**Supplement S2**

**Brief geology of selected studied granitoid plutons**

In this chapter, only very basic characteristics of the studied plutons are described. In the following text, I divide zircon source rocks into four basic geochemical types. While the classification of S- and I-type granitoids (Chappell & White 1974) is generally accepted, the A-type group of rocks is not clearly defined. In this work, I refer to subaluminous to weakly peralkaline granitoids corresponding to A1 type (according to Eby 1992) as "A-types", and to strongly peralkaline rocks corresponding to A2 type sense Eby (1992) as "peralkaline" rocks.

Zircon from strongly fractionated Sn-W (Li, Ta) mineralized peraluminous rare-metal granites (RMGs) is shown on the example of the Nejdek pluton in the western Krušné hory Mts. (Erzgebirge), Beauvoir granite (France), Panasqueira and Argemela plutons (central Portugal), and granites of the Cornubian batholith (England). The **Nejdek pluton**, including the late highly fractionated Podlesí stock, is the most typical example of strongly peraluminous RMG plutons in western Bohemia (Breiter et al. 1999; Förster et al. 1999). This pluton is composed of the older intrusive complex (OIC, 323–318 Ma, Tichomirowa et al. 2019) represented by biotite granites, followed by a younger intrusive complex (YIC, 315–314 Ma, Tichomirowa et al. 2019) of albite–biotite granites with topaz. The most fractionated, F- and extremely P-rich batches of residual magma crystallized at Podlesí in the form of a small, steep stock and layered dikes (Breiter et al. 2005a).

The **Beauvoir pluton** (Massif Central, France, 317±6 Ma, Melleton et al. 2015), composed of three vertically evolved facies of strongly peraluminous leucogranites, is strongly fractionated and enriched in Li, Rb, Cs, F, P, Sn and Ta. As for LILE enrichment, it is comparable with large LCT-pegmatites (Raimbault et al. 1995; Monnier et al. 2019).

The **Panasqueira pluton** (central Portugal, 305.2±5.7 Ma, Carocci et al. 2018) is composed of two-mica granites and leucogranites, the latter slightly greisenized and followed by a huge system of exocontact flat-laying quartz–wolframite lodes, representing the biggest European W deposit (Marignac et al. 2020; Breiter et al. 2023). The **Argemela stock** (central-eastern Portugal, 300–305 Ma, Lima et al. 2019) is formed by extremely fractionated, texturally diversified leucogranite with indices of disseminated Sn mineralization, and veinlets of W mineralization (Michaud & Pichavant 2020; Breiter et al. 2022).

The **Cornubian batholith** (westernmost England, 294–274 Ma, Chesley et al. 1993) is composed of several individual late Variscan intrusions of texturally diversified biotite, two-mica, tourmaline, and topaz granites (Simons et al. 2016, Breiter et al. 2016). Special attention here was given to the Megiliggar dike system representing a well-exposed transition from Li-mica granite to aplite–pegmatite dikes (Breiter et al. 2018).

The subaluminous granites of A-type with a tendency to accumulate HFS elements (Sn, Nb, Ta, Y, REE, Th, U) during fractionation are represented here by the Altenberg–Teplice caldera volcano-plutonic system (Germany, Czech Republic), Wiborg batholith (Finland), Madeira pluton (Brazil), and Khangilay pluton (Russia).

The **Altenberg–Teplice Caldera** (18 × 35 km in size), situated along the German–Czech border in the eastern Erzgebirge, is the largest volcano-plutonic complex in the Variscan central Europe. The following effusive–intrusive phases can be distinguished within the caldera (Breiter 1997; Müller et al. 2005): (1) three pulses of Teplice rhyolite tuffs and ignimbrites, (2) dikes of granite porphyry related to caldera collapse, (3) intrusion of post-caldera biotite granites (plutons of Schellerhau and Preiselberg), (4) intrusion of post-caldera zinnwaldite granites with Li-Sn-W mineralization (plutons of Krupka, Cínovec/Zinnwald, Altenberg, Sadisdorf). The age of the volcanic activity was determined to be 314–313 Ma (Tichomirova et al. 2022), while age of geologically younger rare-metal granites remains controversial (Romer et al. 2007).

