Chapter

Geochemistry of Granitic Rocks of the Moldanubian Batholith (Central European Variscides)

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Abstract

Granitic rocks of the Moldanubian batholith are represented by four magmatic suites: I- to S-type Weinsberg biotite granites-granodiorites, S-type Eisgarn two-mica granites, S-type Melechov/Zvůle two mica, highly fractionated granites and I/S-type Freistadt biotite granites-granodiorites. The biotite granites of the Weinsberg suite are subaluminous to weakly peraluminous granites, enriched in Ba, Sr, and Zr. The two-mica granites of the Eisgarn suite are represented by a peraluminous, the low-Th Deštná granites, intermediate-Th Mrákotín, Číměř/Aalfang granites, and the high-Th Lipnice/Steinberg granites. The alkali feldspar and two-mica granites of the Melechov/Zvůle suite are highly fractionated, peraluminous granitic rocks, depleted especially in Ba, Zr, and Th. The granites to granodiorites of the Freistadt suite are subaluminous on Ba- and Sr-enriched granitic rocks.

Keywords: granitic rocks, petrology, geochemistry, Moldanubian zone, Bohemian Massif

1. Introduction

Generation of granitic rocks batholiths and plutons is a characteristic late-stage feature in the evolution of collisional orogens [1–4]. One of the classic examples is the European Variscan Belt, produced as a result of the late Palaeozoic convergence of Gondwana and Laurussia. The Moldanubian batholith that forms one of the largest plutonic complexes within the European Variscan Belt, covering 10,000 km^2 in the central part of the Moldanubian Zone of the Bohemian Massif, provides an excellent insight into origin and evolution of such crustally derived magmas [5–10]. The most significant previous geochemistry studies of the Moldanubian batholith are concentrated in papers Liew et al., Vellmer and Wedepohl, and Breiter [5, 6, 9]. However, these papers are concentrated only on selected parts (the Austrian and South Bohemian) of this batholith.

The aim of the presented paper is detailed classification of individual magmatic suites of the whole Moldanubian batholith and description of petrology, geochemistry, and origin of its magmatic suites.

2. Geological setting

In map view, the Moldanubian batholith resembles a "V" shape having two nearly perpendicular segments oriented ~NNE-SSW and ~NW-SE (**Figure 1**). The ~NNE-SSW trending segment as the eastern part of the batholith is formed by large continuous exposures of granitic rock pluton, whereas the ~NW-SE as the western part of the batholith is formed by a number of isolated smaller plutons and bodies, some of which seem to be roughly parallel to the ~NW-SE trending regional shear zones (the Pfahl and Danube shear zones [13–15]). Both batholith branches are closely associated with the host migmatites [10, 16, 17]. Estimates of the pluton emplacement depths range from a number of separate smaller plutons, some of which seem to be from 18 to 20 km in the NW-SE segment and/or 7 to 9 km in the NNE-SSW segment of the Moldanubian batholith [10, 12].

The most significant S-type granites of the Eisgarn suite occurred in the NNE-SSW branch of the Moldanubian batholith are hosted in a complex of cordierite-bearing migmatites and migmatitized paragneisses of the Pelhřimov complex [16].

The batholith consists of multiple intrusive units (plutons and stocks), predominantly composed of felsic to intermediate, granitic to granodioritic rocks with either S- or transitional I/S-type character [5, 6, 8, 9, 18]. All these granitoids can be classified into four main suites [6, 8, 9]:

a. Coarse-grained, mainly porphyritic I- to I/S-type biotite granites to granodiorites of the Weinsberg suite including four subtypes (coarse-grained, porphyritic Weinsberg I, very coarse-grained porphyritic biotite to muscovite-biotite Weinsberg II, coarse-grained biotite-amphibole granite to granodiorite "Schlieren granite" and slightly porphyritic Srní granite)

b. S-type two-mica granites of the Eisgarn suite including the equigranular Mrákotín variety, porphyritic Číměř/Aalfang variety, highly porphyritic Lipnice/Steinberg variety and equigranular Deštná variety, occurred only in the Klenov pluton

c. Younger group of highly fractionated, coarse-grained S-type two-mica granites of the Melechov/Zvůle suite formed ring-shaped bodies or stocks, often with zoned internal structure. From the NE to the SW, there are following bodies in the ~NNE-SSW segment of the Moldanubian batholith (the Melechov, Čeřínek, and Zvůle bodies). According to its geologic position, mineralogical and geochemical composition could be to these bodies attached also the coarse-grained, weakly porphyritic biotite-muscovite Plechý granite in central part of the Plechý pluton (Verner et al. [12]) and the fine-grained two-mica Sulzberg granite in the Bärenstein pluton of the ~NW-SE segment of the Moldanubian batholith [19] (**Figure 2**).

d. Fine- to coarse-grained I/S-type-biotite granites and granodiorites of the Freistadt/Mauthausen suite including the coarse-grained "marginal variety," medium-grained "central variety" of the Freistadt pluton, and the muscovite bearing biotite granite of the Graben granite variety occurred only on the eastern margin of the Freistadt town [21, 22].

