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Constraints of fluid inclusions and in-situ S-Pb isotopic compositions on the origin of the North Kostobe sediment-hosted gold deposit, eastern Kazakhstan

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ABSTRACT

The North Kostobe gold deposit in the Kalba gold province, eastern Kazakhstan, is tectonically located in the Chara shear zone of the western Altaids. The Chara shear zone separates the Kazakhstan microcontinent and Siberia craton which collided in the late Carboniferous. In the North Kostobe deposit, Au mineralization is distributed along an E-W striking shear zone linked to the NW-SE trending regional faults, and is mainly concentrated in quartz-sulfide-carbonate veins or in disseminated sulfides hosted in carbonaceous metasedimentary rocks. Sulfide minerals are mainly pyrite and arsenopyrite, and were formed in three generations. The first generation is dominated by pyrite (py1) occurring as microcrystal aggregates, followed by the second generation including euhedral arsenopyrite and compact pyrite (py2) locally overgrowing early py1 grains as rims; third generation of pyrite (py3) is present in barren micro-fractures crosscutting early mineralized rocks. Native gold is present in cracks of brecciated arsenopyrite grains and as inclusions in py2. Investigations on fluid inclusions in auriferous quartz veins indicate that the ore-related fluids are CO_2-bearing, with homogenization temperatures of 288 °C and low salinity (1.42 to 8.03 wt% NaCl equiv). The fluids have calculated $\delta^{18}O$ and δD values ranging from 9.96 to 11.86‰ and from −75 to −97.1‰, respectively, suggesting that they were most likely metamorphic in origin.

The first and second generations of ore sulfides have similar $\delta^{34}S$ values (−6 to +2.6‰) which possibly indicating a common sulfur source as the hosting sedimentary rocks. In contrast, py3 grains have a huge range of $\delta^{34}S$ values (−40 to +54.5‰), indicating a biogenic source for the sulfur. On the other hand, in-situ Pb isotopic compositions of different generations of sulfides show a similarly mixed lead source, possibly involved orogen, mantle and lower crust Pb reservoirs. We propose that the gold-bearing fluids of the North Kostobe gold deposit were most likely derived from gold-rich, pyritic carbonaceous sedimentary rocks through dehydration during the metamorphism that was related to the collision between the Kazakhstan microcontinent and Siberia craton in the late Carboniferous. It is thus concluded that the North Kostobe gold deposit shares many characteristics with typical orogenic gold deposits in terms of tectonic settings, mineralization styles, fluid compositions and source of fluids and gold. Our new findings thus have important implications for regional exploration in the Kalba gold province.

1. Introduction

The Kalba gold province in eastern Kazakhstan is located in the western part of the Central Asian Orogenic Belt (CAOB), which is also known as the Altaids (Fig. 1a and b). The Kalba gold province hosts several large gold deposits, e.g. the Bakyrchik Au deposit (410 t Au; Goldfarb et al., 2014), the Sekisovskoye Au-Te deposit (160 t Au; resource statement of GoldBridges Global Resource Plc., 2014) and the Suzdal Au-As deposit (58 t Au; resource statement of Nord Gold, 2015). Exploration and mining activities in the province can be traced back to the 1950s by the Soviet geologists through systematic mapping, geophysical and soil geochemical surveys to target potential gold resources. Although the Kalba gold province hosts >450 gold deposits/occurrences, it only received little attention in the past owing to poor accessibility. Previous studies have mainly focused on mineralogy of gold and gold-bearing

