Chemical Geology 310-311 (2012) 1–11

Contents lists available at SciVerse ScienceDirect

Chemical Geology

journal homepage: www.elsevier.com/locate/chemgeo

Isotopic geochemistry of the Sawayaerdun orogenic-type gold deposit, Tianshan, northwest China: Implications for ore genesis and mineral exploration

Hua-Yong Chen [a,1], Yan-Jing Chen [b,*], Mike Baker [a]

[a] CODES, ARC Centre of Excellence in Ore Deposits, University of Tasmania, Private Bag 126, Hobart, Tasmania 7001, Australia
[b] Key Laboratory of Crust and Orogen Evolution, Peking University, Beijing 100871, China

ARTICLE INFO

Article history:
Received 15 March 2011
Received in revised form 3 March 2012
Accepted 26 March 2012
Available online 4 April 2012

Editor: L. Reisberg

Keywords:
Orogenic gold deposit
Tianshan
Isotope geochemistry
Fluid source
Fluid evolution

ABSTRACT

The Sawayaerdun gold deposit is hosted by Carbonaceous metasediments and is considered to be the largest Muruntau-type gold deposit in the Chinese Tianshan metallogenic belt. Gold mineralization at Sawayaerdun occurs in quartz veins associated with three major hydrothermal events: an early, barren quartz vein stage, middle stage mineralized quartz veins with pyrite and late carbonate (-quartz) veins.

The isotopic compositions of quartz and sulfides from the Sawayaerdun gold deposit show some variation but are generally comparable to those of other orogenic-type gold deposits. Fluids trapped in early-stage quartz have a $\delta^{18}O$ range of 13.6‰ to 15.4‰, δD of −48‰ to −75‰, $\delta^{13}C$ of 0.5‰ to 4.2‰ and $\delta^{30}Si$ of −0.2‰ to 0‰. In contrast, isotopic compositions of fluids trapped in middle-stage quartz have $\delta^{18}O$ values of 6.7‰ to 14.7‰, δD of −56‰ to −110‰, $\delta^{13}C$ of 0.4‰ to 10.1‰ and $\delta^{30}Si$ of −0.3‰ to 0‰. Diagenetic and hydrothermal pyrite have similar sulfur (−1.8‰ to 0.9‰) and Pb isotopic values that are associated with host rock compositions. The early-stage, ^{18}O and ^{13}C-rich fluids are probably derived from metamorphic decarbonation of the sedimentary host rock at depth, leading to the precipitation of early barren quartz veins. In the middle stage, a decrease in the regional pressure and temperature regime could have resulted in the incorporation of external fluids into the ore-forming system. These external fluids with isotopic signatures similar to that of the host rock and generally rich in ^{34}S and radiogenic Pb mixed with original ore-forming fluids to generate extensive metal precipitation. Late-stage fluids trapped by calcite veins show isotopic compositions similar to meteoric water, indicating the cessation of hydrothermal fluid circulation at Sawayaerdun occurred at this time. The metallogenetic model illustrated by stable and Pb isotopes is also consistent with fluid inclusion studies in Sawayaerdun.

The development of mineralization at Sawayaerdun is strongly linked to fluid mixing, as witnessed by the isotopic signatures of fluids from identified ore-bearing zones. The isotopic compositions of other anomalous zones at Sawayaerdun are similar to those of the mineralized zones, suggesting a high potential for further exploration.

1. Introduction

Since the discovery of the Muruntau gold deposit (175 Moz; Goldfarb et al., 2001) in Central Kyzylkum, Uzbekistan, Muruntau-type orogenic-Au deposits, commonly characterized by structural control, metasediment hosts and multiple hydrothermal stages, have become a major target for both mineral exploration and research in the Central Asian Tianshan belt (Graupner et al., 2001; Wilde et al., 2001; Morelli et al., 2007; Bierlein and Wilde, 2010). Many large-size gold deposits, including Kumtor (18 Moz), Daugyztau (5 Moz) and Jilau (>3 Moz), have been discovered in the Southern Tianshan belt across Uzbekistan, Tajikistan, Kazakhstan and Kyrgyzstan since the early 1980s (Fig. 1, Rui et al., 2002; Yakubchuk et al., 2002). These new discoveries, especially that of the Kumtor deposit (Kyrgyzstan), which is only 40 km from the China–Kyrgyzstan border, have stimulated more recent exploration activity in the Chinese Tianshan and directly resulted in the discovery of the Sawayaerdun gold deposit in Xinjiang, northwest China in the early 1990s (Ye et al., 1998).