Klötzli et al. [23] proposed that the origin of the Moldanubian batholith begun with the partial melting of mid—to lower crustal pre-Variscan rocks, polyphase

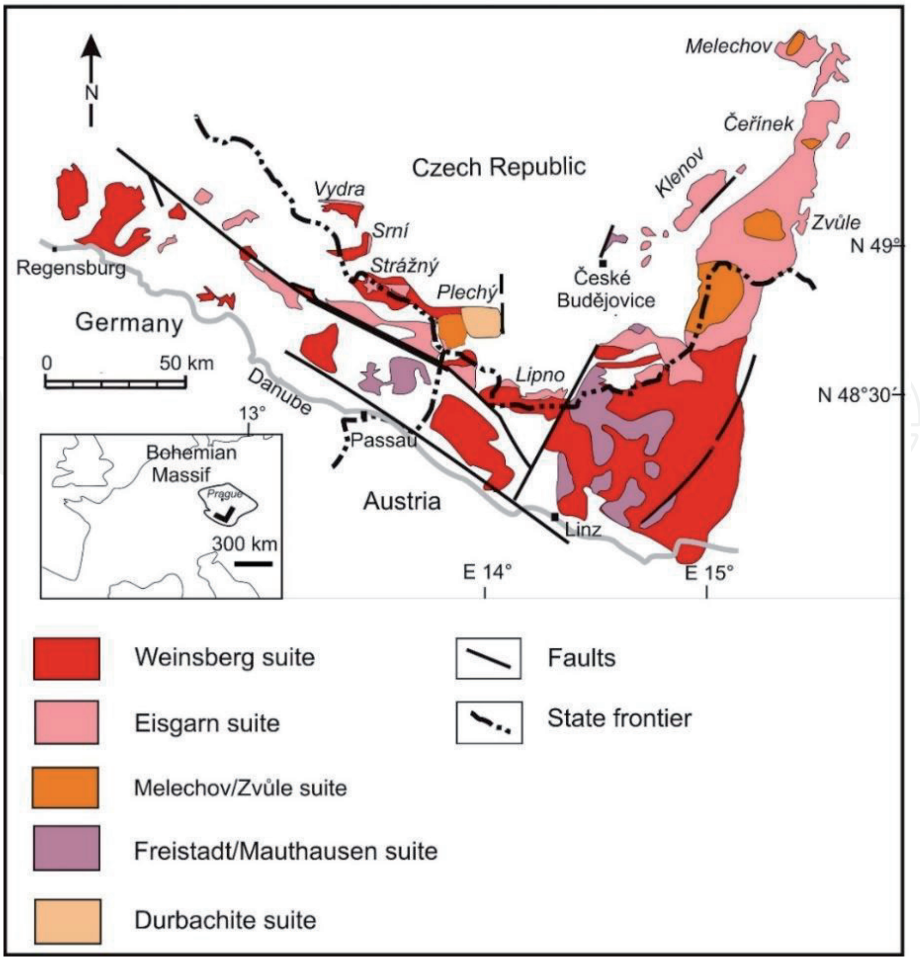

Figure 1.
Geological map of the Moldanubian batholith (after [11, 12], modified by author).

exhumation, anatexis, and deformation, closely followed by emplacement of large volumes S/I-type and S-type granodiorites and granites between 331 and 326 Ma.

According to the high-precision ID-TIMS U-Pb zircon and monazite dating the oldest Weinsberg granite (330.7 ± 0.4 Ma) intruded in southern part of the ~NNE-SSW segment of the Moldanubian batholith. Neighbouring two-mica granites of the Eisgarn suite were dated at 327.0 ± 0.3 Ma (Mrákotín variety), 327.14 ± 0.21 Ma (Deštná variety), and 328.5 ± 2.1 Ma (Číměř/Aalfang variety). However, the Weinsberg granite in the ~NW-SE segment of the Moldanubian batholith is comparably younger (327.7 ± 0.4 to 325.75 ± 0.39 Ma). The two-mica granite of the Eisgarn suite from this magmatic segment in the Lipno/Sternstein pluton was dated at 326.4 ± 0.6 Ma. Thus, the NW-SE segment of the Moldanubian batholith was formed ~3 Ma later than the NNE-SSW segment. However, the Weisberg granite from southern part of NW-SE segment, south of the Pfahl fault, was dated at 322.7 ± 0.7 Ma, implying that the processes of crustal melting migrated in the area of the Moldanubian batholith further toward south with time [24]. These U-Pb ages of granitoid rocks occurred in the NW-SE segment of the Moldanubian batholith and their structural relations with the Pfahl shear zone indicate the initial stages of dextral shearing at c. 342–327 Ma and mylonitic deformation coeval with granite emplacement during c. 326–327 Ma [10, 24]. The I/S-type granodiorites of the Freistadt/Mauthausen suite are distinctly younger. Age of monazite from the Freistadt granodiorite is 302 ± 2 Ma [25], and the age of monazite from the fine-grained, I-type Mauthausen granite is 316 ± 1 Ma [26].

