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Multiple-stage mineralization in the Sawayaerdun orogenic gold deposit, western Tianshan, Xinjiang: Constraints from paragenesis, EMPA analyses, Re–Os dating of pyrite (arsenopyrite) and U–Pb dating of zircon from the host rocks

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ABSTRACT

The Sawayaerdun deposit, located in the southern Tianshan orogenic belt in Xinjiang, NW China, is one of many orogenic gold deposits in the Central Asian Orogenic Belt (CAOB). The deposit is controlled by reverse faults and hosted in highly deformed carbonaceous turbidites that have undergone pyritic, arsenopyritic, silicification, carbonate and sericitic alteration. Gold occurs mainly in the form of electrum and native gold, and is also present in pyrite and arsenopyrite as "invisible gold". Three generations of auriferous pyrite have been recognized through detailed petrographic studies and EMPA analyses. The pyrite with framboidal texture (Py_0) is disseminated in the host rock, and is locally enriched in gold. The anhedral pyrite (Py_1), associated with silicification and quartz veins that experienced strong deformation, has an average Au content of 0.021 wt.%. The euhedral–subhedral pyrite (Py_2), showing octahedron cube and pyritohedron habits, is associated with least deformed quartz veins that are best developed in the main orebodies, and has an average Au content of 0.023 wt.%. The Py_0 is interpreted to have formed contemporaneously with the ore-bearing rocks, with a maximum depositional age of 355 ± 7.3 Ma based on U–Pb dating of detrital zircons. Re–Os isotopic analyses of four Py_1 samples yielded an isochron age of 324 ± 4.8 Ma, and those of five Py_2 samples yielded an isochron age of 282 ± 12 Ma. Py_1 is interpreted to have formed in the syn-tectonic stage, during the collision between the Tarim craton and the Central Tianshan terrane in Late Carboniferous, whereas Py_2 was formed in a later mineralization event, during the late- to post-tectonic stage in Early Permian. These study results suggest that multiple stages of gold mineralization have developed in the Sawayaerdun deposit, and similar mineralization processes may have taken place in other parts of the Western Tianshan Orogen.

1. Introduction

The Western Tianshan Orogen (WTSO), a 2500 km long orogenic belt extending from Uzbekistan, Tajikistan, Kyrgyzstan and Kazakhstan to northwest Xinjiang, China, is located in the southwestern margin of the Central Asian Orogenic Belt (CAOB) (Fig. 1a). A great variety of gold deposits, especially porphyry type and orogenic type, have been discovered in the WTSO (Goldfarb et al., 2014; Yakubchuk et al., 2002), including the world-class Muruntau (Frimmel, 2008), Daugyztau (Bierlein and Wilde, 2010), Amantaitau (Pasava et al., 2013), Zarmitan (Abzalov, 2007), and Kumtor (Mao et al., 2004) deposits. As the largest gold deposit in Xinjiang, the Sawayaerdun deposit is a typical example of orogenic gold deposits in the western Tianshan, with a reserve of >100 t Au and an inferred resource of ~300 t Au (Rui et al., 2002; Xue et al., 2014a, 2014b, 2015).

Since it was discovered in the 1990s, the Sawayaerdun gold deposit has been extensively studied in terms of ore geology (Yang et al., 2005; Liu et al., 2002a), geochemistry (Zheng et al., 2002a, 2002b; Ye et al., 1999a; Chen et al., 2012b), ore-forming fluid (Chen et al., 2004, 2007, 2012a, 2013) and genesis (Yang et al., 2007; Liu et al., 2007). Pyrite and arsenopyrite have been known to be the main auriferous sulfide minerals in the Sawayaerdun ores (Liu et al., 2007), but their textures, relative timing with other minerals and gold contents have not been well documented. The mineralization age is also controversial, ranging from 210 Ma (Ar–Ar dating of auriferous quartz, Liu et al., 2002b), 230 ± 10 Ma (Rb–Sr dating of fluid inclusions in auriferous quartz, Ye et al., 1999b), 342 ± 27 Ma and 247 ± 16 Ma (Rb–Sr dating of fluid inclusions in auriferous quartz, Chen and Li, 2003) to 288 ± 50 Ma (Rb–Sr dating of fluid inclusions in auriferous quartz, Liu et al., 2007). No direct

