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SHRIMP zircon U–Pb geochronology, geochemistry and H–O–Si–S–Pb isotope systematics of the Kanggur gold deposit in Eastern Tianshan, NW China: Implication for ore genesis

Yin-Hong Wang [a,*], Chun-Ji Xue [a], Fang-Fang Zhang [a], Jia-Jun Liu [a], Jun-Bao Gao [b], Tian-Jiao Qi [a]

[a] State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Beijing 100083, China
[b] No. 1 Geological Party, Xinjiang Bureau of Geology and Mineral Exploration, Changji 831100, China

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ABSTRACT

The Kanggur gold deposit is located in the southern margin of the Central Asia Orogenic Belt and in the western segment of the Kanggur–Huangshan ductile shear belt in Eastern Tianshan, northwestern China. The orebodies of this deposit are hosted in the Lower Carboniferous volcanic rocks of the Aqishan Formation and mainly consist of andesite, dacite and pyroclastic rocks. The SHRIMP zircon U–Pb age data of the andesite indicate that the volcanism in the Kanggur area might have occurred at ca. 339 Ma in the Early Carboniferous, and that the mineralization age of the Kanggur gold deposit was later than the age of volcanic rocks in the area. Geochemically, the andesite rocks of the Aqishan Formation belong to low-tholeiite and calc-alkaline series and display relative depletions in high field strength elements (HFSEs; i.e. Nb, Ta and Ti). The $\delta^{18}O_W$ and δD_W values vary from −9.1‰ to +3.8‰ and −66.0‰ to −33.9‰, respectively, indicating that the ore-forming fluids were mixtures of metamorphic and meteoric waters. The $\delta^{30}Si$ values of 13 quartz samples range from −0.3‰ to +0.1‰ with an average of −0.15‰, and the $\delta^{34}S$ values of 18 sulphide samples range from −0.9‰ to +2.2‰ with an average of +0.54‰. The $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ values of 10 sulphide samples range from 18.166 to 18.880, 15.553 to 15.635 and 38.050 to 38.813, respectively, showing similarities to orogenic Pb; these values are consistent with those of the andesite from the Kanggur area, suggesting a common lead source. All of the silicon, sulphur and lead isotopic systems indicate that the ore-forming fluids and materials were mainly derived from the Aqishan Formation, and that the host volcanic rocks of the Aqishan Formation probably played a significant role in the Kanggur gold mineralization. Integrating the data obtained from studies on geology, geochronology, petro-geochemistry and H–O–Si–S–Pb isotope systematics, we suggest that the Kanggur gold deposit is an orogenic-type deposit formed in Eastern Tianshan orogenic belt during the Permian post-collisional tectonism.

1. Introduction

The Tianshan orogenic belt constitutes a major segment of the southern part of the Central Asia Orogenic Belt (CAOB), located between the Siberian Craton to the north and the Tarim Craton to the south (Fig. 1A). The Tianshan orogenic belt is divided into Western and Eastern Tianshan, with the boundary running roughly along the Urumqi–Korla road from west to east (Fig. 1B; Y.J. Chen et al., 2012). The Eastern Tianshan in NW China is a typical Palaeozoic island arc system characterised by a complicated tectonic history and diverse styles of gold mineralization (Charvet et al., 2007; Huang et al., 2013; Ma et al., 1997; Pirajno, 2013; Qin et al., 2002; Sun et al., 2010; Xiao et al., 2004). According to previous studies, three types of gold deposits have been identified in Eastern Tianshan orogenic belt along an EW-trending gold ore belt: shear zone-type gold deposits (e.g. Kanggur, Hongshi and Matoutan gold deposits); quartz vein-type gold deposits (e.g. Xifengshan and Xiaojianshan gold deposits) and epithermal gold deposits (e.g. Shiyingtan and Mazhuangshan gold deposits) (Zhang et al., 2003).