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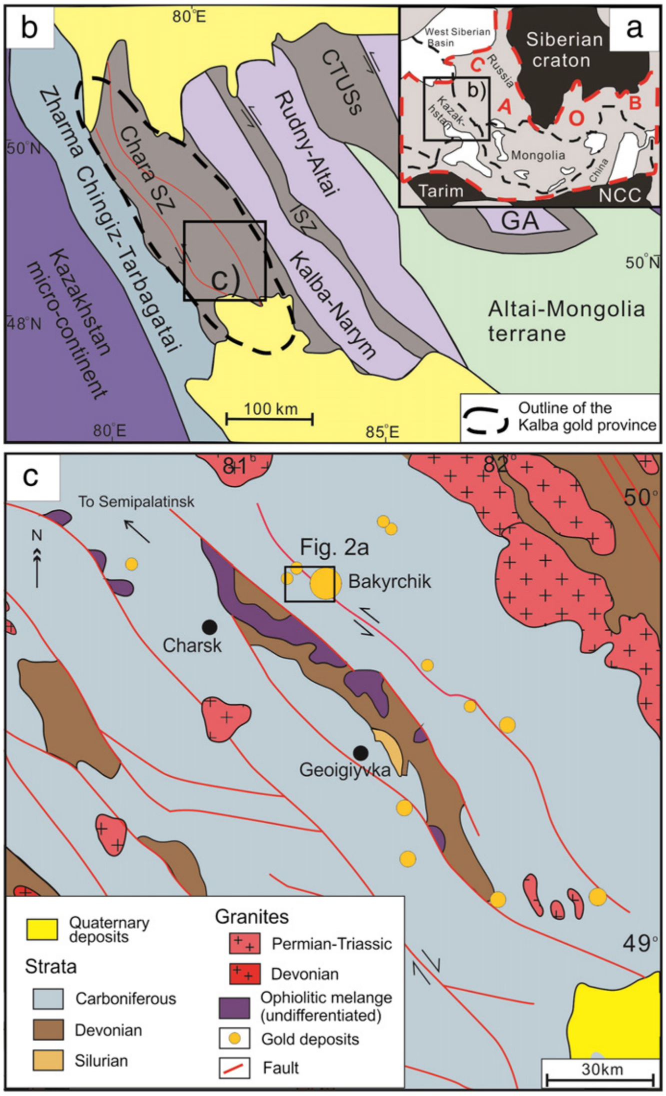

Fig. 1. a and b. Tectonic framework of the Central Asian Orogenic Belt and Kazakhstan microcontinent. ISZ = Irtysh shear zone, CTUSs = Charysh-Terekta-Ulagan-Sayan suture, GA = Gorny Altai, NCC = North China Craton. The outline of NW-SE trending Kalba gold province is also shown. Fig. 1a and b are modified after Glorie et al. (2012); c. Geological map of the Chara shear zone, simplified from Buslov et al. (2004), Daukeev et al. (2008).

sulfides (e.g., Kovalev et al., 2009, 2011, 2014; Kalinin et al., 2009; Kuz'mina et al., 2013), but the source of gold and the nature of the ore-forming fluids are currently poorly constrained.

This study provides a comprehensive description of the geology of the North Kostobe gold deposit, a medium tonnage gold deposit in the Kalba gold province, in order to constrain the origin of gold mineralization and in turn to provide a conceptual model for further exploration in the region. We obtained in-situ S and Pb isotopic compositions of sulfides by using the LA-MC-ICPMS technique that has high spatial resolutions, because the sulfides are fine-grained (<1 mm) and texturally complex, and may have formed in multiple stages (e.g. Large et al., 2007). Conventional fluid inclusions and H-O isotopic data of quartz are also incorporated in order to better constrain the origin of the deposit.

2. Regional geology

The Chara shear zone in CAOB was formed by the collision between the Siberia craton and the Kazakhstan microcontinent as a result of the closure of the Ob-Zaisan Ocean (part of the Paleo-Asian Ocean) in the late Carboniferous (e.g. Sengör et al., 1993; Buslov et al., 2001; Windley et al., 2007). It is several hundred kilometers long, NW-SE trending, and extends from eastern Kazakhstan to the Chinese Altai in Xinjiang, China (Li et al., 2015a). It is bounded by different terranes as a result of a series of accretionary events during the late Paleozoic (Buslov et al., 2001, 2004; Windley et al., 2007; Shen et al., 2016). The Chara shear zone separates the Siberia-derived Kalba-Narym (fore-arc accretionary complex), Rudny Altai and Gorny Altai terranes (island arc systems) and the Kazakhstan-derived active margin of the Zharma-Chingiz-Tarbagatai terrane (Berzin et al., 1994; Buslov et al., 2001) (Fig. 1b).

