

Accessory Minerals in Felsic Igneous Rocks

Part 2

Composition of monazite-(Ce), xenotime-(Y) and zircon from the multi-stage, strongly peraluminous, P–F-rich Li-mica granite massif of Eibenstock

(Erzgebirge–Vogtland metallogenic province, Germany)

Hans-Jürgen Förster

GFZ German Research Centre of Geosciences, Geothermal Energy Systems, Telegrafenberg, 14473 Potsdam, Germany

1. Citation

These data are freely available under the Creative Commons Attribution 4.0 International License (CC BY 4.0). When using the data please cite

Förster, Hans-Jürgen (2018): Accessory Minerals in Felsic Igneous Rocks - Part 2: Composition of monazite-(Ce), xenotime-(Y) and zircon from the multi-stage, strongly peraluminous, P–F-rich Li-mica granite massif of Eibenstock (Erzgebirge–Vogtland metallogenic province, Germany). GFZ Data Services, <http://doi.org/10.5880/GFZ.6.2.2018.002>

2. Abstract

This data set is the second part of a series reporting chemical data for accessory minerals from felsic igneous rocks. Most data refer to plutonic rocks from the Saxothuringian Zone of the Variscan Orogen (Erzgebirge–Vogtland metallogenic province) in Germany performed between about 1995 and 2005 on surface rocks and borehole samples.

This data set assembles the results of electron-microprobe spot analyses of monazite-(Ce), xenotime-(Y) and zircon from the Li-mica granite massif of Eibenstock. This massif is composed of several, compositionally and texturally distinct sub-intrusions. Least evolved members of the fractionation series are exposed as variably sized enclaves. The pluton is cross-cut by fine-grained aplitic dikes. These late-Variscan (~ 318–320 Ma) granites are highly evolved, rich in Si (72.4–75.8 wt% SiO₂), F, P, Li, Rb, Cs, and Sn, mildly to strongly peraluminous (A/CNK = 1.14–1.35), of transitional S–I-type affinity, and spatially and genetically associated with coeval significant Sn–W–(Mo) mineralization.

Most notably, a comparatively large population of grains of all three species is distinguished by abnormal composition, reflecting the chemically evolved nature of their hosts. Probe data indicate that the composition of monazite-(Ce) and zircon changes with fractionation-driven evolution of magma chemistry. Monazite-(Ce) composition extends over an abnormally large range. In the course of magma differentiation, mineral chemistry evolves towards enrichment Th and U and development of flattened and kinked chondrite-normalized LREE patterns, with negative anomalies at La or Nd, or both (also known as lanthanide tetrad

effect). Many grains are so rich in Th that they classify as cheralite-(Ce). The concentrations (in oxide wt%) of the radionuclides Th and U maximize to 51.7 and 5.3, respectively. The maximum concentration of Y amounts to 4.7 wt% Y_2O_3 . Composition of zircon displays a large variability. A greater number of grains or domains are distinguished by abnormal enrichment in (in oxide wt%) P (up to 9.6), Th (up to 12.2), U (up to 8.7), Hf (up to 5.6) Al (up to 2.2), Sc (up to 2.0), Y (up to 7.0), HREE and Y. Enrichment in these elements is usually associated with low analytical totals, reflecting precipitation from volatile-rich magmas and/or their interaction with, and alteration by, late-magmatic fluids. Xenotime-(Y) chemistry is comparatively little sensitive to changes of Eibenstock-magma composition relative to what has been observed for monazite-(Ce) and zircon. The U concentrations in xenotime-(Y) are generally high and maximize to 6.7 wt% UO_2 . Chondrite-normalized MREE and HREE patterns preferentially in xenotime-(Y) from more evolved magma batches mimic that of their host granites in that they are (a) inclined from Tb-Dy towards Lu, (b) partially evolved the lanthanide tetrad effect, and (c) display above-CHARAC Y/Ho ratios up to 41.

3. The data set

The voluminous late-Variscan Eibenstock granite massif (Eastern Germany) is located in the Saxothuringian Zone of the Variscan Orogen, at the northern edge of the Bohemian Massif (Figure 1). It is built up of several sub-intrusions, which are texturally (Table 1) and chemically distinct, but genetically related via fractional-crystallization magma differentiation. The least evolved exposed members of the fractionation series, traditionally termed “marginal granites” and traditionally discriminated into type “Walfischkopf [E(b)] and type Krinitzberg ([E(a)]), are usually present as cm- to several 10m-sized enclaves in the coarse-grained granite subintrusion (EIB1) near the margin of the massif. Late aplitic dikes (A) characterize the terminal stage of pluton building. Larger portions of the massif experienced late-magmatic and post-magmatic overprinting associated with disturbances of the original mineralogy and geochemistry of these domains.

In addition to the diverse sub-intrusions, several local rock varieties are distinguished. EIB/cord designates a domain in the exocontact of the massif, which contains minor cordierite, most likely formed as result of elemental exchange with the metamorphic country rock. Serious overprinting with F-rich fluids gave rise to abnormal enrichment in F-bearing minerals (topaz, Li-F micas) in domains of the EIB3 sub-intrusion (EIB3/tpz).