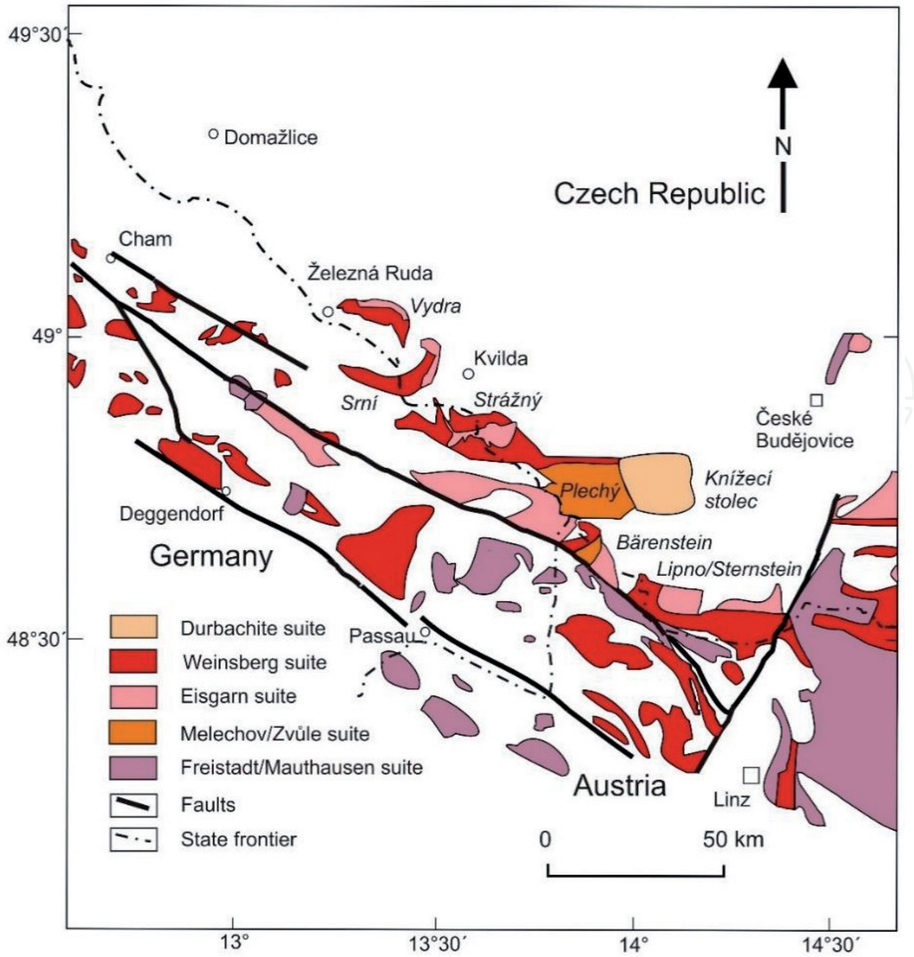

Figure 2.
Schematic geological map of the NW-SE segment of the Moldanubian batholith (after [20] modified by author).

3. Analytical methods

Rock samples of 2–5 kg in weight were crushed in a jaw crusher and a representative split of these materials was ground in an agate ball mill. For geochemical study of analysed granitoids were used 75 representative rock samples (**Table 1**, **Figures 3**–7). Major elements and some trace elements (Ba, Rb, Sr, Zr, Nb, Y, U, and Th) were determined using a Bruker AXS S4 Pioneer X-ray fluorescence spectrometer at the University of Salzburg, Austria, on fused glass discs and pressed rock powder pellets, respectively. The FeO was determined by titration, H_2O^+ and H_2O^- were analyzed gravimetrically in the chemical laboratory of the Institute of Rock Structure and Mechanics, Academy of Sciences of the Czech Republic, Prague. Rare earth elements were quantified by inductive coupled plasma mass spectrometry (ICP-MS) techniques at Activation Laboratories Ltd., Ancaster, Canada, using a Perkin Elmer Sciex ELAN 6100 ICP mass spectrometer, following standard lithium metaborate/tetraborate fusion and acid decomposition sample preparative procedures.

Microprobe analyses of selected minerals (feldspars and biotite) were performed in polished thin sections using a CAMECA SX-100 microprobe operated in wavelength-dispersive mode at the Institute of Geology, Academy of Sciences of the Czech Republic. The raw analytical data were corrected using the PAP procedure [28]. Operation conditions were accelerating potential of 15–20 kV, beam current of 10–70 nA (measured on

Suite	Variety	CaO w. %	Zr ppm	Th ppm	ΣREE	La_N/Yb_N	Eu/Eu*
Weinsberg	Weinsberg I	1.5–3.0	214–441	19–45	269–443	10.0–30.5	0.30–0.60
	Weinsberg II	1.1–2.6	58–491	4–31	58–491	4.9–30.3	0.18–0.53
	Schlierengranite	1.9–4.6	133–652	5–42	n.a.	n.a.	n.a.
	Srní	1.5–4.3	190–331	25–31	266–430	12.6–33.4	0.38–0.58
Eisgarn	Deštná	0.4–1.1	39–81	2–7	33–69	3.2–19.0	0.35–1.18
	Mrákotín	0.4–1.1	72–157	9–41	91–222	11.2–67.7	0.16–0.48
	Číměř/Aalfang	0.5–1.0	96–175	17–54	117–242	21.8–44.2	0.15–0.31
	Lipnice/ Steinberg	0.6–1.1	143–291	39–110	207–423	19.9–64.3	0.09–0.31
Melechov/ Zvůle	Melechov	0.6–0.8	52–60	3	25–54	6.1–8.9	0.11–0.69
	Čeřínek	0.3–0.7	18–114	6–14	93–137	19.9–26.1	0.28–0.32
	Zvůle	0.5–0.9	31–88	7–13	88	29.9	0.40
	Plechý	0.5–0.7	55–113	9–23	66–118	12.5–20.6	0.13–0.46
	Sulzberg	0.5–0.6	130–136	26–35	149–177	27.2–31.8	0.26–0.29
Freistadt	Central	1.9–3.4	102–188	4–19	141–180	12.2–20.9	0.68–0.81
	Marginal	2.0–4.1	101–214	7–18	129–199	9.9–16.6	0.56–0.84
	Graben granite	1.8–2.3	98–171	10–15	155–238	19.7–30.7	0.58

n. a.– not available.

Table 1.
Chemical composition of granitic rock of the Moldanubian batholith.