The Chara shear zone (Fig. 1c) is marked by three types of ophiolitic mélange of different origins (Buslov et al., 2004): 1) the Cambrian to early Ordovician mélange composed of high-pressure metamorphic rocks and gabbro (Buslov et al., 2003; Volkova et al., 2008), 2) the Ordovician mélange containing blocks of serpentinized peridotite, gabbro, and amphibolite (Iwata et al., 1997; Safonova et al., 2012), and 3) the Carboniferous to early Permian NW-SE oriented ophiolitic mélange representing the lithospheric fragments of the Ob-Zaisan Ocean closed in the late Carboniferous (Iwata et al., 1997; Buslov et al., 2001, 2004). These ophiolite mélanges are associated with 5000-m-thick Silurian to Carboniferous sedimentary successions (Safonova et al., 2012). These successions are fore-arc materials derived from both the Kazakhstan microcontinent and Siberia craton during the evolution of the Ob-Zaisan Ocean (Buslov et al., 2004). The Silurian strata are mainly composed of alternating limestone, siltstone and chert, whereas the Upper Devonian strata are mainly dominated by chert and siltstone with minor amounts of pillow basalts (Iwata et al., 1997). These sequences are overlain by Carboniferous fore-arc turbidite and intermediate to felsic volcanic rocks that define an active continental margin in the Carboniferous. Intrusions in the Chara shear zone are rarely exposed, and those that do occur are present as small plutons and dyke complexes. They have mostly formed between the late Carboniferous and Triassic (Lyons et al., 2002; Vladimirov et al., 2008).

The Chara shear zone is characterized by complex regional scale folding, shearing and faulting with a NW-SE trend. The deformation has created foliations in the rocks and juxtaposed, different geological units. Large-scale strike-slip faults were activated during the Permian. The timing of sinistral deformation of the Irtysh shear zone in the Kazakhstan segment, which is situated ~80 km northeast to the study area, is constrained to be ~290 to 265 Ma (Travin et al., 2001; Buslov et al., 2004, and references therein; Vladimirov et al., 2008) although the Irtysh shear zone was reactivated in the Mesozoic (Yuan et al., 2006; Glorie et al., 2012). Sinistral strike-slip deformation of the Chara shear zone was most likely coeval with the Irtysh shear zone (Li et al., 2015b). Some workers have suggested that such events are likely related to the collision between the Siberia craton and the Kazakhstan microcontinent and their differential rotations with respect to the major continental blocks (Didenko et al., 1994; Buslov et al., 2001, 2003).

Numerous gold deposits are distributed along the Chara shear zone, defining the Kalba gold province. Naumov et al. (2012) and Kovalev et al. (2009) reported $^{40}Ar/^{39}Ar$ and SHRIMP U-Pb ages of some selected gold deposits in the Kalba province, ranging from 306.6 ± 3.8 Ma to 248.3 ± 3.4 Ma. These ages suggest that the mineralization was synchronous with the deformation in the Irtysh shear zone as well as the major episode of emplacement of post-collisional granitoids in the Kalba-Narym terrane (295 to 274 Ma) (Vladimirov et al., 2008). However, it is not clear whether the gold mineralization was genetically related to igneous activity in the Kalba gold province (Kovalev et al., 2014).

3. Deposit geology

The North Kostobe gold deposit is located in the Bakyrchik ore district of the Kalba gold province (Fig. 2). In the district, NW-trending