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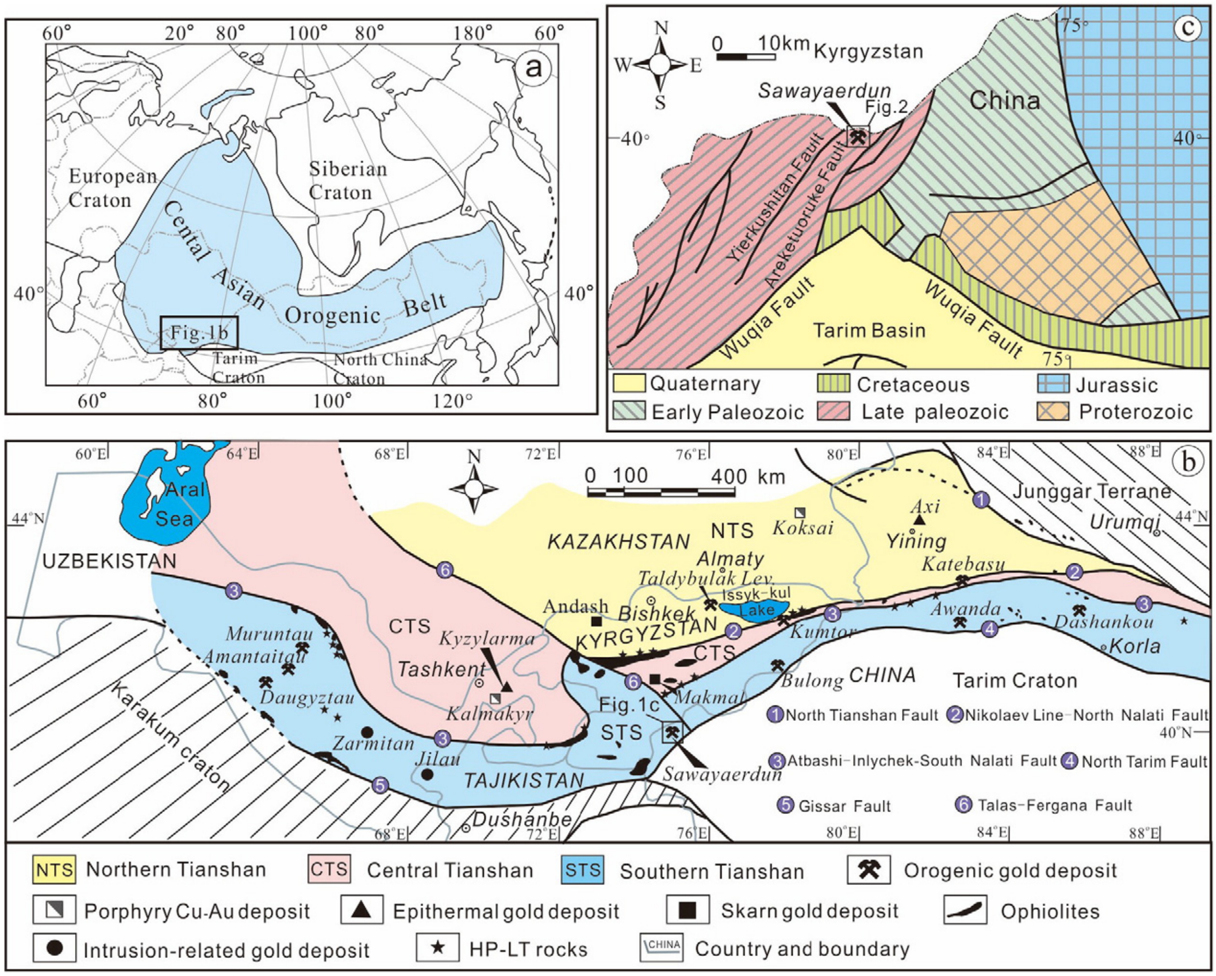