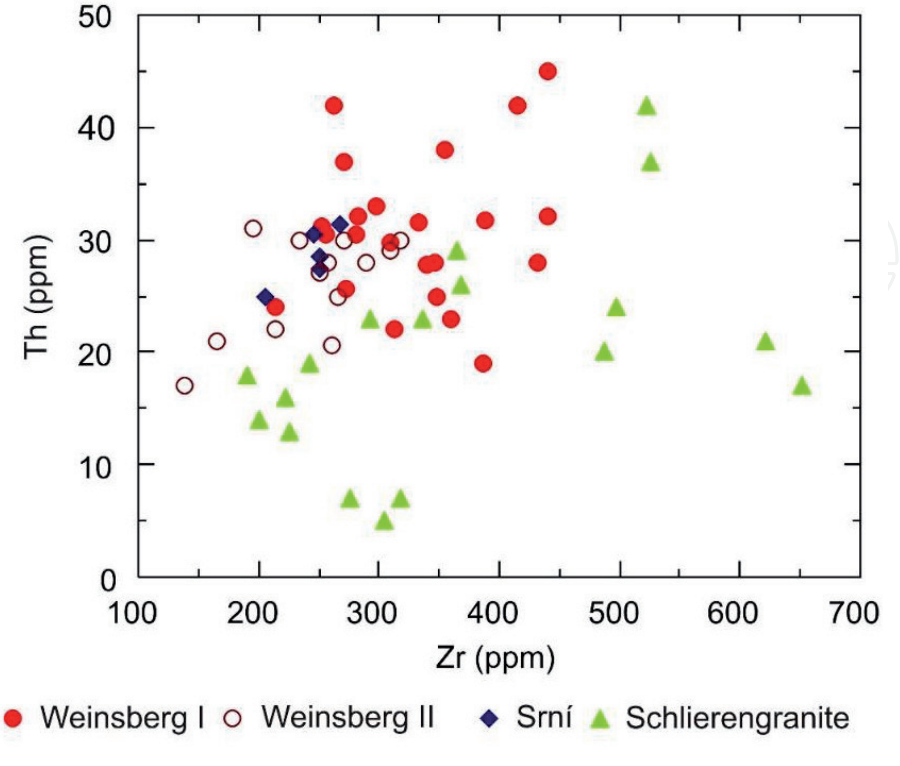

Figure 3.
Distribution Th and Zr in granitic rocks of the Weinsberg suite.

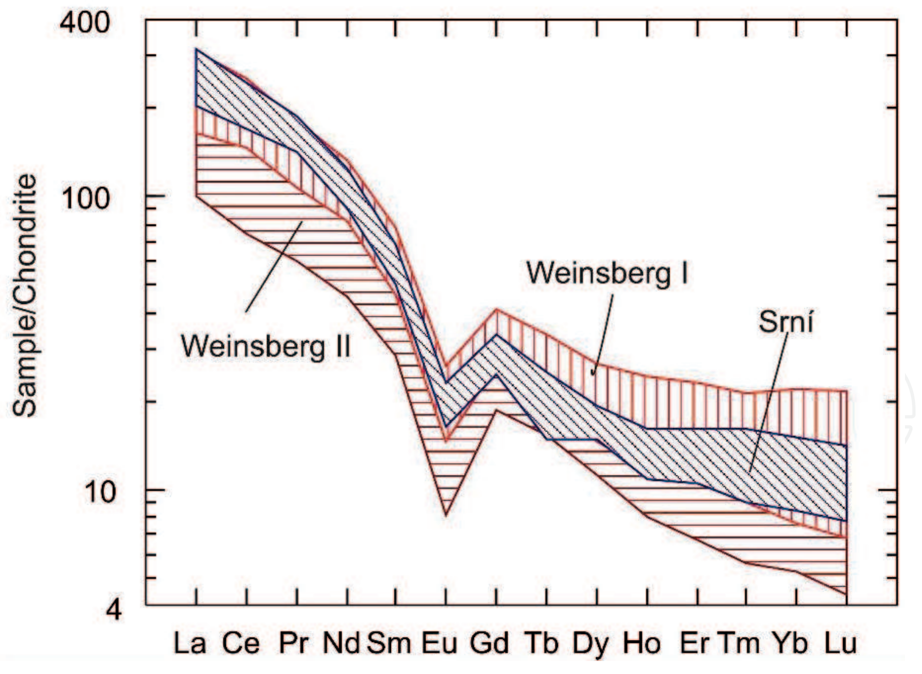

Figure 4.
Chondrite-normalized REE pattern for the Weinsberg suite. Normalizing values are from Boyton [27].

