Sample description

A1. Wolframite from Sweden (Bagge), Rwanda (Sewa), France (MTM), and China (YGX-2107, YGX-2113)

Wolframite sample Bagge was collected from the Baggetorp deposit near Tjällmo in the southwestern part of the Bergslagen region, south central Sweden. This mine was shut down after the Second World War due to the drop in tungsten and fluorite price (Khavari, 2018). The age of this mineralization is not known. The regional geological development provides the following age constraints: The rocks of the Bergslagen ore province formed during the Svecofennian orogeny and were intruded along the western and southern margin of this province by rocks of the Transscandinavian Granite-Porphyry Belt (Ohlsson, 1979). There are three main periods of magmatic activity in the Svecofennian domain: Early Svecofennian (1.85-1.89 Ga) volcano sedimentary supracrustal units, Early Svecofennian (1.85-1.89 Ga) plutonic bodies, and Late Svecofennian (ca. 1.80-1.78 Ga) granites (Andersson et al., 2006). These events in part overlap with magmatic events in the Transscandinavian Granite-Porphyry Belt, which includes geochemically distinctive 1.82-1.75 Ga and 1.73-1.65 Ga old magmatic rocks (Andersson et al., 2004). Within the Bergslagen ore province there are several granite-related tungsten deposits, among which the Yxsjöberg tungsten-skarn deposit is the most important one. Romer and Öhlander (1994) obtained a U-Pb titanite age of 1789 ± 2 Ma (2σ) for the Yxsjöberg deposit using isotope dilution thermal ionization mass spectrometry (ID-TIMS). There are numerous rare element pegmatites in the southern part of the Bergslagen ore province, most importantly ca. 1.80-1.82 Ga old NYF (Niobium-Yttrium-Fluorine) pegmatites and ca. 1.80-1.75 Ga old LCT (Lithium-Cesium-Tantalum) pegmatites (Romer and Smeds, 1997). Skrupetorp, the LCT-type pegmatite closest to the Baggetorp pegmatite, yields a U-Pb columbite age of 1786 ±1 Ma (2σ) (Romer and Smeds, 1997). The ages of the Yxsjöberg tungsten deposit and the Skrumpetorp pegmatite possibly give the best expectation values for the age of the Baggetorp pegmatite.

Sample Sewa is a ferberitic wolframite, and the exact location of Sewa is unknown, but it probably originates from Rwanda.

Sample MTM originates from Les Montmins, a granite-related hydrothermal W ± Sn deposits in the French Massif Central. Wolframite from this location had been studied by Harlaux et al. (2018a; 2018b) for U-Pb age and fluid inclusions. MTM wolframite has a very large range of U contents and the crystallization age constrained by ID-TIMS is 334.4 ± 1.7 Ma (2σ, MSWD = 3.6) (Harlaux et al., 2018a). Luo et al. (2019) used the water vapor-assisted LA-ICP-MS U-Pb dating method and obtained a lower intercept age of 333.3 ± 1.0 Ma in the Tera-Wasserburg diagram.

Wolframite samples YGX-2107 and YGX-2113 were collected from the Yaogangxian tungsten deposit, Hunan Provence, South China. Both samples are hübneritic wolframite. The Yaogangxian tungsten deposit is one of the numerous W deposits in the Nanling metallogenic belt. In this region, W mineralization commonly occurs within the granites and/or extends into the Paleozoic wall rocks. Fluid inclusion studies demonstrate that the area was affected by several mineralization events (e.g., Legros et al. 2020). Isotopic dating of ore and gangue minerals, including $^{40}Ar/^{39}Ar$ dating of muscovite and, Re-Os dating of molybdenite, and U–Pb dating of hydrothermal zircon, cassiterite, and wolframite suggest that W mineralization and multiple overprints of the mineralization occurred between 170 Ma and 133 Ma (e.g., Wang et al., 2008; Wang et al., 2009; Hu et al., 2012; Wang and Ren, 2018; Deng et al., 2019; Legros et a., 2020). The Yaogangxian deposit is a granite-related vein-type W deposit (Peng et al., 2006; Zhao et al., 2017). The granites had been dated between 170.7 ± 1.5 Ma and 152.7 ± 1.8 Ma by zircon U–Pb dating (Che et al., 2009; Wang et al., 2009; Li et al., 2011; Dong et al., 2014). Recently, Deng et al. (2019) dated the wolframite from Yaogangxian deposit by LA-ICP-MS, using a non-matrix-matched water-vapor assisted method, and distinguished

early and late wolframite domains. The two texturally defined domains yielded U-Pb ages of 159.1 ± 2.0 Ma (2σ; MSWD=0.7) and 153.7 ± 0.7 Ma (2σ; MSWD=0.5), respectively.

