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Geological and geochronological constraints on the formation of the Jurassic Maozaishan Sn deposit, Dayishan orefield, South China

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ABSTRACT

The Dayishan orefield in the central Nanling belt is one of the most important Sn districts in South China. Within this district, there are more than seven medium-to-large Sn, Sn-Cu and Pb-Zn-Sn deposits. The mineralization is associated with altered granites and greisen-quartz veins, both of which occur in the inner part of the Dayishan granite batholith. Cassiterite is the principal ore mineral, accompanied by subordinate molybdenite. Cassiterite separates from altered and mineralized granite and greisen-quartz veins have concordia ages of 156.5 ± 2.8 Ma (MSWD = 3.1) and 158.0 ± 1.8 Ma (MSWD = 1.4), respectively. Molybdenite separates from molybdenite-quartz veins that crosscut the greisen alteration have a Re-Os isochron age of 157.9 ± 7.7 Ma (MSWD = 26), whereas zircon separates from the porphyry monzogranite have a U-Pb age of 156.3 ± 1.2 Ma. These ages are identical within the analytical error and, together with the field relationships, provide tight constraints on the Sn mineralization at around 156 Ma. Rhenium contents of the molybdenite suggests that the ore-forming materials were derived from a crustal source, whereas S and Pb isotopic data point to mixed sources. We suggest that the Maozaishan deposit was formed by intrusion of the related pluton, and occurred in the Late Jurassic during a period of lithospheric thinning and crustal extension of the South China Block.

1. Introduction

South China has been recognized as the most important W-Sn metallogenic region of the world (Liu et al., 2017). In the past decade, numerous geochronological studies have shown that the W-Sn polymetallic mineralization and related granitic magmatism in the Nanling Range have variable ages ranging from Late Triassic to Late Cretaceous, with most falling within a narrow range of 160–150 Ma (Mao et al., 2007; Yuan et al., 2015; Hu et al., 2017; Zhao et al., 2017) (Fig. 1a and b). Although the age of these deposits is well established, the precise genetic relationships between the ore-bearing granites and W-Sn deposits are still unclear because most metallogenic ages were obtained indirectly by a variety of techniques (Mao et al., 2007). Fortunately, cassiterite, which as main ore phase occurs in most Sn deposits, is ideal for direct dating of Sn-dominated, polymetallic mineralization. Numerous investigators have evaluated the cassiterite U-Pb isotope system as a geochronometer and demonstrated its reliability (Deng et al., 2017; Li et al., 2016; Yan et al., 2016; Yuan et al., 2008, 2011; Zhang et al., 2015).

In the Dayishan orefield, located at the central part of the Nanling Range, numerous alluvial Sn deposits have a proven reserve of 270,000 t of Sn, 78,000 t of Cu, 27,500 t of Pb + Zn and 483,686 t of B_2O_3 (Zeng, 2013). Recent exploration has revealed numerous large- to medium-sized Sn deposits stretching from the northwest to the southeast across the Dayishan batholith (Fig. 2). However, most of these deposits have not been exploited because of ecological concerns. Many geological studies of the Dayishan orefield, including basic geology, have already been carried out. Several more detailed investigations include a fluid inclusion study (Wu et al., 2008), an examination of stable isotopes (Zeng, 2013) and extensive age dating (Liu et al., 2006; Zhang et al., 2014). These studies have shown that the Sn-dominated, polymetallic deposits in this orefield formed at ca. 160 Ma and are genetically related to the associated late Jurassic granites. They have enhanced our understanding of the mineralization in the region, however, a well-constrained genetic model is still lacking because of a shortage of precise age data on the Sn mineralization, uncertainty on the source of the ore-forming materials and the nature of the geological environment.

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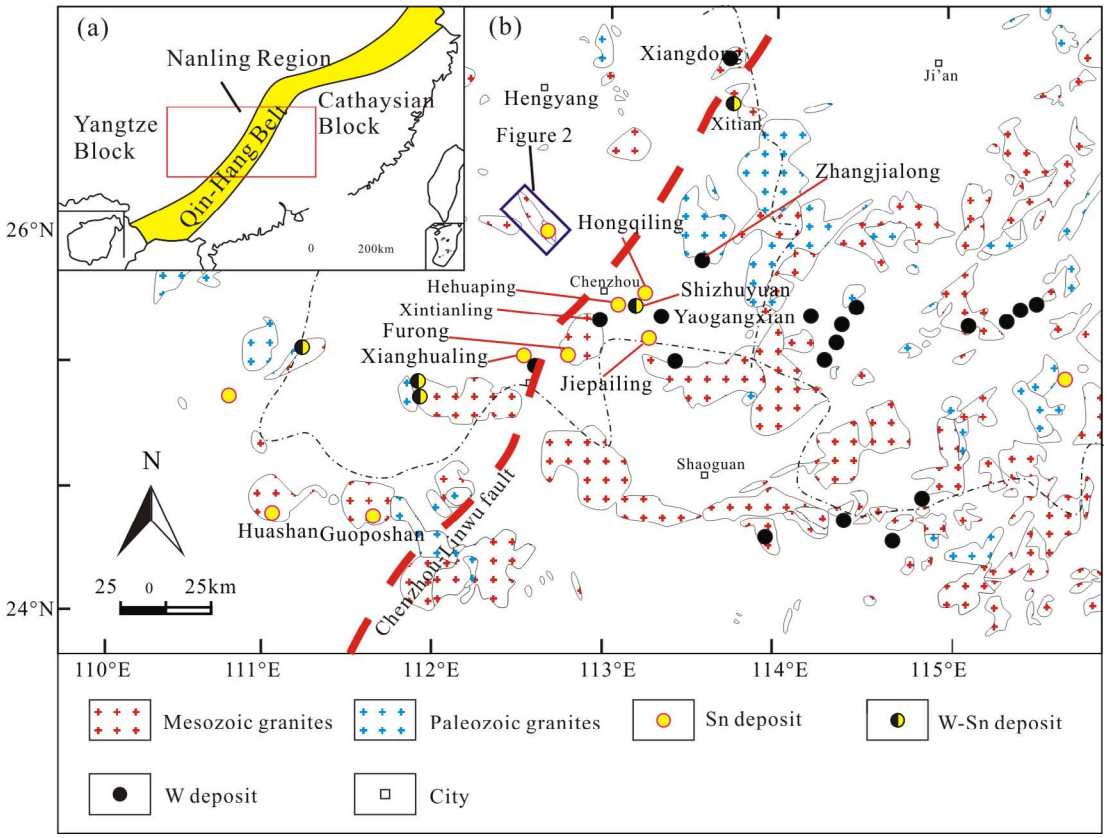