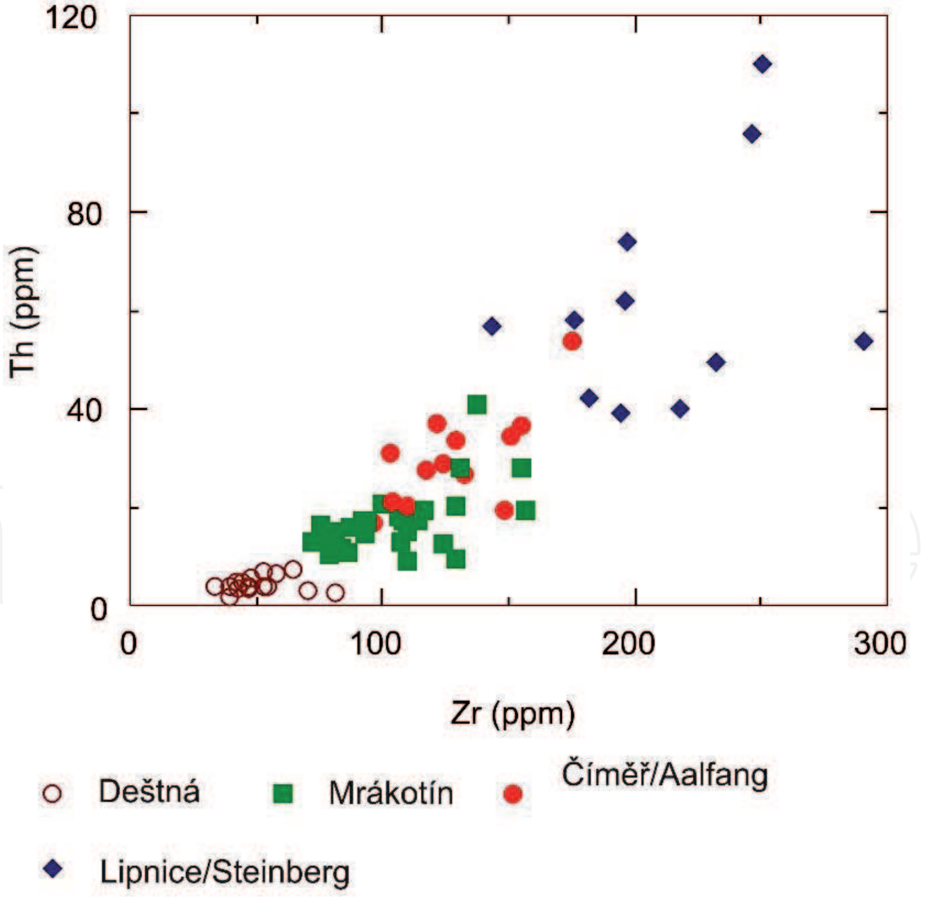

Figure 5.
Distribution of Th and Zr in granitic rocks of the Eisgarn suite.

a Faraday cup), and a beam diameter of 2 μm. Both synthetic and natural minerals were used as a reference material. Mineral formulae were recalculated using the MinPet 2.02 software [29].

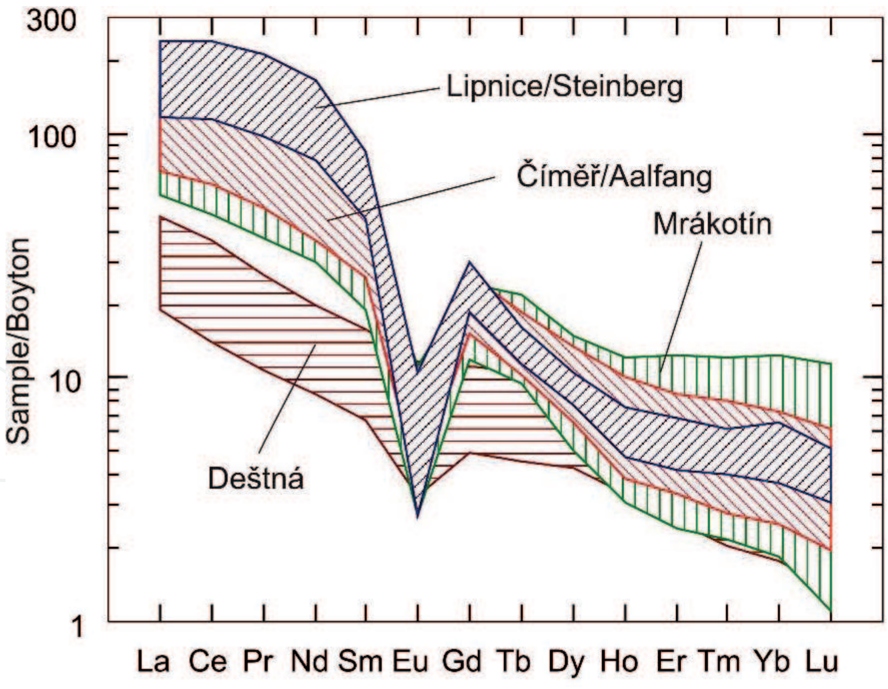

Figure 6.
Chondrite-normalized REE pattern for the Eisgarn suite. Normalizing values are from Boyton [27].

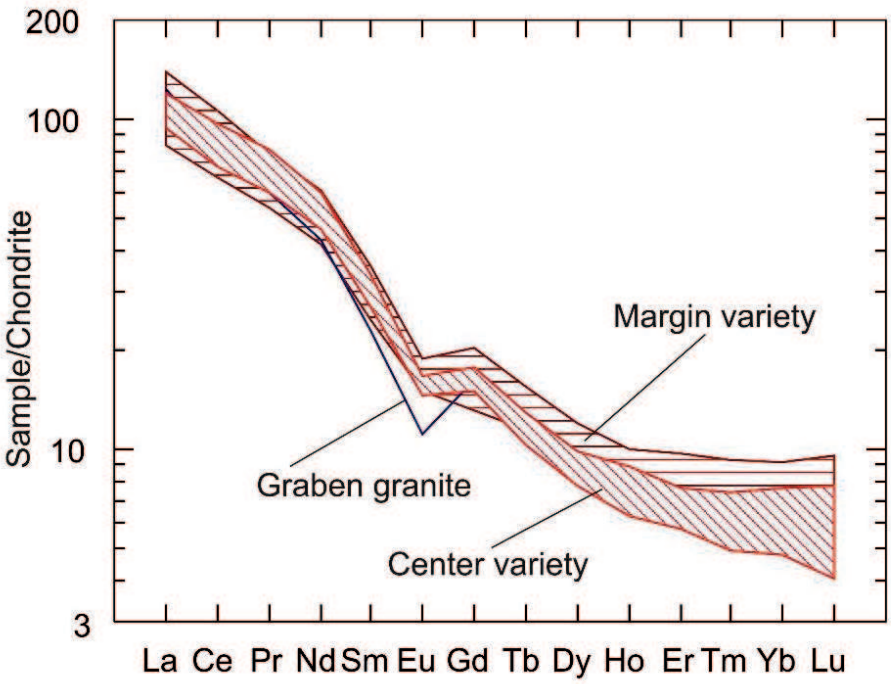

Figure 7.
Chondrite-normalized REE pattern for the Freistadt suite. Normalizing values are from Boyton [27].