The **Wiborg batholith** is the largest and the petrologically most diversified Proterozoic (1.67–1.54 Ga) rapakivi-type (A-type) batholith in southern Finland composed largely of porphyritic coarse-grained biotite-hornblende granite with cm-sized ovoids of alkali feldspars mantled by plagioclase rims, followed by biotite and Li-mica-topaz granites of the Kimi stock (Haapala & Rämö 1992; Lukkari et al., 2009; 1.64 Ga in age, Vaasjoki 1977).

The Paleoproterozoic **Madeira pluton** (Pitinga magmatic province, Central Amazonian Craton, Brazil, 1818±2 Ma, Costi et al. 2000) is composed of hornblende-biotite and biotite granites, alkali feldspar granites and albite-Li-mica granites with disseminated Sn, Nb and Ta mineralization (Costi et al. 2000, 2009). The extreme enrichment in F and HFSE during final fractionation is expressed by the common presence of cryolite, REE-fluorides, thorite, zircon and pyrochlore.

The **Khangilay pluton**, Jurassic in age (144–140 Ma, Badanina et al. 2023), is composed of a central body of biotite granite and two satellite cupolas. The Orlovka cupola is vertically distinctly zoned, consisting of two-mica, muscovite and lepidolite sheets, the latter intruded by flat amazonite–zinnwaldite dikes and mineralized with tantalite and pyrochlore (Badanina et al. 2004).

Zircon from peralkaline granites/syenites is presented on examples of two plutons from Mongolia and one from Brazil. The **Khan Bogd pluton,** Early Permian in age (290±1 Ma, Kovalenko et al. 2006), located in southern Mongolia , is formed by aegirine-arfvedsonite granite with common zirconosilicates. Its circular structure is underscored by thousands of ring dikes of layered pegmatites and ekerites (aegirine-bearing alkali feldspar aplites). The **Khalzan Buregte pluton** in western Mongolia (395 Ma, Kempe et al. 2015) is composed of six phases of peralkaline syenites/granites/rhyolites with zirconosilicates and indices of Nb mineralization, followed by the 7th phase of typical A-type metaluminous rare-metal granite (Kovalenko et al. 1995; Kynický et al. 2011; Sarangua et al. 2019). The **Europa pluton** located to the NW of Madeira pluton, Amazonas, Brazil, is a homogeneous circular body, 90 km2 in areal extent, formed by peralkaline hypersolvus riebeckite-bearing alkali feldspar granite 1829±1 Ma in age (Costi et al. 2000).

In an effort to better show the peculiarities of zircon from RMGs, zircons from some less fractionated plutons without known indications of mineralization are also included in the general diagrams.

The chemical composition of zircon from peraluminous to strongly peraluminous but poorly fractionated granites is presented using the example of dominantly two-mica granites of the **Central Moldanubian** **pluto**n (Breiter & Koller 1999). This pluton, situated in southeastern Bohemia and northern Austria, is composed of the strongly peraluminous Číměř–Mrákotín and Eisgarn suites of two-mica granites ( 330–320 Ma, see overview in Cháb et al. 2008), terminated with the emplacement of numerous dikes of granite porphyry and small bodies of albite-topaz-muscovite granites (320±4 Ma, Breiter & Scharbert 1998).

Zircon from **metamorphosed equivalents of peraluminous granites** is presented on examples from biotite (i.e., Želiv type), garnet-biotite and two-mica (i.e., Blaník type), muscovite and muscovite-tourmaline (i.e., Přibyslavice-type) orthogneiss, all lower Paleozoic in age and situated in northern Moldanubicum, Bohemian Massif (Breiter et al. 2005b). Zircon from pegmatite and leucogranite immediately associated with Přibyslavice orthogneiss (Novák & Cempírek 2010) is also shown.

Zircon from **geochemically primitive granitoids** is presented by samples from the slightly peraluminous lower Paleozoic (?) biotite Tis granite (western Bohemia, Breiter 2004), Variscan transitional I-S type biotite Weinsberg granite (southern Bohemia, 326–328 Ma with relative large uncertainty, Finger et al. 1997; Gerdes et al. 1998; Breiter & Koller 1999), Variscan melagranites/melasyenites of the Třebíč Pluton (Holub 1997; 335 Ma, Janoušek & Svojtka 2021) and small similar melagranite and glimmerite intrusions in the Šumava Mountains, southern Bohemia (Breiter & Koller 2009).