Ore Geology Reviews 101 (2018) 700–724

Contents lists available at ScienceDirect

Ore Geology Reviews

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

Tungsten mineralization in the Tien Shan Gold Belt: Geology, petrology, fluid inclusion, and stable isotope study of the Ingichke reduced tungsten skarn deposit, western Uzbekistan

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ARTICLE INFO

Keywords:
Reduced skarn
Tungsten
Fluid inclusions
Stable isotopes
Tien Shan
Central Asia

ABSTRACT

The Ingichke reduced W skarn deposit (100Kt WO_3, with the average grade of 0.58% WO_3) is the largest one among W deposits known in the Tien Shan Gold Belt. It is associated with an Early Permian multiphase granitoid pluton that comprises ilmenite-series to ilmenite-titanite-bearing, medium- to high-K, metaluminous to peraluminous I-type granitoid (monzodiorite-granodiorite to granite-leucogranite) rocks. The pluton is related to crustal accretionary-type reservoirs of granitoid magma likely formed in response to an ascent of asthenospheric material at the post-collisional stage. It is part of the continuum of plutonic suites related to reduced W-Au-polymetallic deposits, with further links to reduced intrusion-related Au deposits. The deposit comprises abundant pyroxene (mainly hedenbergitic) skarn, and a minor garnet skarn (mostly grossular-rich garnet with elevated almandine and spessartine contents). Hydrosilicate (propylitic) alteration (amphibole-chlorite-calcite-quartz with abundant pyrrhotite and minor chalcopyrite) partially overprints skarn and is in turn overprinted by zones of phyllic alteration (quartz-sericite-Fe-carbonate, locally with albite, scheelite, and sulfides, Bi and Au minerals).

Prograde and retrograde skarns were formed from aqueous, dominantly magnesian-sodic-chloride, moderately-saline (10–14 to 4–7 wt% NaCl-eq.) hot fluid, with its progressing enrichment in Ca. Hydrosilicate (propylitic) and phyllic alteration assemblages were formed from boiling low salinity, carbonic-aqueous, magnesium-sodic-calcic fluids at moderate (330–355 °C) to lower (250–265 °C) temperatures, respectively, with separation of carbonic (with varying CO_2/CH_4 ratio) and aqueous-chloride fluids. Trapping pressures ranged from ~2000 to 1500 bars, indicating a lithostatic depth of some 6 to 8 km, i.e., a lower-intermediate level in an integrated model of reduced W skarn deposits. The stable isotope data indicate an influence of a sedimentary (limestone) source of oxygen and carbon at the retrograde skarn stage ($\delta^{18}O_{H2O}$ = +8.1 to +9.0%, $\delta^{13}C_{CO2}$ = −2.5 to +0.3%), and a dominantly magmatic (mantle- to crustal-derived) source of water ($\delta^{18}O_{H2O}$ = +7.0 ± 0.5%) at the hydrosilicate (propylitic) and phyllic alteration stages and carbon ($\delta^{13}C_{CO2}$ = −7.8 to −4.7%) at the hydrosilicate (propylitic) stage. At the phyllic alteration stage, a strong enrichment in the light carbon isotope ($\delta^{13}C_{CO2}$ = −10.1 to −9.4%) indicates a possible influence of a reduced organic carbon source. A magmatic source of sulfur is envisioned for the hydrosilicate (propylitic) ($\delta^{34}S$ = +2.0 ± 0.5%) and phyllic ($\delta^{34}S$ = −1.0 ± 0.3%) alteration stages.

1. Introduction

The Tien Shan Gold Belt is a metallogenic province primarily distinguished for its strong endowment in Au mineralization of the orogenic to reduced intrusion-related types (e.g., Yakubchuk, 2004; Yakubchuk et al., 2005; Goldfarb et al., 2014); significant Au-Cu porphyry and associated Au-Ag epithermal deposits are also present (e.g., Seltmann and Porter, 2005; Seltmann et al., 2011, 2014). However, since the first definition of the belt (Kudrin et al., 1990), it was recognized that it incorporates a number of significant W deposits, with most of them known (and mined) long before the Au potential of the belt was established. Some of these W deposits have been recently described in more detail (e.g., Soloviev and Kryazhev, 2018a,b, and references therein).

