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Cassiterite U–Pb and muscovite ^{40}Ar–^{39}Ar age constraints on the timing of mineralization in the Xuebaoding Sn–W–Be deposit, western China

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ABSTRACT

The Xuebaoding deposit in the Songpan–Garzê orogenic belt, western China, spatially associated with the Xuebaoding granitic complex, is a unique pegmatite-type Sn–W–Be deposit within the giant Songpan–Garzê polymetallic belt. A lack of precise geochronological constraints on the timing of mineralization for this deposit has precluded definitive statements relating to a genetic link between ore formation and granitoid intrusion, up to now. To address the temporal relationship between the emplacement of granite and the spatially associated Sn–W–Be polymetallic mineralization in the Xuebaoding deposit, systematic cassiterite U–Pb and muscovite Ar–Ar dating were undertaken. U–Pb data of cassiterite analyzed by In-situ LA-MC-ICP-MS provided an isochron age of 193.6 ± 6 Ma (at 95% confidence level, MSWD = 4). The ^{40}Ar/^{39}Ar dating on the muscovite intergrown with the cassiterite sample yielded a plateau age of 194.50 ± 1.02 Ma (MSWD = 1.26), and an inverse isochron age of 194.53 ± 1.05 Ma (MSWD = 1.34). Both the Ar–Ar dates overlap the U–Pb date within uncertainties, placing the timing of tin mineralization at ~193–194 Ma. This is consistent with field geological relationships that show veins cutting marble and granite, and with previous Sm–Nd dating, within experimental error, for scheelite and indicates that Sn–W polymetallic mineralization at the Xuebaoding deposit occurred during the Early Jurassic. Combined with previous published trace element and REE data from the Xuebaoding granites and other ore minerals, as well as the timing of granite emplacement, the temporal and genetic associations between granite intrusion events and Sn–W mineralization of this deposit have been discussed in this paper. The results suggest that the Pankou granite is genetically related to the polymetallic mineralization in Xuebaoding Sn–W–Be deposit, and further demonstrate that the latest-phase of granitic intrusion is commonly favorable for Sn and/or W mineralization. Although the Pukou granite also exhibits close relationships with the ore formation in its spatial distribution and element characteristics, the possibility as a parent for this deposit is excluded duo to the time span from its emplacement to mineralization event that exceed the estimated life of modern geothermal systems (<1–2 Ma). The constraints on the timing of mineralization and for the element and fluid source provide important insight into the genesis of the Xuebaoding deposit.

1. Introduction

The Xuebaoding Sn–W–Be deposit is located in Sichuan Province, western China. While this deposit is typical of polymetallic deposits within the Songpan–Garzê orogenic belt, it differs from other occurrences in the South China W–Sn polymetallic province in terms of the type of mineralization, element association, ore mineralogy, metallogenic epoch, and tectonic setting (e.g. Hua et al., 2010; Mao et al., 2004, 2007; Peng et al., 2006a; Yuan et al., 2007, 2008a, 2012a, 2012b). Due to the presence of large euhedral and colorful crystals of cassiterite, scheelite, beryl, etc. (Fig. 1), the Xuebaoding deposit is world renowned, and has attracted much attention (e.g., Cao et al., 2004; Liu et al., 2007a, 2010; Ottens, 2005). However, because of inaccessibility relating to high altitude (>4200 m), the isolated geographical location, and severe or inclement weather, precise geochronological data relating to the mineralization episode are lacking. Furthermore, the temporal relationship between tin-polymetallic mineralization and emplacement of the associated granitic complex has yet to be identified. Although Sm–Nd dating of scheelite has been attempted (Liu et al., 2007a), the result (182 ± 9.2 Ma) highlights considerable uncertainties, and is clearly younger than Ar–Ar dates of magmatic muscovite from the Xuebaoding granites (200 Ma–193 Ma; Liu et al., 2010), and thus, this Sm–Nd age cannot provide a

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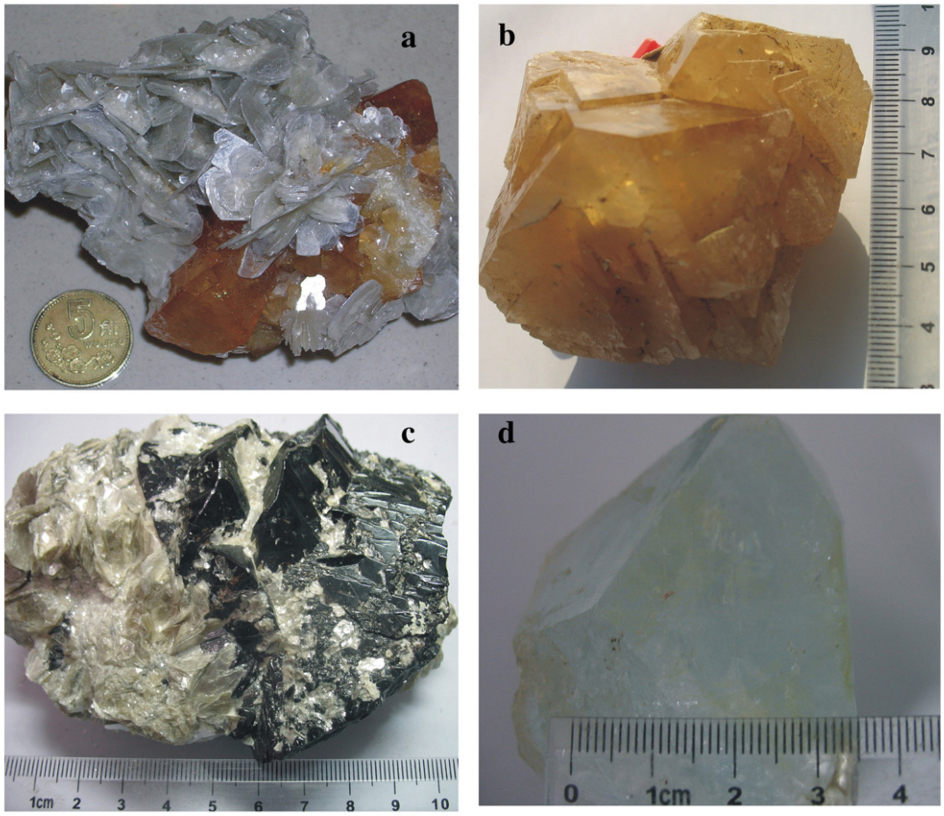

