1 Introduction

Mineralized occurrences in the Baiganhu district were discovered in 2002 after extensive exploration in the Eastern Kunlun domain in the Kunlun terrane. Tungsten-Sn deposits in the area contain total resources of 174,913 tonnes of WO₃ and 79,091 tonnes of Sn, which makes the Baiganhu field a new large W-Sn metallogenic province. The Keke-Kaerde deposit is the first economic W-Sn mineralization found on the Tibetan plateau, thus the documentation of the deposit is useful in exploration for W-Sn mineralization in the region and elsewhere. Previous work related to the area hosting the W-Sn mineralization includes a regional metallogenetic study (Li et al., 2006), the geological setting of the deposit (Li et al., 2006), and the geochemical characteristics and genetic model of the mineralization (Liu et al., 2007). We have determined U-Pb zircon ages of monzogranite that is closely associated with the W-Sn mineralization, a U-Pb isochron age of cassiterite, fluid inclusion heating-cooling data, and H and O isotope compositions of mineralizing fluids.

2 Geology of Mineral Deposits

The Baiganhu district is situated west of the Baiganhu deformation zone in the Qimantage area, in the Northern Kunlun (Qimantage) early Paleozoic arc of the East Kunlun domain. The Baiganhu district is at elevations ranging from 4100 to 4400 m above sea level, located ~90 km southwest of the town of Huatugou. It may be accessed by gravel roads from the town. The area is underlain by the Mesoproterozoic Xiaomiao formation and the Silurian Baiganhu formation. The Xiaomiao formation is mostly comprised of two-mica quartz schist, amphibolite, biotite-bearing plagiogneiss and quartzite. The protoliths may be siliciclastic and carbonate sedimentary rocks with minor volcanic rocks. The area has abundant granitic intrusions of varying size, including monzogranite and potassic granite, that are accompanied by contact metamorphic aureoles in siliciclastic rocks and skarns in carbonate rocks of the Xiaomiao formation. Potassic granite is a late phase intruding into monzogranite (Fig. 1). The W-Sn deposits with economic grades are all associated with the monzogranite (Fig. 1). Alteration includes greisenization and silicification. Greisenization resulted in an increase in quartz and muscovite, and a decrease in feldspars.

As of 2013, a total of 76 discrete mineral occurrences have been discovered in the Baiganhu W-Sn field and can be grouped into three main clusters: Bashi-Erxi, Baiganhu Main and Keke-Kaerde (Fig. 1). The W-Sn deposits formed through three principal events. The first stage involves the early crystallization of tremolite, diopside and scheelite in tremolite-diopside skarns during the skarnization along the contacts between monzogranite intrusions and the Xiaomiao formation. The skarns contain minor biotite, chlorite and quartz. Diopside is an early mineral formed at high temperatures and is mostly replaced by tremolite. Biotite is partially altered to chlorite. Carbonate rocks in the host Xiaomiao formation close to skarns are extensively recrystallized to form marble. Siliciclastic rocks of the Xiaomiao formation are altered to form sericite-quartz schist. The second event is the development of greisen-type deposit, where quartz, muscovite, tourmaline, fluorite, wolframite and scheelite crystallized in the upper part and wall rocks of monzogranite intrusions. In this greisenization event, plagioclase and K-feldspar are replaced by muscovite and tourmaline. Fluorite is locally
common, along with muscovite, and it replaces plagioclase and K-feldspar. The host rocks are silicified and chloritized. The third event formed W- and Sn-bearing quartz-veins in the Xiaomiao formation and muscovite-bearing zone of monzogranite. Cross-cutting relationships clearly indicate that the veining took place after the greisenization. The veins are composed of quartz, wolframite, cassiterite, and minor chlorite and scheelite. The wall rocks of the veins are chloritized.

3 Age Constraints on Ore Formation

Monzogranite associated with the mineralization yielded a $^{238}\text{U}/^{206}\text{Pb}$ zircon age of 430.5±1.2 Ma ($n=25$). Cassiterite yielded an isochron age of 427 ± 13 Ma on the diagram of $^{238}\text{U}/^{207}\text{Pb}$ vs. $^{206}\text{Pb}/^{207}\text{Pb}$ ($n=32$, Fig.2), which confirms a close relationship of the early Silurian intrusion and the W-Sn mineralization. This period corresponds to the end of subduction of the Proto-Tethyan oceanic plate followed by local extension. The timing of the mineralization indicates another important W-Sn metallogenic event in China besides the period of late Jurassic (from 160 to 150 Ma) in
the Nanling region.

4 Nature of Vein-Forming Fluids

Quartz in the wolframite- and cassiterite-bearing quartz veins shows two types of fluid inclusions; liquid-rich two-phase aqueous inclusions and CO₂-rich and CH₄-bearing three-phase inclusions. Inclusions have medium salinity (10-14 wt%NaCl equiv), low density (0.60-1.06 g/cm³), and moderate homogenization temperatures (240-270 °C). The CO₂-phase in three-phase inclusions shows a large variation from 10 to 70 vol.%, which is attributed to immiscible separation of a CO₂-rich phase from saline aqueous fluids. The immiscible separation likely contributed to the mineralization in quartz veins. The δ¹⁸O and δD values of the mineralizing fluids calculated from quartz and inclusions in quartz vary from +4.5 to +6.4 ‰ and -65 to -43 ‰, respectively, supporting that the mineralizing fluids originated from the parental magmas.

Acknowledgments

We thank Anshun Zhou, Su Wang, Kan Li and Bing Qian for their help during our field works. We also thank Kejun Hou at Chinese Academy of Geosciences, Huaikun Li and Jianzhen Geng at Tianjin Institute of Geology and Mineral Resources for their help in sample selection and data processing. This research was financially supported by grant from Natural Science Foundation of China (No: 41102050), Natural Science Basic Research Plan in Shaanxi Province of China (No: 2013JM5010) and project from China Geological Survey (No: 1212011121088).

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