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https://doi.org/10.1016/j.oregeorev.2018.08.020
Received 11 May 2018; Received in revised form 15 August 2018; Accepted 16 August 2018
Available online 19 August 2018

The Ingichke deposit belongs to the reduced type of W skarns (Einaudi et al., 1981; Kwak and White, 1982) and is related to ilmenite-series granitoids (Ishihara, 1981, 2004). By these signatures, it is similar to many large reduced W skarn deposits (e.g., MacTung and CanTung, Canada; Fujigatani, Japan; Salau-Costabonne, France; Vostok-2 and Lermontovskoe, Far East Russia; Dick and Hodgson, 1982; Sato, 1980; Guy et al., 1988; Fonteilles et al., 1989; Soloviev et al., 2017a,b). These W deposits are parts of Sn-W metallogenic belts that include reduced intrusion-related Au deposits (Thompson et al., 1999) formed in the late- to post-collisional tectonic settings and can be considered as part of a spectrum of reduced Au-W deposits (e.g., Lang and Baker, 2001; Hart, 2007). The respective Au deposits contain significant W mineralization in skarns and other replacement zones as well as in younger hydrothermal assemblages, thus further highlighting genetic links of the W and Au mineralization in a broader Au-W magmatic-hydrothermal system. Consistently, studying reduced W skarn deposits aimed to expanding their integrated genetic model is important both from the economic perspective and in the context of their possible indicatory metallogenic role.

The Ingichke deposit is the largest W skarn, and the largest W deposit, in the Tien Shan God Belt (e.g., Rabchevsky, 1988). It was discovered in 1941, explored and mined by deep (up to ~800 m from the surface) underground operations in 1942–1996. Pre-production resources and reserves of the deposit contained in skarn bodies were 100,000 t WO_3 at the average grade of 0.58% WO_3 (at 0.15% WO_3 cut-off). The mining has been ceased in 1996 but the deposit still contains ~60,000 t WO_3 at the average grade of 0.60% WO_3.

2. Regional tectonic and metallogenic setting

The Tien Shan Gold Belt (Fig. 1) is a metallogenic province occurring in the Paleozoic orogenic systems of Central Asia, which extend along a southern active continental margin of the Kazakhstan-Tien Shan paleocontinent, part of the Altaid orogenic collage (e.g., Kudrin et al., 1990; Yakubchuk et al. 2002, 2005). The belt includes a number of subparallel metallogenic zones (e.g., Kudrin et al., 1990) that correspond to the evolution from active subduction to collisional (including late- and postcollisional) processes. The northern zones cover the structures of both Middle and Southern Tien Shan and comprise oxidized to redox-intermediate deposits: alkalic Cu-Au porphyry (e.g., Almalyk; Seltmann and Porter, 2005; Seltmann et al., 2014; Cheng et al., 2018), shoshonite-related oxidized W-Mo-Cu-Au skarn deposits (e.g., Kensu, Kumbel, Chorukh-Dairon, Kashkasu; Soloviev and Kryazhev, 2018a, and references therein), redox-intermediate W-Mo skarn deposits (e.g., Soloviev and Kryazhev, 2018b), and intrusion-related to orogenic Au (± W) deposits (e.g., Kumtor, Muruntau; Mao et al., 2004; Graupner et al., 2010; Kempe et al., 2016). In contrast, the southern zones are coincident with the collisional structures of the Southern Tien Shan and comprise mostly reduced intrusion-related Au deposits (e.g., Jilao; Cole et al., 2000) as well as Sn, Sn-Cu-Zn, W-Sn, W, Au-W deposits including reduced W skarns.

