The Huachanggou gold deposit is located in Lueyang County, Shaanxi Province, central China; it is situated in the Mian–Lue sutural zone in the western Qinling Orogen and controlled by a WNW-striking ductile shear zone. The ore deposit is developed in spilite, limestone and phyllite in the Middle–Lower Devonian Sanhekou Group, and the wall rocks show evidence of deformation. Pyrite is the main gold-bearing mineral, and the native gold is either visible or microscopic.

The Huachanggou gold deposit is considered to be an orogenic gold deposit controlled by a ductile shear zone related to the Indosinian Qinling orogenic event. The ores show a strong enrichment in Au, Ag and As but exhibit a simple assemblage of Au and Ag that are strongly correlated together. Gold was deposited from a moderate to low salinity, salt solution–CO_2 hydrothermal fluid at medium temperature. Variations in S, Pb, C, and O isotopic composition indicate that the sulfur was derived from the reduction of seawater sulfate in the wall rocks; the lead was derived mainly from the wall rocks; the carbon was derived from the dissolution of marine carbonate. The variations in H and O isotopic composition indicate that the ore-forming fluids were derived originally from metamorphic fluid with meteoric water mixing in later stages. Au migrated mainly in the form of $Au(HS)_2^-$ to form the deposit. Boiling of the fluid triggered the precipitation of the metal sulfides that contain the gold.

1. Introduction

The Qinling Orogen, in central China, separates the North China Block (NCB) from the South China Block (SCB) and links the Kunlun Orogen to the west with the Dabie–Sulu Orogen to the east (Fig. 1a). This region is an important tectonic domain in China, and the gold metallogeny has drawn international attention (e.g., Lerch et al., 1995; Webb et al., 1999; Ratschbacher et al., 2003; Luo et al., 2012; Zeng et al., 2012; Goldfarb et al., 2014). The western Qinling region is one of the most important gold producing regions in China. Over 50 gold deposits are distributed within the east-trending thrust and sutural zones in this region (Fig. 1b). The deposits are typical orogenic, Carlin-type and Carlin-like gold deposits (Hu et al., 2002; Mao et al., 2002, 2005, 2012; Chen et al., 2004; Liu et al., 2015a).

In the western Qinling region, most of the orogenic gold deposits occur between the Shang–Dan suture and Fengxian–Zhen'an fault, but some are located along the Mian–Lue suture; these deposits are confined to WNW-trending brittle–ductile shear zones in the Devonian and Carboniferous greenschist-facies metasedimentary rocks which were strongly deformed and metamorphosed during the Indosinian collision between the North China Block and the South China Block (Mao et al., 2002; Chen et al., 2004; Liu et al., 2015a). Phanerozoic collisional orogenic event produced the orogenic gold deposits of the western Qinling region (Feng et al., 2002, 2003; Chen et al., 2004; Zhu et al., 2009, 2010; Dong et al., 2011). The geological characteristics of orogenic gold deposits in this region, which include the Baguamiao, Ma'anqiao and Liziyuan orogenic gold deposits, include compressional to transpressional structures, deformed and variably metamorphosed host rocks, and moderate–low salinity, CO_2-rich, neutral to slightly alkaline fluids (Mao et al., 2002; Chen et al., 2004; Wen et al., 2007; Yang et al., 2012a; Liu et al., 2015a). These characteristics are similar to those of many orogenic gold deposits throughout the world (e.g., Groves et al., 1998, 2003; Chen et al., 2007; Goldfarb et al., 2014).

The Huachanggou gold deposit is located in Lueyang County, about 300 km southwest of Xi'an in Shaanxi Province, China. It has a contained gold reserve of about 10 tonnes with a grade of 2–10 g/t (Li et al., 2014). The deposit is controlled by a ductile–brittle shear zone along the Mian–Lue sutural zone (Fig. 1b). Three ore zones (termed ore zones I, II and III)

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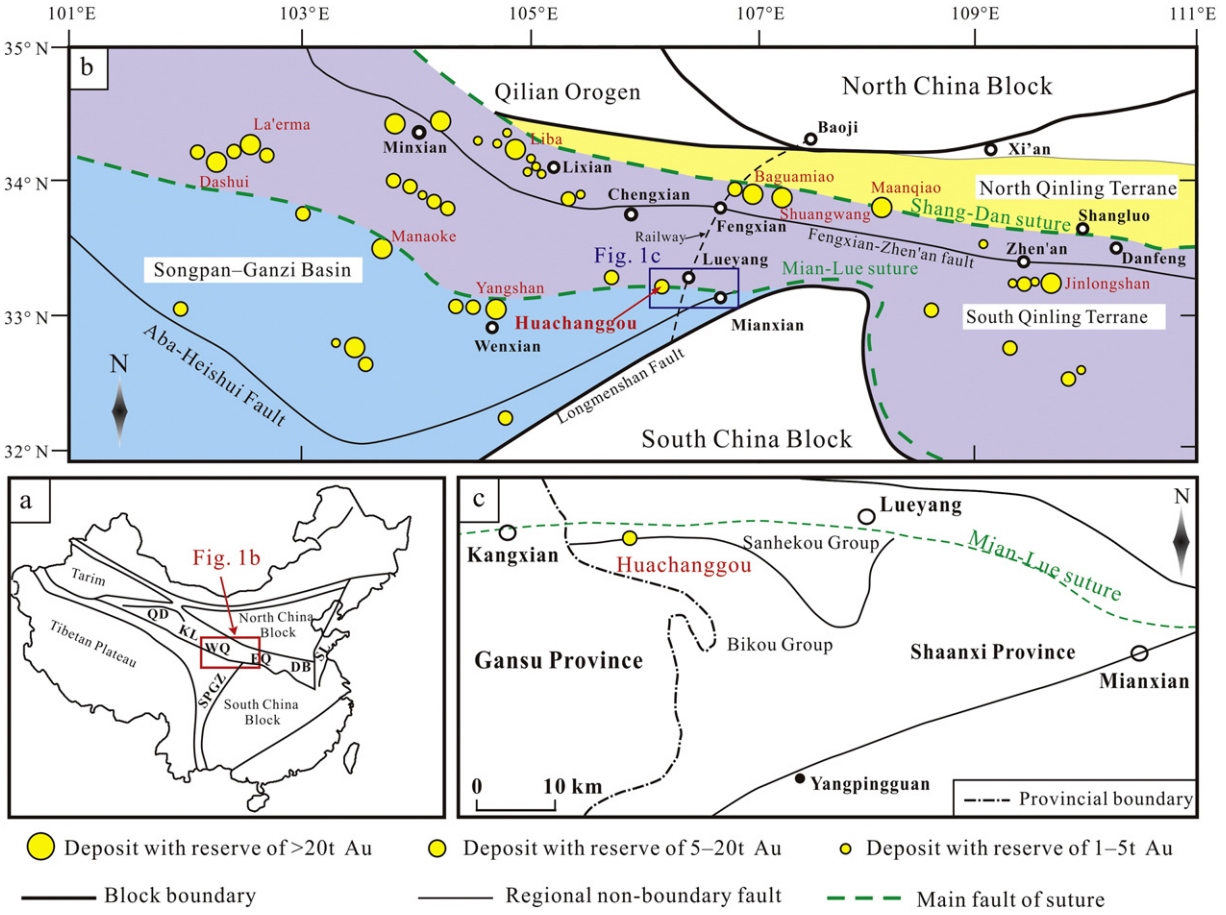