The Sawayaerdun deposit contains >3 Moz Au with an inferred resource of at least 10 Moz (Rui et al., 2002). It is considered to be the largest Muruntau-like gold deposit discovered in China (Liu et al., 2007). Previous studies have shown that the Sawayaerdun gold deposit shares many similarities with the Muruntau deposit and other orogenic-type Au deposits, including geological setting, alteration assemblages, paragenetic relationships and ore-forming fluids (Liu et al., 2007; Yang et al., 2007; Chen et al., 2012). Recent investigation indicates that hydrothermal fluids forming the Sawayaerdun deposit are CO_2-rich and probably evolved through

* Corresponding author. Tel.: +86 10 62757390.
E-mail addresses: Huayong.chen@utas.edu.au (H.Y. Chen), yjchen@pku.edu.cn (Y.J. Chen), bakermj@utas.edu.au (M. Baker).
1 Tel.: +61 3 62261735.

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doi:10.1016/j.chemgeo.2012.03.026

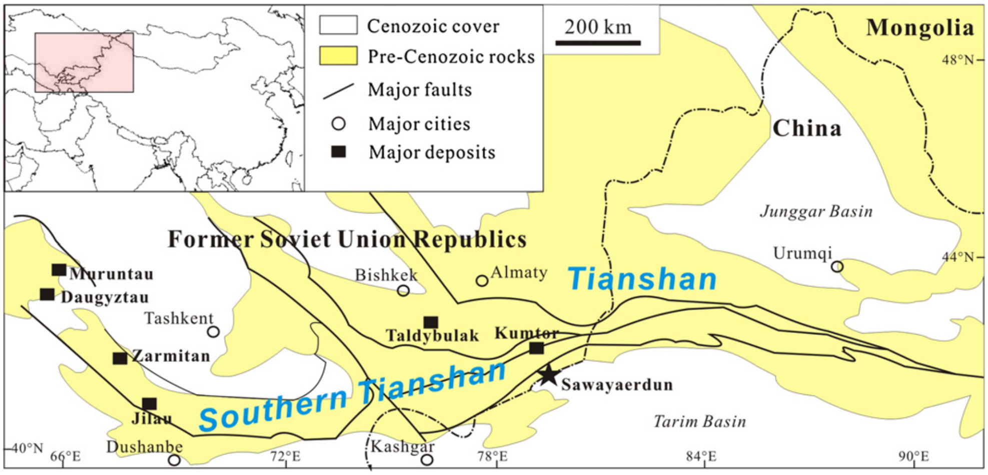

Fig. 1. Simplified regional geologic map of the Central Asia showing the location of major Au deposits. Modified from Chiaradia et al. (2006).

multiple stages (Chen et al., 2012), consistent with most orogenic-type deposits (Chen et al., 2007). This paper aims to present the isotopic geochemical constraints on the sources of fluids and metals, as well as the geochemical nature of fluids from the major hydrothermal stages, in order to determine the mechanism of metal deposition at Sawayaerdun.

Detailed studies of the geology, alteration, mineralization and ore-forming fluids have been performed on the major Muruntau-type Au deposits of the Southern Tianshan belt, such as Muruntau (Wilde et al., 2001; Bierlein and Wilde, 2010), Kumtor (Ivanove, 2000; Mao et al., 2004) and Jilau (Cole et al., 2000). The discriminating features of Au mineralization in the wider Tianshan belt have also been investigated (Yakubchuk et al., 2002, 2005; Chiaradia et al., 2006). Despite this work, systemic isotope studies of the major Au deposits of the Southern Tianshan belt are still rare. The Sawayaerdun gold deposit provides an excellent opportunity to study in detail the sources of fluids and metals and the fluid evolution of an orogenic-type hydrothermal system using isotopic geochemistry. This study aims to improve our understanding of this major mineralization style and in turn enhance exploration success in the Southern Tianshan belt.

