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Geochronological and He–Ar–S isotopic constraints on the origin of the Sandaowanzi gold-telluride deposit, northeastern China

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ABSTRACT

Northeastern China is characterized by widespread Mesozoic volcanic rocks and Au–Cu–Mo mineral deposits with a total gold reserve of >2000 t. Amongst those gold deposits, the newly discovered Sandaowanzi has a total reserve of ≥25 t of Au and an average grade of 15 g/t. This deposit is important because it is the first reported case of a dominantly Au(±Ag)-telluride deposit containing economically valuable bonanza Au- and Ag-telluride ores in the region. The Sandaowanzi quartz vein system and associated Au–(±Ag)-telluride mineralization are mainly hosted by trachyandesites and andesitic breccias. Native gold is closely associated with abundant tellurides including petzite, sylvanite, calaverite, hessite, and altaite. Twelve pyrite samples from the alteration zone yield a well defined Rb–Sr isochron age of 119.1 ± 3.9 Ma, which is in agreement with a robust Rb–Sr isochron age of 121.3 ± 2.6 Ma derived from 10 auriferous quartz samples. The obtained isochron age of ~120 Ma represents the formation of the Sandaowanzi gold-telluride epithermal system, which is much younger than the host trachyandesite with a zircon U–Pb age of 312.5 ± 0.5 Ma and the spatially associated monzogranite with a zircon U–Pb age of 182.2 ± 1.1 Ma. Dating results indicate a close relationship between the local Au–Ag–Te mineralization and a magmatism episode in the Early Cretaceous. Noble gas (He and Ar) isotopes obtained from telluride, sulfide and quartz and sulfur isotopes determined from sulfides including chalcopyrite, sphalerite and pyrite demonstrate clear mixing trends between crustal and mantle-derived components, confirming a significant contribution of fluid produced from mantle-derived magmas into the epithermal system. Like many Mesozoic porphyry Cu–Mo ± Au deposits, the coeval epithermal Au–Ag ± Te deposits in the region are genetically related to magmatism triggered by the subduction of the Pacific oceanic plate beneath the Eurasian continent at the time.

1. Introduction

Tellurides of Au, Ag and numerous base metals commonly occur as trace minerals associated with gold in various mineral deposits that span magmatic-hydrothermal types, and particularly within epithermal gold deposits which formed at shallow depths (<l.5 km) and low temperatures (<300 °C) in subaerial hydrothermal systems (Cook et al., 2009; Cooke and Simmons, 2000; Simmons et al., 2005; White and Hedenquist, 1995). Geologically, these telluride-bearing epithermal gold deposits are spatially associated with alkaline to calc-alkaline volcanic rocks (Ciobanu et al., 2006; Sillitoe, 2002). Generally in epithermal deposits sulfides are frequently reported as the dominant ore minerals in association with native gold; whereas significant dominance of tellurides accompanying gold is less observed. However, when highly concentrated throughout, or in limited parts of a deposit, Au–(Ag) tellurides may themselves constitute highly economic ores (Cook and Ciobanu, 2005; Cook et al., 2009). In numerous large gold deposits worldwide, Au–(Ag) tellurides comprise an abundant component of ore minerals and may also contribute a significant portion of the overall gold balance, such as observed in the Cripple Creek and Golden Sunlight deposits in USA (Porter and Ripley, 1985; Thompson et al., 1985), the Emperor deposit in Fiji (Ahmad et al., 1987; Pals and Spry, 2003), the Dongping and Dashuigou deposits in China (Mao et al., 2002a, 2003), the Acupan and Baguio deposits in Philippines (Cooke and McPhail, 2001) and the Sacarîmb deposit in Romania (Ciobanu et al., 2008), etc. Previous studies of geology, mineralogy, alteration, isotope geochemistry, fluid inclusion and metallogenesis in epithermal gold-telluride deposit have been undertaken to understand ore genesis and to establish genetic models (Ciobanu et al., 2012; Cooke and McPhail, 2001; Simmons et al., 2005; Tombros et al., 2010). However, precise geochronological constraints on gold-telluride deposits are rare, owing to the fine-grained occurrences of alteration and ore minerals, and lack of suitable minerals which are associated with gold deposition for direct isotopic dating (Tretbar et al., 2000). Also, the connections between ore-

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forming fluid and deep (mantle-derived) fluid, as well as ore genesis and specific tectonic control, are not well established; both are essential to understand the formation of gold-telluride ores in epithermal systems.

The Sandaowanzi deposit is a newly discovered gold-telluride deposit in the northeastern segment of the Great Hinggan Range (abbreviated as GHR) Metallogenic Belt (Fig. 1). This deposit bears a total reserve of ≥25 t of Au, with an average grade of 15 g/t. The deposit is very uncommon for two reasons: (1) it is the first reported case of a dominantly Au–(±Ag)-telluride deposit in NE China, as more than 95% of the gold occurs as coarse-grained tellurides (Liu et al., 2011); (2) exploration work revealed unusually high concentrations of gold- and silver-telluride ores. Although studies on ore deposit geology, structural geology, mineralogy, petrology, stable isotope geochemistry (S, H, O) and fluid inclusions of this deposit have been reported elsewhere (e.g., Liu and Lu, 2006; Liu et al., 2011, 2013; Lu et al., 2005, 2009; Wu et al., 2005a; Zhao et al., 2010; Zhai and Liu, 2014), issues related to geochronology, fluid origins and tectonic controls of the Au–Ag–Te mineralization remain debated. Uncertainties mainly arise from the lack of precise and appropriate dating methods and minerals, and paucity of definitive constraints on fluid sources and regional tectonic setting.

