SEM and FIB-TEM analyses on nanoparticulate arsenian pyrite: Implications for Au enrichment in the Carlin-type giant Lannigou gold deposit, SW China

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ABSTRACT

Gold in Carlin-type gold ores is commonly hosted in the arsenian pyrite rim, but the formation of arsenian pyrite and its contribution to Au adsorption are poorly understood. Based on our previous NanoSIMS Au mapping, we conducted SEM and HR-TEM analyses to examine the Au deportment and nanoscale texture of individual auriferous arsenian pyrite grains from the giant Carlin-type Lannigou gold deposit, SW China. The results indicate that the arsenian pyrite rim is composed of numerous nanoparticulate pyrite grains (rather than a single crystal), and gold nanoparticles (Au0) occur mainly in sub-rim with the highest Au content, which are porous and have lower degrees of order. We propose that nanoparticulate arsenian pyrite attachment and aggregation is the main mechanism for the arsenian pyrite rim growth, and such mechanism is crucial for the Au efficient enrichment for this giant gold deposit.

Keywords: Nanoparticulate arsenian pyrite, nano-pore, FIB-TEM, Au efficient enrichment, Carlin-type gold deposits

INTRODUCTION

The Carlin-type gold deposits (CTGDs) are mainly found in Nevada (U.S.A.) (Hofstra and Cline 2000; Muntean and Cline 2018) and southwest (SW) China (Hu et al. 2002, 2017; Su et al. 2018). These deposits host the second largest Au resource on Earth and provide over 9% of the global gold production (Cline et al. 2005; Muntean et al. 2011; Large et al. 2011). Gold in unoxidized CTGDs is hosted exclusively in hydrothermal arsenian pyrite, which usually contains thousands of ppm Au, three orders of magnitude higher than that in typical ore fluid (<10 ppm) (Su et al. 2009; Kusebauch et al. 2019). This implies an effective mechanism for concentration of Au into arsenian pyrite to form giant Au CTGDs.

Arsenian pyrite in CTGDs commonly precipitated around earlier gold-barren pyrite cores, forming core-rim texture and/or small individual arsenian pyrite grains (Su et al. 2018; Muntean et al. 2011; Cline 2001). In addition, gold distribution in arsenian pyrite rim shows micrometer-scale zoning, which was interpreted to be related to ore-fluid geochemical changes during the pyrite rim growth (Barker et al. 2009; Yan et al. 2018).

Previous works concluded that Au+ captured in pyrite rims is strongly affected by the pyrite growth rate and mechanism (Fougereau et al. 2016; Wu et al. 2019) and surface electronegativity (Kusebauch et al. 2019; Rickard and Luther 2007; Deditius et al. 2014; Xian et al. 2019). Polycrystalline arsenian pyrites were reported in previous studies and were interpreted to have formed by Au exsolution, rapid local ore-fluid geochemical changes and/or temperature drop (Palenik et al. 2004; Deditius et al. 2008; Wu et al. 2021). However, the role of nanoparticulate pyrites and As-rich pyrite-rim formation in Au-efficient enrichment in CTGDs has not been well understood.

Based on previous works on CTGDs in Nevada, we investigated the Au deportment and nanoscale texture of individual auriferous arsenian pyrites from the giant Carlin-type Lannigou gold deposit in SW China, via a combination of high-resolution transmission electron microscopy (HR-TEM) and secondary electron microscopy (SEM). We proposed that the attachment and aggregation of nanoparticulate arsenian pyrites to form an As- and Au-rich rim occurs during the fluctuating disequilibrium mineralization process.

GEOLOGICAL BACKGROUND

South China is composed of the Yangtze and Cathaysia blocks in the northwest and southeast, respectively, and is bounded by the North China Craton and Indochina-Simao Block to the north and southwest, respectively. The Youjiang Basin is located in the southwestern Yangtze Block (Fig. 1) and is locally known as the “Golden Triangle” due to the many Carlin-type gold deposits discovered since 1978 (Tu 1992). The Youjiang Basin is composed of Neoarchean-Neoproterozoic metamorphic rocks and Cambrian-Triassic carbonates and shales (Hu et al. 2002; Peters et al. 2007; Su et al. 2008; Hu and Zhou 2012; Fig. 1). Indosinian (Triassic) to Yanshanian (Jurassic-Cretaceous) granitic plutons are present only on the margin of the basin, although Triassic-Jurassic intrusions are inferred to be concealed beneath the sedimentary strata according to inherited zircon data of mafic dikes (Hu et al. 2002; Peters et al. 2007; Su et al. 2008; Hu and Zhou 2012; Mao et al. 2013; Pi et al. 2017; Zhu et al. 2017; Fig. 1).

The Lannigou (aka. Jinfeng) gold deposit is a giant CTGD in the Youjiang Basin (Hu et al. 2002; Su et al. 2009, 2018; Fig. 1). The orebodies occur as veins and lenses in the Middle Triassic Xuman and Bianyang formations calcareous siltstone...