4. Results

4.1 Petrography

The coarse-grained I/S-type granites and granodiorites of the Weinsberg suite are in the Moldanubian batholith represented by four varieties—Weinsberg I, Weisberg II, Schlieren granite, and Srni variety. The subtypes Weinsberg I and II, represented by coarse-grained porphyritic biotite granite to quartz monzodiorite

(Weisberg I) and very coarse-grained porphyritic biotite to muscovite-biotite granite (Weinsberg II), were distinguished based on zircon morphology and minor differences in composition [30, 31]. The Schlieren granite represent predominantly in situ evolved intrusion occurred in the Mühlviertel area (Upper Austria) and attached area of the Bavaria (Germany). The Schlieren granite, however, was originally described as "coarse-grained" gneisses [32]. The Srní variety occurred only in the Vydra and Prášily plutons of the NW-SE segment of the Moldanubian batholith (**Figure 2**) is medium-grained, weakly porphyritic granite to granodiorite. Major components of the Weinsberg granites to quartz monzodiorites are quartz, K-feldspar, plagioclase, biotite and rare amphibole (Schlieren granite), muscovite, or garnet (Srní variety). The accessories include apatite, zircon, ilmenite, titanite, allanite, monazite, and rare xenotime (**Table 2**).

The two-mica granites of the Eisgarn suite are the most abundant granitic rocks in the Moldanubian batholith. Several petrographic varieties in the Eisgarn suite were identified, containing variable texture and biotite to muscovite proportions. In the Czech part of the Moldanubian batholith, the equigranular Mrákotín variety predominates. Similar equigranular two-mica granites occur in the Bavarian part of the Moldanubian batholith (Haidmühle, Theresienreut variety). In the Austrian part of the Moldanubian batholith, the Číměř/Aalfang porphyritic variety with biotite over muscovite predominated. In the Klenov pluton occur the equigranular two-mica leucogranites, described as the Deštná variety [33, 34]. In the Melechov and Plechý plutons occur highly porphyritic granites of the Lipnice/Steinberg variety. Major components of the Eisgarn monzogranites are quartz, K-feldspar, plagioclase, biotite, and muscovite. Monazite accessory minerals are represented by apatite, andalusite, ilmenite, zircon, and rare cordierite, sillimanite and xenotime (**Table 3**).

The younger group of highly fractionated S-type two-mica granites of the Melechov/Zvůle suite are composed by coarse-grained two-mica alkali feldspar granites to monzogranites that forms ring-shaped stocks, often with zoned internal structure. There are in the Moldanubian batholith represented by the Melechov, Čeřínek, Zvůle, Plechý plutons, and the Sulzberg granite in the Bärenstein pluton. Major rock-forming minerals of these granites are plagioclase (28–36 vol. %) ($An_{1–23}$), quartz (27–34 vol. %), K-feldspar (26–31 vol. %),

Variety	Modal composition (vol. %)	Accessories	Plagioclase	Biotite
Weinsberg I	Qtz 16–43, Kfs 12–54, Pl 11–44, Bt 6–27	Apatite, zircon, ilmenite, titanite, monazite, allanite	$An_{15–42}$	Annite, Fe/(Fe+ Mg) 0.60–0.67, Al^{4+}2.05–2.39, Ti 0.23–0.45 apfu
Weinsberg II	Qtz 24–30, Kfs 22–33, Pl 23–37, Bt 7–15	Apatite, zircon, ilmenite, monazite	$An_{24–41}$	Annite, Fe/(Fe+ Mg) 0.79–0.81, Al^{4+} 2.43–2.47, Ti 0.34–0.42 apfu
Schlieren granite	Pl 32–50, Kfs 7–37, Qtz 18–34, Bt 6–32, Amp 0–3	Apatite, zircon, titanite, ilmenite, magnetite, allanite	$An_{20–40}$	Annite, Fe/(Fe+ Mg) 0.0.53–0.55, Al^{4+} 2.10–2.13, Ti 0.23–0.42 apfu
Srní	Pl 19–53, Pl 19–53, Kfs 7–41, Bt 4–27, Ms 0–6, Gt 0–3	Apatite, zircon, ilmenite, monazite, xenotime	$An_{9–31}$	Annite-siderophyllite, Fe/(Fe+ Mg) 0.64–0.81, Al^{4+} 2.24–2.57, Ti 0.26–0.42 apfu

Table 2.
Modal composition and mineralogy of granitic rocks of the Weinsberg suite.

