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Fluid immiscibility and gold deposition in the Xincheng deposit, Jiaodong Peninsula, China: A fluid inclusion study

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ABSTRACT

The Xincheng gold deposit, located in west Jiaodong Peninsula in southeast North China Craton, is a representative mesothermal lode deposit hosted in Late Mesozoic granitoids in Jiaodong. Gold mineralization occurs as disseminated- and stockwork-style ores within the hydrothermal breccias and cataclastic zones controlled by the Jiaojia fault, whereas echelon tensile auriferous veins hosted in the NE- and NNE-trending subsidiary faults cutting the granitoids occur subordinately. According to crosscutting relationships and mineral paragenesis, four paragenetic stages were identified, which are pyrite–quartz–sericite (stage 1), quartz–pyrite (stage 2), quartz–polysulfide (stage 3) and quartz–carbonate (stage 4). Gold was deposited during the quartz–pyrite and quartz–polysulfide stages.

On the basis of microthermometry and Raman spectroscopy on fluid inclusions contained within the quartz veins from stages 2 and 3, three types of fluid inclusions were recognized: (1) type 1 H_2O–CO_2 inclusions that show high temperatures (ca. 260 °C), low salinities (2.4–8.9 wt.% equiv. NaCl) and variable XCO_2 (0.03 to 0.20), (2) type 2 aqueous inclusions with medium temperatures (ca. 220 °C) and low to moderate salinities (3.1–13.3 wt.% equiv. NaCl); (3) type 3 pure CO_2 inclusions with a carbonic phase density of 0.712 ± 0.03 g/cm^3. Types 1 and 2 inclusions appear in the same growth phase of the quartz grains from the breccias and tensile auriferous veins. These coexisting inclusions are likely formed by fluid immiscibility due to unmixing from a single homogeneous H_2O–CO_2 parent fluid at trapping P–T conditions of 221 to 304 °C (average 261 ± 19 °C) and 780 to 2080 bar. The fluid immiscibility is interpreted to be initiated by fluid pressure decrease at ca. 300 °C.

The ore-fluid P–T–X conditions of the Xincheng gold deposit are the same as those for mesothermal deposits. Gold was most probably transported as a $Au(HS)_2^-$ complex at Xincheng. Fluid immiscibility over the temperature interval of 221–304 °C resulted in significant H_2S loss from the hydrothermal solution, thereby reducing $Au(HS)_2^-$ solubility with concomitant deposition of gold. The mineralizing process of the granitoid-hosted Xincheng lode-gold deposit is likely related to the fluid immiscibility.

1. Introduction

The Jiaodong Peninsula, located in southeast North China Craton (Deng et al., 2003a, 2009; Fig. 1), is the largest gold producer in China (Li et al., 2013), with reserves of 2300 t gold (Goldfarb et al., 2013a), and constitutes a part of the circum-Pacific metallogenic domain (Goldfarb et al., 2013b). Unlike the deposits in other Archean cratons such as Canada and Western Australia, the gold deposits in Jiaodong Province were formed at ca. 120 Ma (Guo et al., 2013; Yang et al., 2007a, 2013a), about 2 Ga younger than regional metamorphism of these Precambrian Jiaodong basement rocks, and are hosted dominantly by Late Mesozoic granitoids (Chen et al., 2004; Fan et al., 2005; Goldfarb et al., 2007; Wang and Huo, 2008; Wang et al., 2014; Yang et al., 2003), making Jiaodong one of the biggest known mesothermal lode-gold provinces hosted in granitoids in the world (Li et al., 2013).