In western Uzbekistan, the southern metallogenic assemblage is coincident with the Kuldjuktau-Zirabulak-Karatyube segment of the Southern Tien Shan (Fig. 2). Brookfield (2000) defined this segment as a zone of strong faulting, shearing and plastic deformation, likely a Middle Carboniferous thrust-fault zone. It is formed of thick, highly deformed metamorphosed Silurian volcaniclastic turbidite sandstones,

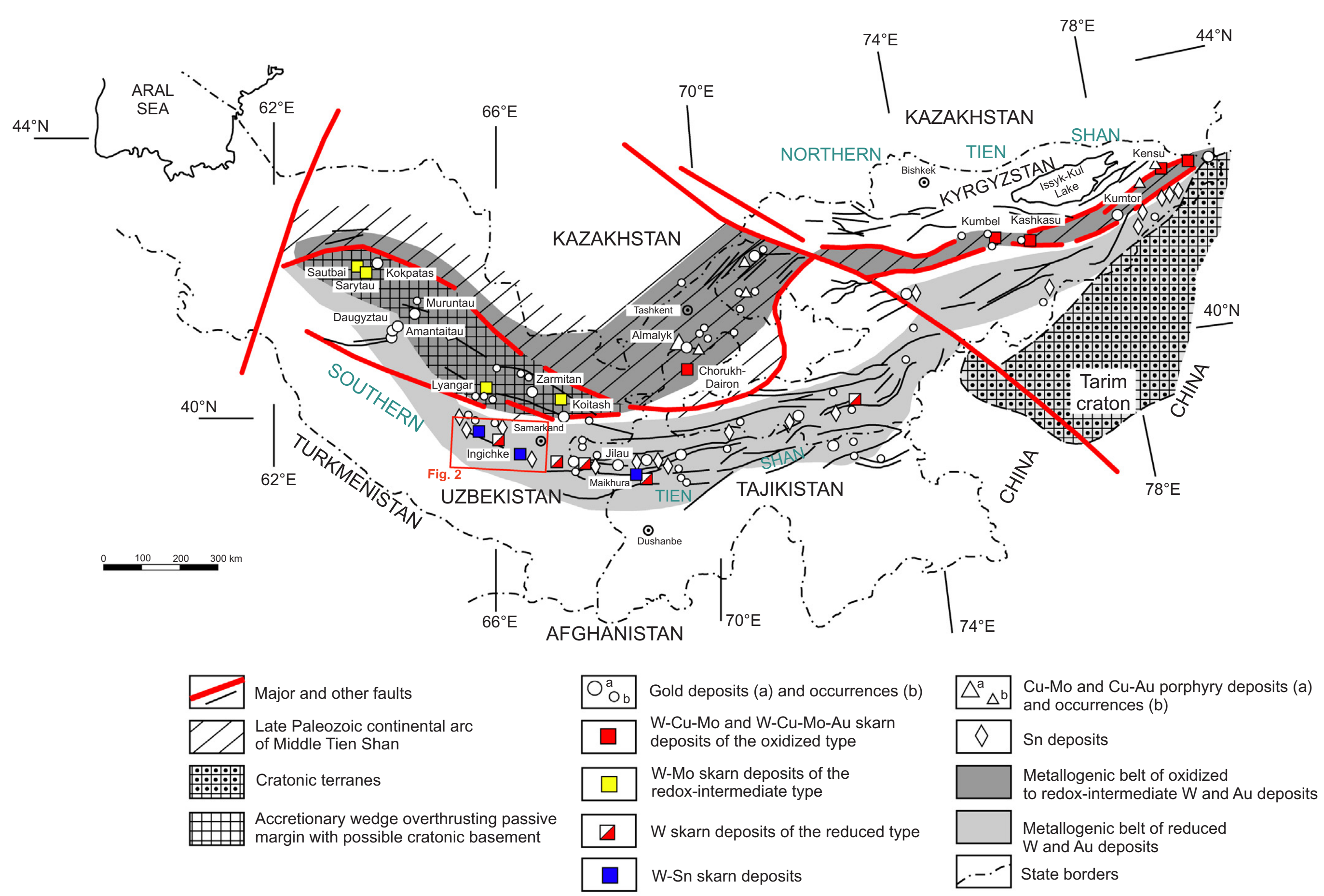

Fig. 1. Regional tectonic setting and the major W and Au deposits of the Tien Shan Gold Belt (modified after Kudrin et al., 1990; Cole et al., 2000; Yakubchuk et al., 2005; Seltmann and Porter, 2005; Seltmann et al., 2011, 2014; Soloviev and Kryazhev, 2018a,b, and references therein).