Variety	Modal composition (vol. %)	Accessories	Plagioclase	Biotite
Mrákotín	Qtz 23–46, Kfs 14–42, Pl 10–37, Ms 3–17, Bt 3–11	Apatite, andalusite, ilmenite, zircon, monazite	$An_{9–25}$	siderophyllite, Fe/(Fe + Mg) 0.63–0.72, Al^{4+} 2.45–2.73, Ti 0.25–0.38 apfu
Číměř/Aalfang	Kfs 14–50, Qtz 22–41, Pl 8–38, Bt 3–16, Ms. 1–8	Andalusite, apatite, ilmenite, zircon, monazite, cordierite	$An_{9–23}$	annite–siderophyllite, Fe/(Fe + Mg) 0.64–0.72, Al^{4+}2.44–2.61, Ti 0.24–0.39 apfu
Lipnice/Steinberg	Kfs 23–40, Qtz 25–37, Pl 19–37, Bt 6–10, Ms. 2–7	Apatite, ilmenite, monazite, zircon, rutile, sillimanite	$An_{13–20}$	Annite Fe/(Fe + Mg) 0.59–0.75, Al^{4+} 2.10–2.42, Ti 0.22–0.35 apfu
Deštná	Qtz 28–42, Kfs 21–41, Pl 15–50, Ms. 1–8, Bt 1–5	Apatite, ilmenite, monazite, zircon, xenotime	$An_{12–25}$	Annite-siderophyllite, Fe/(Fe + Mg) 0.64–0.74, Al^{4+} 2.27–2.67, Ti 0.17–0.42 apfu

Table 3.
Modal composition and mineralogy of granitic rocks of the Eisgarn suite.

muscovite (3–9 vol. %) and biotite (3–4 vol. %) [annite-siderophyllite, Fe/(Fe + Mg) 0.67–0.77, Al^{4+} 0.67–0.0.74, Ti 0.16–0.41]. Accessory minerals are represented by apatite, ilmenite, rutile, zircon, monazite, tourmaline, and garnet.

The I/S-type Freistadt biotite granodiorites are medium- to coarse-grained granitic rocks. Major rock-forming minerals of the both main varieties ("central" and "marginal") of the Freistadt suite are quartz, plagioclase, K-feldspar, and biotite. The Graben granite contains also 3 vol. % of muscovite. The accessory minerals in granitic rocks of the Freistadt suite are represented by apatite, ilmenite, zircon, titanite, allanite, and rare xenotime (**Table 4**). The Graben granite is more fractionated granitic rock with relatively high LREE/HREE ratio (20–31).

4.2 Geochemistry

The granites and granodiorites of the Weinsberg suite are subaluminous and weakly peraluminous rocks with A/CNK [mol. $Al_2O_3/(CaO + Na_2O + K_2O)$] of 0.9–1.2. For all varieties of the Weinsberg granite suite are significant high Ba (291–2016 ppm), Sr. (75–680 ppm), Zr (89–652 ppm), and ΣREE (133–491 ppm) concentrations (**Table 1**). The highest concentrations of Ba, Sr, and Zr are significant especially for the Schlieren granite (354–2016 ppm Ba, 196–680 ppm Sr, 133–652 ppm Zr) (**Figure 3**, **Table 1**). For individual varieties of the Weinsberg suite, the partly different fractionation of REE is significant (**Figure 4**).

The granites of the Eisgarn suite are subaluminous to strongly peraluminous rocks (A/CNK 1.0–1.3) with low CaO concentrations (0.4–1.2 wt. %) (**Table 1**). In the strongly peraluminous varieties, magmatic andalusite, sillimanite, and rarely occurred cordierite are present. In the Mrákotín variety, the peraluminosity is also expressed by widespread dominance of muscovite over biotite. Three main geochemical varieties of two-mica granites could be distinguished by their concentrations of Th on the low-Th (2–7 ppm) Deštná granites, the intermediate Th Mrákotín/Číměř/Aalfang granites (8–54 ppm), and the high-Th Lipnice/Steinberg granites

Variety	Modal composition (vol. %)	Accessories	Plagioclase	Biotite
Freistadt central	Qtz 23–29, Pl 34–49, Kfs 13–25, Bt 9–14, Ms 0–2	Apatite, zircon, ilmenite, monazite, titanite, xenotime	$An_{20–22}$	Annite Fe/(Fe + Mg) 0.58–0.59, Al^{4+} 2.20–2.24, Ti 0.34–0.47 apfu
Freistadt marginal	Qtz 12–32, Pl 32–68, Kfs 3–27, Bt 6–17, Ms 0–1	Apatite, zircon, ilmenite, titanite, monazite, allanite	$An_{25–37}$	Annite Fe/(Fe + Mg) 0.44–0.62, Al^{4+}2.09–2.28, Ti 0.30–0.50 apfu
Graben granite	Qtz 29–31, Pl 33–40, Kfs 19–25, Bt 5–9, Ms 2–6	Apatite, zircon, ilmenite, monazite	$An_{23–26}$	Annite Fe/(Fe + Mg) 0.66–0.69, Al^{4+} 2.33–2.41, Ti 0.31–0.41 apfu

Table 4.
Modal composition and mineralogy of granodiorites and granites of the Freistadt suite.

(39–110 ppm) (**Table 1**, **Figure 5**). The highest ΣREE was found in the Lipnice/Steinberg granite variety (207–242 ppm), whereas the lowest ΣREE is for the Deštná granites significant (33–69 ppm). The highest LREE/HREE ratio is for the Lipnice/Steinberg variety significant (**Figure 6**).

The granites of the Melechov/Zvůle granite suite are peraluminous rocks (A/CNK 1.1–1.3) with low CaO concentrations (0.3–0.9 wt. %) (**Table 1**). The individual varieties of these granites could be distinguished especially by their concentrations of Zr and Th. The highest concentrations of both elements are significant for the Plechý (55–113 ppm Zr, 9–23 ppm Th) and Sulzberg (130–136 ppm Zr, 26–35 ppm Th) granites. The lowest concentrations of the both elements occur in the Stvořidla granites, which form the central stock in the Melechov pluton (36–67 ppm Zr, 2.8–2.9 ppm Th). These granites also have the lowest concentrations of ΣREE (27–35 ppm) and the lowest LREE/HREE ratio (3.2–8.6). In the opposite, the highest content of ΣREE (149–177 ppm) and the highest LREE/HREE ratio (27–32) are for the Sulzberg granites significant.