2. Regional and local geology

The Sawayaerdun gold deposit is situated approximately 28 km north-northwest of Wulukeqiati Township, Wuqia County, Xinjiang (Yang et al., 2007). It is located in the southern Tianshan orogenic belt, which has contributed to the northwest margin of the Tarim plate (Fig. 1). The deposit is hosted in a Late Carboniferous greenschist facies metamorphosed turbidite sequence that can be subdivided into three lithologic units. The lower unit consists of gray metamorphosed quartz-sandstones and carbonaceous slates. The base of this unit is intercalated with marlstone and limestone containing fossils such as *Hapsiphyllide Grabau* (Liu et al., 2007). The middle unit contains dark-gray to black thinly-bedded siltstones with interbedded carbonaceous slates. It is overlain by an upper unit of gray to dark gray, medium- to thinly-bedded silty slate, siltstone, and pebbled siltstone (Zheng et al., 2001; Liu et al., 2007). The orebodies of the Sawayaerdun deposit mainly occur in the middle stratigraphic unit (Fig. 2). The host rocks have yielded two Rb–Sr isochron ages of 304.7 ± 11.6 Ma and 292.4 ± 0.4 Ma, and a Sm–Nd isochron age of 294 ± 19 Ma (Liu et al., 2007).

At Sawayaerdun, subsidiary faults and shear zones between the two regional faults host most of the auriferous quartz veins in this region. These faults were active during late-Hercynian orogeny and show strike-slip shearing features (Liu et al., 1996). They usually have a northeast strike similar to the host strata and have evolved from ductile through to brittle deformation (Ye et al., 1999). As illustrated in Fig. 2, fault F1 and subsidiary fractures control the location of ore formation, with orebodies occurring in the hanging wall of F1.

Only minor andesite and tuff flows have been identified at the top stratigraphic horizons of the host rocks and no associated large intrusions have been identified in the area. A few alkaline diabase and diorite dykes were identified in the deposit and in Permian-aged strata outside the ore zone. All dykes strike NNE or close to N–S (Liu et al., 2007) and commonly intrude turbidities, causing pervasive sericite, chlorite, epidote and carbonate alteration. K–Ar ages of the diabase dykes range from 270.5 Ma to 127.9 Ma and probably record at least two different phases of magmatic activity in the district (Liu et al., 2007).

3. Alteration and mineralization

Twenty-four ore-bearing zones have been identified at the Sawayaerdun deposit (Fig. 2), with four ore zones (I, II, IV and XI) of economic grade. The NW-dipping ore zone IV is the largest with ~4200 m length and 15–48 m width and Au reserves exceeding 2.5

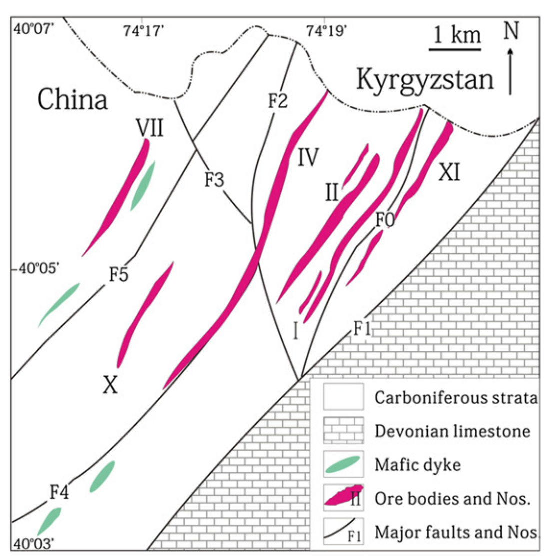

Fig. 2. Simplified geological map of the Sawayaerdun gold deposit. Modified from Liu et al. (2007) and Chen et al. (2012).