Fig. 1. (a) Tectonic map of Central Asian Orogenic Belt (modified from Gao et al., 2009), (b) Sketch map of western Tianshan showing the location of the Sawayaerdun gold deposit (modified form Xue et al., 2014a), (c) Tectonic map of the western part of the Chinese Southern Tianshan showing the strata and faults in the region (modified from Yang et al., 2007; Chen et al., 2012a).

dating of auriferous sulfide minerals has been attempted. In addition, the age of the host rocks is also controversial, ranging from Late Silurian or Late Silurian–Early Devonian (Ye et al., 1999a, 1999b; Yang et al., 2007) to Late Carboniferous (Liu et al., 2007).

In this paper, we present detailed petrographic evidence to show that there are three generations of pyrite, and use EMPA data to confirm that each of them contains gold. We also provide U–Pb isotopic ages of detrital zircon to constrain the maximum age of the host rocks, and Re–Os isotopic ages of pyrite and arsenopyrite to estimate the mineralization ages. These new data serve to constrain the mineralization processes of the Sawayaerdun deposit in the context of regional tectonic evolution, and provide an example of multi-stage gold mineralization which will be useful for re-evaluation of the gold metallogeny in the Chinese part of the Western Tianshan Orogen.

2. Geological background

The Chinese Tianshan orogenic belt is subdivided into three structurally bounded tectonic units, which are named, from north to south, the Northern Tianshan (NTS), Central Tianshan (CTS), and Southern Tianshan (STS) (Fig. 1b). The Northern Tianshan is separated from the Junggar Terrane by the North Tianshan fault in the north, and from the Central Tianshan by the Nikolave Line–North Nalati suture in the south. The Southern Tianshan is separated from the Central Tianshan by the Atbashi–Inlychek–South Nalati fault in the north, and from the Tarim craton by the North Tarim fault in the south (Fig. 1b, Gao et al., 2009; Xue et al., 2014a, 2014b; Zhao et al., 2014, 2015). In addition, the NW-striking Talas–Fergana dextral strike-slip fault transects the three tectonic units obliquely (Fig. 1b).

The Southern Tianshan consists of Precambrian metamorphic rocks which are covered by Cambrian–Carboniferous marine carbonates and clastic rocks with volcanic interlayers (Allen et al., 1993; Gao et al., 2009). Permian fluvial sedimentary and volcanic rocks unconformably overlie the Upper Carboniferous carbonate rocks in the central part of STS (Carroll et al., 1995; Huang et al., 2012). Some ophiolites and high-pressure/low-temperature metamorphic (HP–LT) rocks are exposed sporadically along the Atbashi–Inlychek–South Nalati Fault (Fig. 1b; Gao et al., 2006; Xiao et al., 2013). The glaucophane in the ophiolites has a K–Ar age of 360 $\pm$ 10 Ma (Gao et al., 2009), which is interpreted to indicate that the ophiolites were formed during the northward subduction of the South Tianshan Ocean. The phengite and metamorphic zircon in the HP–LT rocks have $^{40}Ar–^{39}Ar$ ages of 331–310 Ma and U–Pb age of 320 Ma, respectively (Klemd et al., 2005; Su et al., 2010; Gao et al., 2011), interpreted to represent the subsequent collision between the Tarim craton in the south and the Central Tianshan terrane in the north during Late Carboniferous (Gao et al., 2009; Huang et al., 2012). Intrusive rocks, which make up ~5% of the total area of the STS, were mostly formed from Late Carboniferous to Early Permian (Huang et al., 2012). Post-collisional granites have ages ranging from 298 to 260 Ma (Solomovich, 2007; Konopelko et al., 2007; Long et al., 2008; Gao et al., 2011), consistent with the inference that the closure of the South Tianshan Ocean took place during Late Carboniferous.