As the largest gold deposit in this gold ore belt, the Kanggur gold deposit contains an estimated 40 t of Au resources at an average ore grade of 9.92 g/t (Zhang et al., 2003) and has attracted the interest of many geologists in terms of geological investigation (Wang et al., 2004b; Y.T. Wang et al., 2006; Xue et al., 1995; Zeng et al., 1994; Zhang et al., 2003), isotope geochemistry (Wang et al., 2004a; Zhang et al., 2003; Zhang et al., 2012b) and geochronology (Zhang et al., 2002, 2003). However, the timing of host rock formation remains controversial. The age of the host rocks has previously been inferred from Rb–Sr dating of the andesite at 290 to 330 Ma (Ma et al., 1997; Zhang et al., 2003) as well as from U–Pb zircon ages of the tonalite and Rb–Sr ages of the quartz-syenite porphyry at 275 to 282 Ma (Zhang et al., 1999, 2003). Moreover,

* Corresponding author at: State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, 29 Xue-Yuan Road, Haidian District, Beijing 100083, China.
E-mail address: wyh@cugb.edu.cn (Y.-H. Wang).

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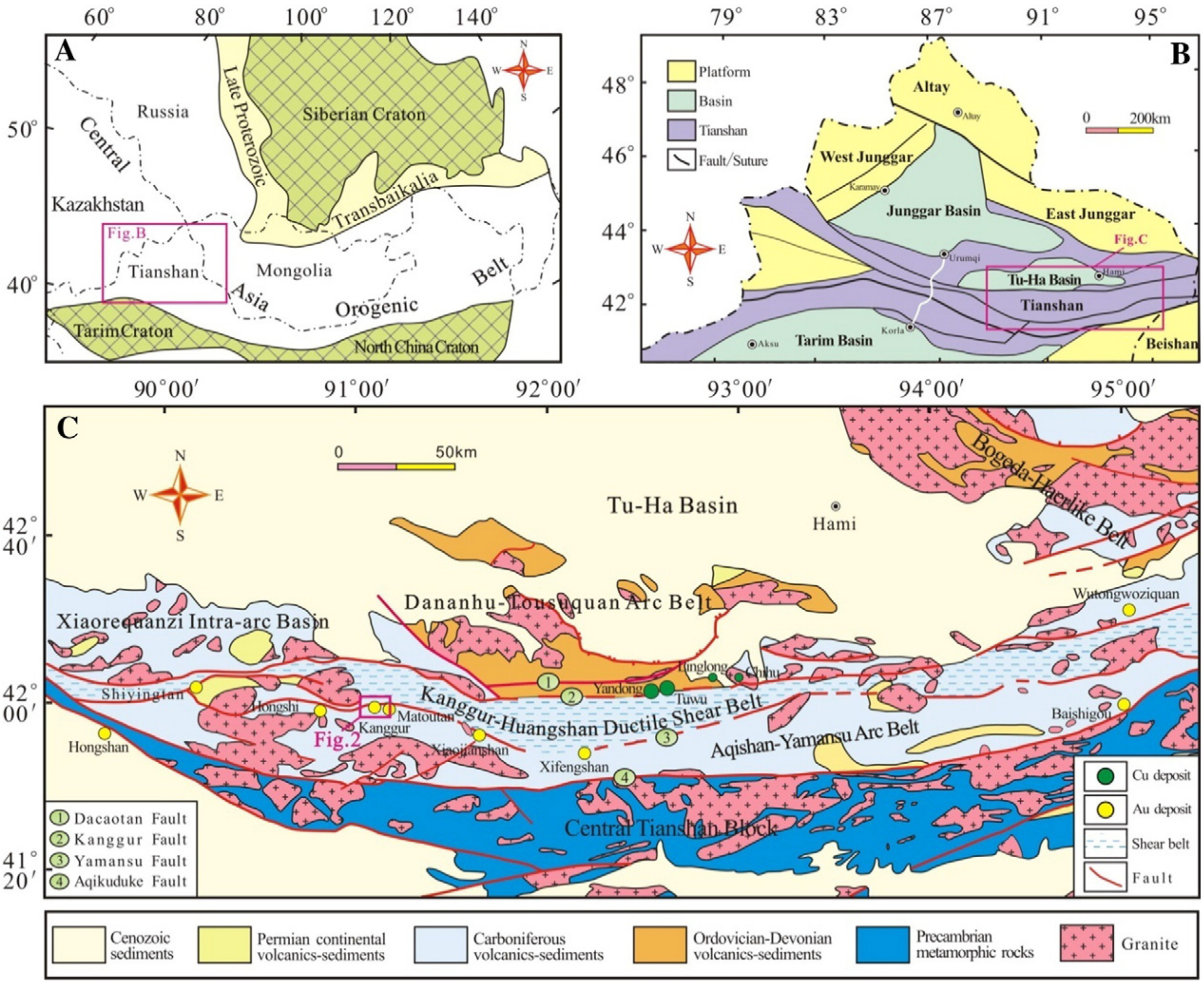