Fig. 1. Sketch geological maps of the Huachanggou gold deposit. a. Simplified map of China, showing major tectonic units of China (after Zheng et al., 2010). b. Sketch geological map of the Qinling Orogen, showing the location of gold deposits in this area (modified after Chen et al., 2004; Zeng et al., 2012). c. Sketch regional geological map of the Huachanggou gold deposit (modified after Wei et al., 2000). QD = Qaidam; KL = Kunlun Shan belt; WQ = West Qinling; EQ = East Qinling; DB = Dabie belt; SL = Sulu belt; SPGZ = Songpan–Ganzi terrane.

comprise the Huachanggou mine, of which zone I has been the main focus of previous studies where evidenced was presented for a hydrothermal origin of the gold in the altered spilite (e.g., Bai, 1996a,b; Wei et al., 2000; Li and Tai, 2007). Only the orebodies in ore zone I are hosted in spilite; limestone and phyllite host the ore in zones II and III.

In this paper, we describe aspects of the geology of the Huachanggou gold deposit, including the structural framework, ore petrology, alteration, and the style of mineralization. We present data on the pyroelectricial property of pyrite, the composition of the ore-forming elements, together with fluid inclusion and stable isotope data (S, Pb, H, O, and C). We propose a model for the source of the ore-forming fluid and metals, the evolution of these fluids, and the mechanism of mineralization.

2. Regional geology

The Qinling Orogen is divided by three major tectonic zones termed the Shang–Dan suture, the Fengxian–Zhen'an fault and the Mian–Lue suture (Fig. 1b). The Paleozoic Shang–Dan suture separates the North Qinling Terrane (NQT) from the South Qinling Terrane (SQT) (Dong et al., 2011). The NQT, which hosts minor gold mineralization, was accreted to the NCB along the Shang–Dan suture (Mao et al., 2002; Zeng et al., 2012). Geographically, the boundary between the western and eastern Qinling regions is approximated by the Baoji–Fengxian–Lueyang Railway (a part of Baoji–Chengdu Railway) (Fig. 1b; Zheng et al., 2010; Zeng et al., 2012).

The Mian–Lue oceanic basin opened up within the northern margin of the SCB since Devonian and separated the SQT from the SCB (Yin and Nie, 1996; Zhang et al., 2007a; Zheng et al., 2010). The Mian–Lue oceanic crust underwent northward-facing subduction beneath the SQT from Permian to Early Triassic (Dong et al., 2011). After the extinction of the Mian–Lue oceanic crust, the collision between the SCB and SQT took place along the Mian–Lue suture in Middle–Late Triassic (Zhai et al., 1998; Meng and Zhang, 1999, 2000; Jiang et al., 2010).

The Huachanggou gold deposit is located in the middle section of the Mian–Lue sutural zone (Wei et al., 2000). It is generally accepted that an important period of gold-formation took place in the western Qinling region during Late Triassic after the closure of the Mian–Lue Ocean (Mao et al., 2002; Chen et al., 2004). A fuchsite K–Ar age for the gold-formation of the Huachanggou gold deposit is 215 ± 0.5 Ma (Bai, 1996a,b). A number of zircon SHRIMP U–Pb ages of the quartz veins, which were formed during the main mineralization stage, range from 199 to 230 Ma (Lin et al., 2011). These age data of the Huachanggou gold deposit are consistent with the mineralization ages of other major gold deposits of the western Qinling region (233–197 Ma; Liu et al., 2015a), and these ages are close to the time of collision along the Mian–Lue suture (Jiang et al., 2010; Dong et al., 2011). Metavolcanic rocks from the Heigouxia Valley, which was produced by the subduction of the Mian–Lue oceanic crust, have yield a Sm–Nd isochron age of 242 ± 21 Ma and a Rb–Sr isotopic age of 221 ± 13 Ma which is believed to represent the time of metamorphism (Li et al., 1996b). The granulite mineral samples from the central segment of the Mian–Lue suture yielded a Sm–Nd isochron age of 206 ± 55 Ma