Fig. 1. Photographs of mineral crystals from the Xuebaoding deposit: (a) scheelite and muscovite; (b) scheelite; (c) cassiterite and muscovite; (d) beryl.

precise temporal constraint on the association between mineralization and granite emplacement.

Cassiterite is one of the most important ore minerals found among the various types of tin deposit, that include pegmatite-type, greisen-type, skarn-type, sulfide-type, and their placers (Gulson and Jones, 1992; Yuan et al., 2008b). As one of chief tin-bearing minerals, cassiterite commonly contains significant amounts of U and radiogenic Pb, since U^{4+} can be incorporated into cassiterite by substitution at Sn^{4+} structural sites in the mineral lattice. Due to its refractory nature, cassiterite is resistant to post-mineralization hydrothermal disturbance (Jiang et al., 2004; Plimer et al., 1991). Compared to conventional approaches in determining the timing of mineralization through the analysis of hydrothermal alteration minerals (e.g., mica, Snee et al., 1988; K-feldspar, Wilson et al., 2003) or accessory minerals (e.g., zircon, Wong et al., 1991; calcite, Peng et al., 2003) presumed to be co-genetic with ore minerals, direct dating of the ore mineralogy is more appealing (Gulson and Jones, 1992; Peng et al., 2006a, 2006b). Thus, since Marini and Botelho (1986) first attempted to date cassiterite via the U–Pb isotope system, this geochronological approach has attracted considerable interest (Gulson and Jones, 1992; Liu et al., 2007b; Sparrenberger and Tassinari, 1999; Yuan et al., 2008b, 2011), and the methods for U–Pb isotopic analysis of cassiterite have developed from conventional isotope dilution thermal ionization mass spectrometry (ID-TIMS) to in-situ laser ablation (multi-collector) inductively coupled plasma mass spectrometry (LA-MC-ICP-MS) (e.g., Yuan et al., 2011); the latter can provide high spatial resolution sampling, and sample preparation for this method is considerably easier than with solution-based techniques.

While dating of ore minerals, such as cassiterite, is perhaps the most effective approach in determining the timing of mineralization events, this methodology has not yet been attempted for the Xuebaoding deposit, and as such has considerably hampered an understanding of its ore genesis and material sources. To address this issue, we recently collected several cassiterite samples, from the Xuebaoding tin-polymetallic deposit, that occur intergrown with muscovite. The samples contain significant U concentrations that allow for U–Pb dating of the tin mineralization. Thus, the objectives of this contribution are to date cassiterite by in-situ LA-MC-ICP-MS U–Pb methods and muscovite by the Ar–Ar method, as their presence within this deposit will help to constrain the timing of the polymetallic mineralization event and its genetic relationships with associated granitic intrusions.

2. Geological background

The Songpan–Garzê orogen, set between the North China, Qiangtang–Changdu, and Yangtze blocks (Fig. 2), is often referred to as "the Bermuda Triangle" of Chinese geology (Xu et al., 1992). This orogen represents a suture zone resulting from paleo-plate assembly during the Indosinian (Zhang et al., 2004) and occurs as a NWW-trending fold belt. The Songpan–Garzê orogen is also an important metallogenic belt in western China as it plays host to many kinds of resources, that include tin, tungsten, copper, lead, zinc, gold, and other rare metals. The Xuebaoding Sn–W–Be deposit is a typical example of pegmatite-type, polymetallic deposit found within this metallogenic belt.

The Xuebaoding Sn–W–Be deposit is located in Pingwu County, northwestern Sichuan Province. It belongs to the Pankouwan subdome in the northern part of the Longmenshan Fault, west of the Huyaguan Fault, and east of the Xuebaoding dome of the western Yangtze Block. Tectonically, this deposit is situated in the northwestern side of the Songpan–Garzê orogenic belt, and is adjacent to the Motianling anticline of southern Qinling Orogen (Cao et al., 2004). The studied area of this paper is at the margin of the Pankouwan subdome, and lies between the Pankou and Pukou granites (Fig. 3).

The lithologies in the Xuebaoding area mainly comprise the Triassic Bocigou Formation, Triassic Zagashan Formation and Triassic Zhuwo Formation; the latter two units are host to the ore. Zagashan Formation