A2. Wolframite from Jiangxi province (XHS16, DP-12), south China

Wolframite sample XHS16 is from the Xihuashan tungsten deposit, which is a vein-type deposit genetically associated with the Xihuashan granite pluton that is located in the Nanling metallogenic belt, southeastern China. Magmatic rocks in this region typically are 180 Ma to 150 Ma old (Sun, 2006; Zhou et al., 2006; Li et al., 2007; Wang et al., 2011; Li et al., 2013; Zhang et al., 2017) and, thus, tungsten mineralization related to these rocks should fall in a similar age range (Mao et al., 2007; Hua et al., 2008; Guo et al., 2011; Wang et al., 2011; Mao et al., 2013). Wang et al. (2011) reported a Re–Os isochron age of 157.0 ± 2.5 Ma (2σ) for molybdenite intergrown with wolframite in the oldest generation of the Xihuashan pluton. This age is in good agreement with the LA-ICP-MS U–Pb zircon age of 155.7 ± 2.2 Ma (2σ).

Wolframite sample DP-12 is from the Dangping tungsten deposit in the Nanling region. Magmatic rocks in this region dominantly include Yanshanian granitic complexes (Zhang et al., 2012). Zhang et al. (2012) that yield U-Pb zircon ages of 180.8 Ma to 154.9 Ma, i.e., which falls in the same age range as the 180 Ma to 150 Ma Xihuashan granitic complex (Sun, 2006; Zhou et al., 2006; Li et al., 2007; Wang et al., 2011; Li et al., 2013; Zhang et al., 2017).

A3. Ferbrite from Portugal (Panasqueira) and the United Kingdom (Cornwall)

The Panasqueira W–Sn–Cu ore deposit, one of the largest tungsten deposits in Western Europe, is located in the Variscan Central Iberian Zone (CIZ) in north-central Portugal. Several generations of voluminous granitoids intruded the CIZ during the late stages of the Variscan orogeny (320–280 Ma), The Panasqueira mineralization is genetically associated with the greisen cupola of one of these granites, the Panasqueira granite, that is exposed in the deepest part of the mine (Foxford et al. 2000; Jacques et al., 2015; Carocci et al., 2018). The age of the Panasqueira deposit is not well known. From the regional context, it should be younger than ca. 320 Ma, i.e., the older generation of post-kinematic granites, and older than 288 Ma, i.e., the age of last-stage muscovite (Snee et al., 1988).

The ferberite sample named Cornwall was collected from a tin and copper deposit associated with the Tregonning-Godolphin Granite that formed during the late stages of the Variscan orogeny (Neymark et al., 2018; Smith et al., 2019; Moscati and Neymark, 2020). The granitic plutons of the Cornubian Batholith were intruded from ~ 295 to 270 Ma (Smith et al., 2019; Moscati and Neymark, 2020). Neymark et al. (2018) reported the U-Pb age of a cassiterite sample from a deposit related to the Tregonning granite to be 283.2 ± 1.8 Ma, which agrees with the age range known for Cornubian granites of the Cornubian ore field (Smith et al., 2019).

A4. Hübnerite from the United States (HTD, SHM)

The hübnerite sample HTD is from the Hamme Tungsten District, which includes a series of steeply dipping quartz wolframite veins in the Piedmont of North Carolina, United States (Foose et al., 1980). The tungsten-bearing quartz veins are concentrated along the western contact between the Vance County granite and late Precambrian to early Paleozoic slates and phyllite (Foose et al., 1980). Granitic rocks similar to the Vance County pluton yielded Rb-Sr and U-Pb ages ranging from 520 to 620 Ma (Fullagar, 1971; Glover and Sinha, 1973). Foose et al. (1980) demonstrated that the Hamme Tungsten District had experienced at least two episodes of folding and shearing. The entire area has been overprinted by the 300-280 Ma Alleghenian orogeny.

The hübnerite sample SHM was collected from the Sweet Home Mine located in the Alma mining district on the eastern slope of central Colorado's Mosquito Range. The deposit originally has been mined for silver, but is best known for its gem-quality rhodochrosite. Late stage hübnerite forms blade-crystals that are intergrown with quartz Similar rhodochrosite-hübnerite veins are spatially related with Teritay porphyry-type molybdenum mineralization, including the nearby world-class deposits of Climax and Henderson (Seedorff and Einaudi, 2004; Lüders et al., 2009). Romer and Lüders (2006) analyzed three Sweet Home Mine hübnerite fragments from a single crystal and reported a $^{206}Pb/^{238}U$ age of 25.7 ± 0.3 Ma, which is consistent with the $^{40}Ar/^{39}Ar$ ages from sericite ranging from 26.1 ± 0.1 and 25.5 ± 0.1 Ma (Barbá et al. 2005).

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