Gold deposits in the area occur as disseminated- and stockwork-style mineralization ("Jiaojia-type") as well as auriferous quartz-veins ("Linglong-type") (Deng et al., 2000, 2006; Li et al., 2006; Yang et al., 2013b). The "Jiaojia-type" gold deposits mainly consist of disseminated- and stockwork-style pyrite–sericite–quartz-altered ores that are controlled by major regional-scale faults such as the Sanshandao, Jiaojia and Xincheng faults (Shen et al., 2001; Zhou et al., 2002; Fig. 1). The

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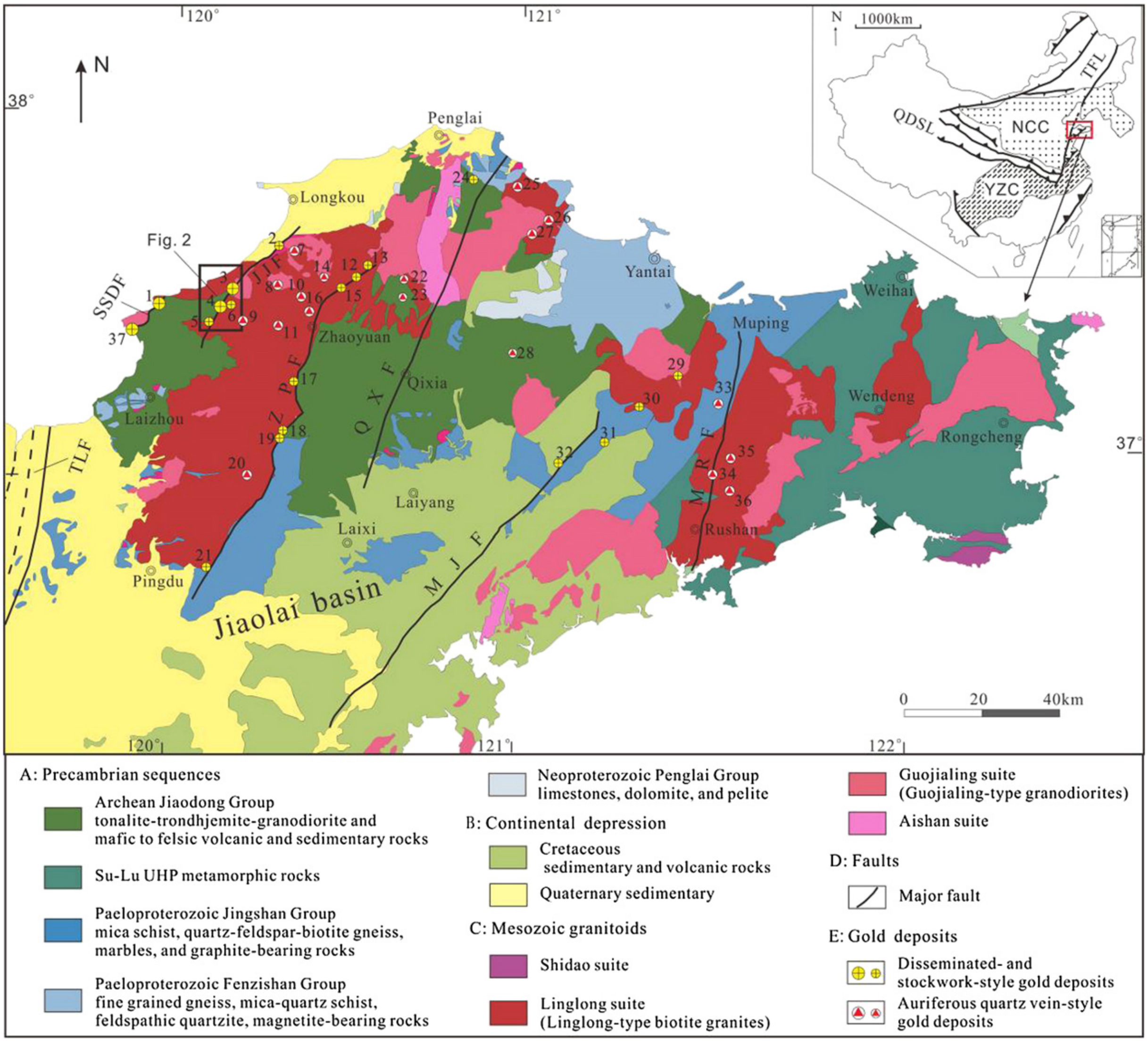