The granites and granodiorites of the Freistadt suite are subaluminous rocks (A/CNK = 1.0–1.1) with partly elevated CaO concentrations (1.8–4.1 wt. %). The central and marginal granodiorites of this suite are enriched in Ba (616–1017 ppm) and Sr (253–471 ppm). Their total concentrations of REE in granites and granodiorites of the Freistadt suite are 129–238 ppm and the central and marginal granodiorites display relatively low LREE/HREE ratio (9–21) with moderate negative Eu anomaly (Eu/Eu* = 0.56–0.84) (**Table 1**, **Figure 7**).

5. Discussion

In the past, the orig

in and fractionation of granitic rocks of the Moldanubian batholith was discussed by geochemical modelling based on trace-element fractionation [6, 18, 31, 35, 36] and experimental study of biotite stability [34]. According to these studies, granitic rocks of the Moldanubian batholith could originated by LP-HT partial melting of various metasediments and/or by melting of a mixture of metasediments and amphibolites [6, 18, 31, 36]. According to the majority of these studies, the granitic rocks of the individual magmatic suites occurred in the Moldanubian batholith were also differently fractionated [35, 36]. The fractionation of these magmatic suites could be well documented by distribution some trace elements (e.g., Ba, Sr, Th, Zr, REE) (**Figures 3**–7).

For distinguishing, source rock series (greywackes vs. pelites) could be used CaO/Na_2O and Al_2O_3/TiO_2 ratios [37]. According to this study, discussed in detail by René et al. [34] and René [18], the granitic rocks of the Eisgarn suite originated by partial melting of metapelites, whereas granites and granodiorites of the Weinsberg and Freistadt suites originated by partial melting of a metagreywackes-metabasalt mixture.

The estimation of melting temperatures of granitic melts is usually based on saturation thermometers based on melting of zircon and monazite [38–40]. According to zircon saturation, thermometry granitic rocks are usually divided on the hot and cold granites [41]. The most detailed study of all problems connected with the use of zircon thermometry was published by Siégel et al. [42] and Clemens et al. [43]. For all granitic rocks from the Moldanubian batholith, the T_{Zrnsat} was calculated according to the revisited formula published by Boehnke et al. [39] and T_{Mnzsat} according to the model of Montel [40]. The highest saturation temperatures from both models were found for granitic rocks of the Weinsberg suite (681–900°C) and for the Zr- and Th-enriched Lipnice/Steinberg granites of the Eisgarn suite °C (760–910°C). The lowest saturation temperatures were found for some two-mica granites of the Eisgarn suite, especially for the Zr- and Th-depleted Deštná granites (628–740°C). The saturation temperatures for the Mrákotín granites varied between 682 and 859°C. However, the crystallisation temperature derived from experimental melting of biotite for the Mrákotín granite is 830–850°C [34]. It is also interested that in all these cases that the T_{Mnzsat} temperatures are usually partly higher that the T_{Zrnsat} temperatures. These differences could be explained by restitic (inherited) monazite crystals from original metasediments. On the other hand, during detailed study of zircon crystals from granites of the Eisgarn suite in rare cases, inherited zircon cores overgrowth by younger magmatic zircon were found [44].

Partly controversial are sources of heating, which were used for the generation of magmatic rocks of the Moldanubian batholith. According to Velmer and Wedepohl [6], the main heating source of the Moldanubian crust was intrusion of tholeiitic rocks during underplating of an upper crust. However, Gerdes et al. [8] proposed as a main heat source the contribution of internal radiogenic heat production within the thickened upper crust. Some other source of heating needed for generation of granitic rocks in the NW-SE segment of the Moldanubian batholith, together with LP-HT metamorphism rock series southern of the Pfahl zone, was a late Variscan delamination of upper mantle [10, 45]. Recent structural studies that granite plutons in the NW-SE segment of the Moldanubian batholith were emplaced at a shallow level into previously exhumed upper crust during dextral strike-slip shear zones that are later multiply reactivated [13, 15].

6. Conclusion

Granitic rocks of the Moldanubian batholith are represented by four magmatic suites. The biotite granites of the Weinsberg suite are subaluminous to weakly peraluminous granites enriched especially in Ba, Sr, and Zr. The two-mica granites of the Eisgarn suite are represented by the low-Th Deštná granites, the intermediate-Th Mrákotín, Čímĕř/Aalfang granites, and the high-Th Lipnice/Steinberg granites. The highly fractionated alkali feldspar and two-mica granites of the Melechov/Zvůle suite are depleted in Ba, Zr, and Th. The granites to granodiorites of the Freistadt suite are of Ba- and Sr-enriched granitic rocks. The granitic rocks of the individual magmatic suites occurred in the Moldanubian batholith were variable fractionated. The fractionation of these magmatic suites is documented by distribution some trace elements, especially by the Ba, Sr, Th, Zr, and REE. The granitic rocks of the Eisgarn suite originated by partial melting of metapelites, whereas granites and granodiorites of the Weinsberg and Freistadt suites originated by partial melting of a metagreywackes-metabasalt mixture. The estimation of melting temperatures of granitic melts for all magmatic suites of the Moldanubian batholith, based on zircon and monazite saturation thermometers, show that the highest temperatures from both models were found for granitic rocks of the Weinsberg suite and for Zr- and Th-enriched Lipnice/Steinberg granites from the Eisgarn suite (681–910°C). The partial differences between both saturation thermometers could be explained especially by restitic (inherited) zircon and monazite occurred in investigated granitic rocks.

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Conflict of interest

The author declares no conflict of interests.

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