Fig. 1. (A) Location of the study area in the Central Asia Orogenic Belt (modified from Huang et al., 2013); (B) sketch map showing geological units of the Tianshan orogenic belt (modified from Y.J. Chen et al., 2012); (C) simplified geological map of the Eastern Tianshan orogenic belt (modified from J.B. Wang et al., 2006).

the ore-forming mechanism has not been adequately constrained until now, largely due to a lack of detailed geochemical data for the deposit. This paper provides new geological, geochemical and isotopic evidence that can contribute to the debate and help resolve genetic aspects of the Kanggur gold deposit. Here we report SHRIMP zircon U–Pb dating, whole-rock geochemical data and H–O–Si–S stable and Pb radiogenic isotope data for the Kanggur gold deposit. We also discuss the sources of the fluids and ore metals as well as the ore-forming mechanism. We hope that this study will also further promote research on similar gold deposits in Eastern Tianshan orogenic belt or the CAOB.

2. Geological setting

2.1. Regional geology

The Eastern Tianshan metallogenic belt is one of the important producers of Cu (+/− Ni), Au, Fe and Ag in China (Chen et al., 2011; Deng et al., 2011, 2013; Han et al., 2006; Mao et al., 2005; Pirajno, 2009, 2013; Wang et al., 2014a; Zhai et al., 1999, 2011; Zhang et al., 2008). It experienced a complex tectonic evolution including subduction, accretion and subsequent collision between the Siberian Craton and Tarim Craton (Gao et al., 1998; Han et al., 2006, 2010; Li et al., 2003; Ma et al., 1993, 1997; Xiao et al., 2004). The Eastern Tianshan can be divided into three major tectonic zones: namely, the Dananhu–Tousuquan arc belt, the Kanggur–Huangshan ductile shear belt and the Aqishan–Yamansu arc belt (Fig. 1C). The main structures of Eastern Tianshan are characterised by a series of approximately EW-trending faults including the Dacaotan, Kanggur, Yamansu and Aqikuduke faults (Fig. 1C; Ma et al., 1997). The lithologies exposed in the study area include the Lower Carboniferous Aqishan, Kushui and Yamansu Formations (Ji et al., 1994; Y.T. Wang et al., 2006; Xue et al., 1995; Zhang et al., 2003). The Aqishan Formation is composed of mainly calc-alkaline volcanic rocks with minor carbonate rocks and sandstone. The Kushui Formation comprises turbiditic graywacke and sandstone. The Yamansu Formation is composed of a suite of intermediate to felsic calc-alkaline volcanic lavas, pyroclastic and sedimentary rocks.

Intrusive and subvolcanic rocks including tonalite, quartz-syenite porphyry, dacite porphyry and mafic-ultramafic bodies were primarily emplaced in the Early Carboniferous and Permian (Xue et al., 1995; Zhang et al., 2003) and are located in a nearly EW-trending band along the Kanggur–Huangshan ductile shear belt (Fig. 1C). The Kanggur–Huangshan ductile shear belt, located between the Kanggur and Yamansu faults with a width of 10–30 km and a length of over 500 km, is well developed in Eastern Tianshan. This ductile shear belt, which trends EW and dips N, is characterised by a series of mylonites and mylonitised rocks. The typical metamorphic mineral assemblage is composed of actinolite, biotite and chlorite. A number of shear zone-hosted gold deposits (e.g. Hongshi, Kanggur and Matoutan) were formed along the southern margin of the Kanggur–Huangshan ductile shear belt; such deposits are related to this ductile shear zones as well as to deep faults (Ji et al., 1994; Rui et al., 2002b; Zhang et al., 2003).