Fig. 1. Simplified geological map of the Jiaodong Peninsula showing the distribution of major structures and representative gold deposits (modified from Deng et al., 2010). Differently sized symbols for gold deposits show different gold resources, big symbol shows Au > 50 t, small symbol shows Au < 50 t. 1 = Sanshandao; 2 = Huangshan'guan; 3 = Xincheng; 4 = Jiaojia; 5 = Sizhuang; 6 = Wang'ershan; 7 = Shipeng; 8 = Beijie; 9 = Lingshan'gou; 10 = Yuantuan; 11 = Caotougou; 12 = Luoshan; 13 = Damoqujia; 14 = Linglong; 15 = Taishang; 16 = Shilipu; 17 = Dayingezhuang; 18 = Xiadian; 19 = Shanhou; 20 = Jiudian; 21 = Shanwang; 22 = Sujiadian; 23 = Guandi; 24 = Longshandian; 25 = Daxue; 26 = Donghe; 27 = Huangjinhe; 28 = Majiayao; 29 = Xiayucun; 30 = Sijia; 31 = Pengjiakuang; 32 = Guocheng; 33 = Denggezhuang; 34 = DaYinggezhuang; 35 = Rushan; 36 = Sanjia; 37 = Cangshang. Abbreviations: TLF, Tan–Lu fault; SSDF, Sanshandao fault; JJF, Jiaojia fault; ZPF, Zhaoping fault; QXF, QiXia fault; MJF, Muping–Jimo fault; MRF, Muru fault.

"Linglong-type" deposits are composed of single or multiple quartz veins and occur along the second- or third-order faults that cut the Mesozoic granitoids (Fan et al., 2003; Miao et al., 1997; Fig. 1). Both deposit types exhibit similar alteration types, mineral associations, isotope signatures and mineralization ages (Deng et al., 2003b, 2008, 2010; Yang et al., 2006, 2008), indicating the same wall rock compositions, uniform mineralizing fluids and similar P–T conditions of gold mineralization occurring throughout the Jiaodong Province (Cheng et al., 2011; Mao et al., 2008). The difference in gold mineralization styles of the deposits is suggested to be controlled by the deformation degree of the host structures (Lu et al., 1999; Qiu et al., 2002).

Fluid inclusion studies on vein quartz from "Jiaojia-type" gold deposits (Xincheng, Dayingezhuang and Damoqujia deposits, etc.) and "Linglong-type" gold deposits (Linglong, Rushan, Denggezhuang, and Sanjia deposits, etc.) show that the ore fluids are consistent through the Jiaodong Province, with similar mineralizing temperature and pressure conditions (Fan et al., 2010; Zhao et al., 2005). Three types of fluid inclusions: H_2O–CO_2, CO_2-rich and aqueous inclusions, have been recognized in both the disseminated- and stockwork-style ores and auriferous quartz-veins (Cai et al., 2011; Hu et al., 2008). They are H_2O–$CO_2 \pm CH_4$-bearing fluids with low–medium salinity (1.2–13.6 wt.% equiv. NaCl). Minimum mineralizing P–T conditions were regarded as being 170–377 °C and 500–3160 bar (Hu et al., 2005, 2007; Shen et al., 2000; Yang et al., 2007b, 2009; Zhang et al., 2007). These studies contribute to the better understanding of the hydrothermal gold mineralization in the Jiaodong gold province. However, few studies reported more than the homogenization temperature, salinity and/or pressure for the fluid inclusions, with little discussion about the gold-bearing fluids' composition and the physico-chemical constraints, as well as the precipitation mechanisms of gold mineralization. Fan et al. (2003) made the detailed microthermometric study of fluid inclusions on the Sanshandao deposit located at the Sanshandao fault. The gold-related inclusions are CO_2–$H_2O \pm CH_4$, which have the bulk densities of 0.82–0.01 g/cm^3 and salinities of <7.1 wt.% equiv. NaCl. The total