In this contribution, we present systematic Rb–Sr isochron ages of auriferous quartz and pyrite, as well as zircon U–Pb isotopic ages of volcanic and intrusive rocks to precisely define the timing of Au–Ag–Te mineralization in the Sandaowanzi epithermal system. We further utilize noble gas (He and Ar) and sulfur isotopes to decipher hydrothermal fluid origins and their possible connections with deep source (e.g., mantle-derived) fluids. Utilizing regional geological evolution and temporal-spatial distributions of volcanic rocks and mineralization, a possible tectonic setting for widespread volcanism and Au–Cu–Mo mineralization in NE China and adjacent areas during the Late Mesozoic is proposed.

2. Regional geological background

The Sandaowanzi deposit is located in the northeastern segment of the GHR in NE China. The GHR is located in the eastern section of the Central Asian Orogenic Belt (CAOB), which is a giant accretionary

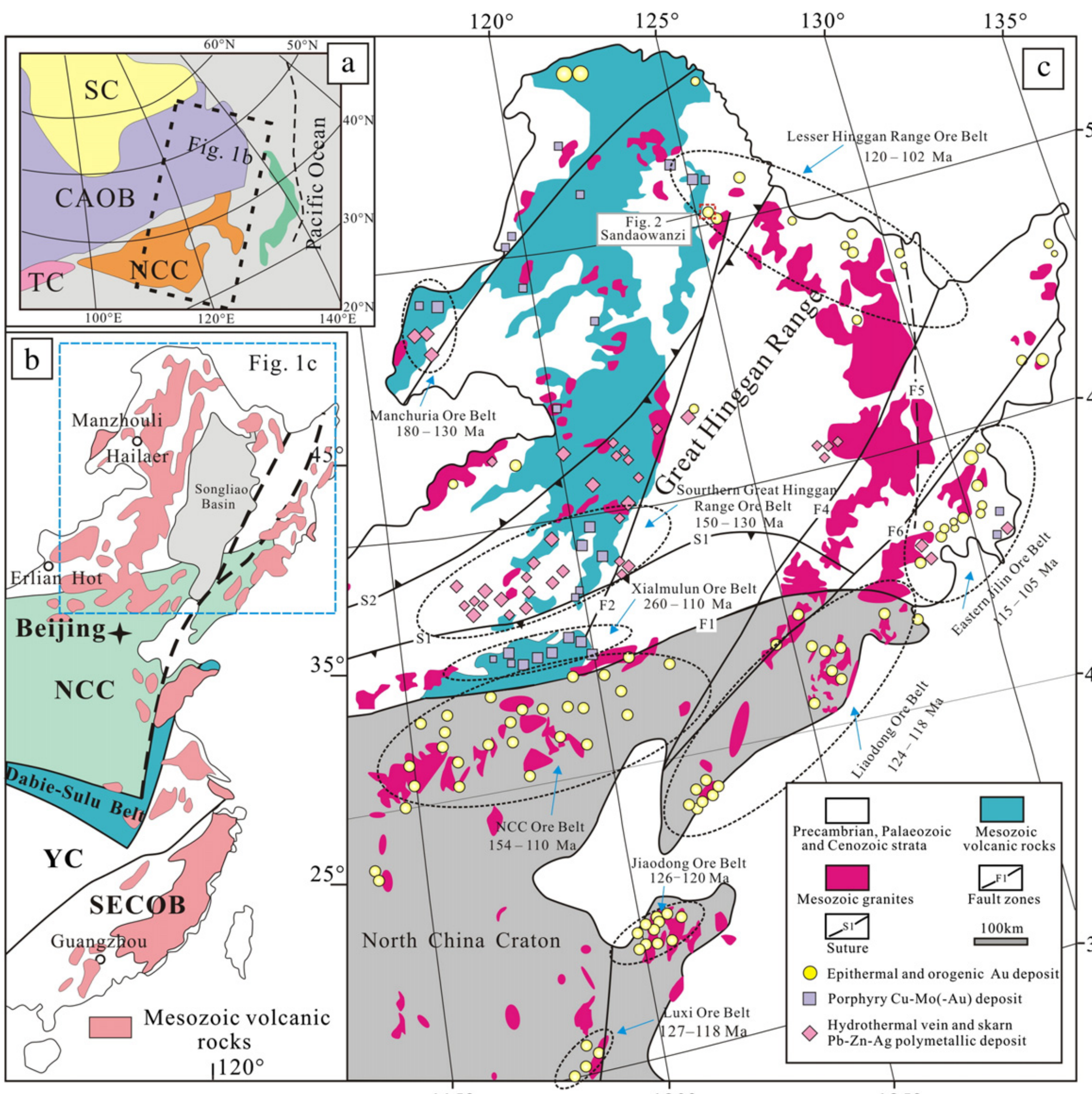

Fig. 1. (a) Tectonic scheme of the Central Asian Orogenic Belt (based on Safonova, 2009); (b) Simplified tectonic units of eastern China showing the distribution of the Mesozoic volcanic rocks (modified from Wu et al., 2005b); (c) Spatial–temporal distribution of major ore belts in eastern China and the Mesozoic volcanic and granitic rocks in NE China (modified from Qi et al., 2005; Sun et al., 2013; Zhai et al., 2014a). Abbreviations: CAOB — Central Asian Orogenic Belt; NCC — North China Craton; SC — Siberian Cration; SECOB — SE China Orogenic Belt; TC — Tarim Cration; YC — Yangtze Craton.