Fig. 1. (a) Sketch map showing the location of the Qin-Hang Belt of Mesozoic intrusive rocks in the South China (Modified after Mao et al., 2007, 2011); (b) simplified geological map of the Nanling Range showing the distribution of granitoids (Modified after Chen et al., 2014).

In the Maozaishan Sn deposit, there are two main types of mineralization, namely altered granite and greisen-quartz vein types. In this study, we summarized the existing isotopic and elemental data for W-Sn mineralization in the Nanling Range and obtained new cassiterite U-Pb, zircon U-Pb and molybdenite Re-Os ages, which enable us to directly constrain the age of the mineralization. We use these data to discuss the nature of the ore-forming materials and the geodynamic setting of the Sn-W deposits in the Dayishan orefield and the Nanling Range.

2. Regional geology

South China was formed by the Neoproterozoic collision of the Yangtze and Cathaysia Blocks along the Jiangshan-Shaoxing Fault (Fig. 1a) (Zhao et al., 2011). The Yangtze Block consists of crystalline basement overlain by Neoproterozoic (Sinian) to Cenozoic sedimentary strata (Zhou et al., 2014), whereas the Cathaysia Block consists of Precambrian basement and Sinian to Mesozoic sedimentary cover (Yu et al., 2005). Extensive magmatism in the Mesozoic produced widespread granitoid intrusions in South China (Li et al., 2009a; Ji et al., 2017). Spatially, these granitoid plutons are fault-controlled (Peng et al., 2006) and the Jurassic to Cretaceous magmatism is considered to be genetically related to the metallic mineralization in the Cathaysia Block (Hsieh et al., 2008) (Fig. 1b).

The Nanling Range, which has an area of ~200,000 km^2, is one of the 19 most important metallogenic belts in China (Chen et al., 2014). It consists of strongly folded and metamorphosed, Neoproterozoic-Ordovician flysch and volcanic basement overlain by Late Devonian to Early Triassic sedimentary rocks (Wang and Shu, 2012). Rift basins and granitoid intrusions are widespread in the region. The granitoid plutons formed by multiple cycles of tectono-magmatism, and are mostly directly associated with the W-Sn-rare metal mineralization (Zhang et al., 2015).

Previous studies of these plutons have shown that there is a NE-trending magmatic zone, referred to as the Qin-Hang belt or Shi-Hang zone, in which the magmatic rocks have high $\varepsilon_{Nd}(t)$ values and low T_{DM} ages (Gilder et al., 1996). The Qin-Hang zone is thought to have originated from mantle upwelling along a "paleo-rift" (Gilder et al., 1996; Tang et al., 2017). Abundant mafic microgranular enclaves (MMEs) in the granites are indicative of crust-mantle mixing (Zhu et al., 2008). Accompanying these granites are large Sn and W deposits, including the Furong and Hehuaping Sn deposits and the Shizhuyuan W-Sn-Bi-Mo deposit, amongst others. Most of the Sn and W deposits in this belt formed during the Late Jurassic to Early Cretaceous, except for the Late Triassic Qingshan W-Sn deposit (Zhao et al., 2018) and the Late Cretaceous Jiepailing Sn deposit (Chen et al., 2014; Peng et al., 2008; Yuan et al., 2015).

3. Ore deposit geology

The Dayishan orefield, central Qin-Hang belt, is located in southern Hunan Province. In this area, Sinian and Ordovician strata are mainly distributed south of the Dayishan granite batholith, and consist of weakly metamorphosed, clastic rocks with minor carbonates. These strata have been intruded by Mesozoic granitoid plutons (Fig. 2). Devonian, Carboniferous and Permian strata are widespread in the area and consist mainly of carbonates with minor clastic rocks. The Dayishan granite batholith, which appears to have been controlled by a NW-trending fault, has an elliptical shape with a total outcrop area of 280 km^2 (Fig. 2). It is a polyphase body with three components, from SE to NW, referred to as the Guankou, Tangshipu and Nibantian granites. These magmatic phases consist mostly of coarse-, medium- and medium- to fine-grained porphyritic granites (Wu et al., 2005; Zhou et al., 2005) with SiO_2 contents in the range of 67.0–73.12 wt%. The granites are strongly peraluminous, calc-alkaline rocks, with Al_2O_3