The bulk of the studied samples come from surface outcrops. A small selection of samples was collected from drill-core at the locality Tellerhäuser, close to the eastern margin of the massif. These samples are denoted Tlh given in parentheses after the abbreviation of the respective sub-intrusion.

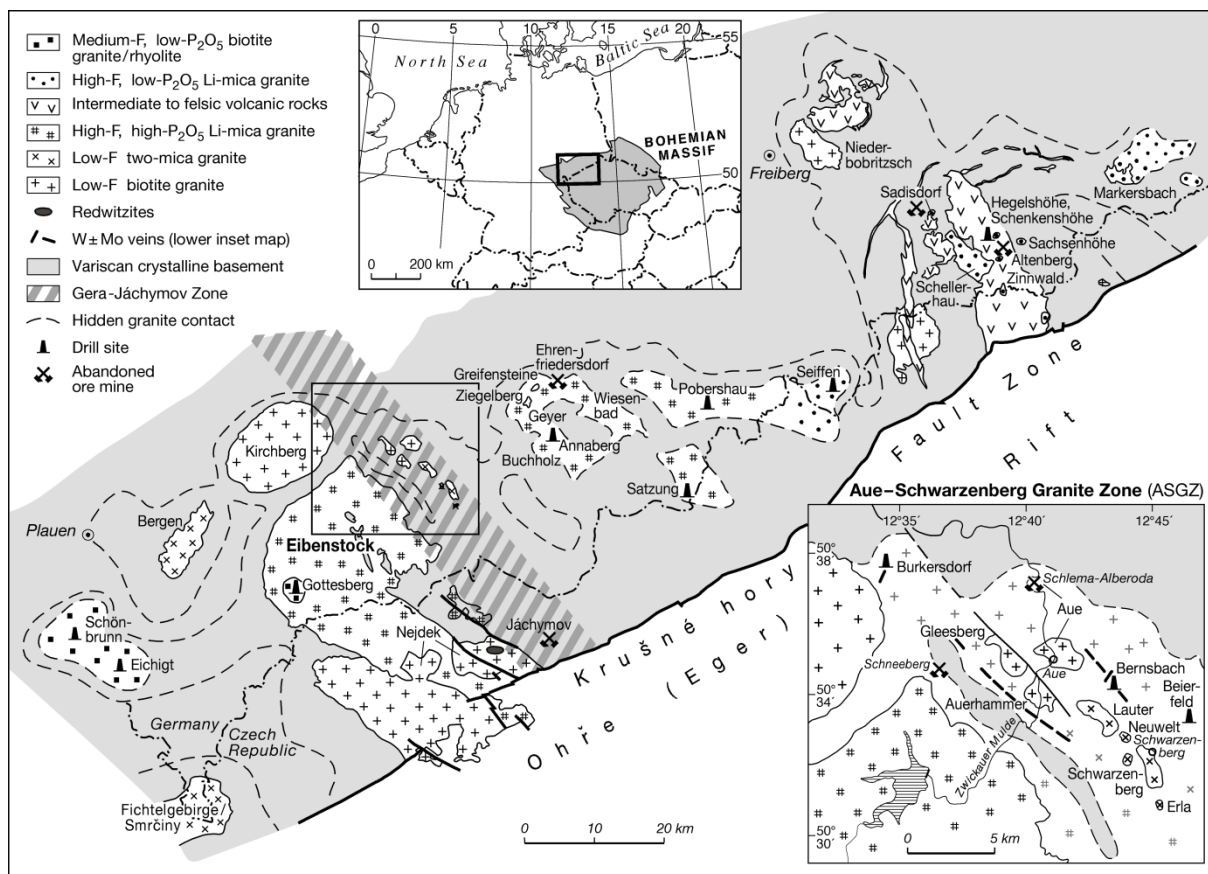


FIGURE 1. GEOLOGICAL MAP OF THE ERZGEBIRGE–VOGTLAND METALLOGENIC PROVINCE OF GERMANY IN THE SAXOTHURINGIAN ZONE OF THE CENTRAL EUROPEAN VARISCAN OROGEN. THE EIBENSTOCK MASSIF, POSITIONED IN THE WESTERN PART OF THE PROVINCE, IS MARKED IN BOLD LETTERS.

TABLE 1. INTERNAL STRUCTURE OF THE MULTI-PHASE EIBENSTOCK PLUTON

Massif		Eibenstock EIB
Subintrusion	Texture	Abbreviation
aplite	very fine-grained	A-EIB
most evolved (3)	fine-(to medium-) grained, occasionally porphyritic	EIB 3
more evolved (2)	medium-grained, slightly porphyritic	EIB 2
evolved (1)	coarse- to medium-grained, porphyritic	EIB 1
least evolved	fine- to medium-grained, porphyritic	E(b)-EIB 1 E(a)-EIB 1

A = aplitite, E = enclave.

The petrography, mineralogy, geochemistry, and isotopic composition of the Eibenstock pluton have been described in detail by Förster *et al.* (1999). This work and the articles of Förster (1998a, b) report a small selection of representative results of electron-microprobe analyses of monazite-(Ce), xenotime-(Y), and zircon, but the bulk of the data remained unpublished. The data set published here contains the complete pile of data acquired for these three accessory minerals. Data are provided as three separate excel files, one for each species (monazite-(Ce); xenotime-(Y); zircon). Each file contains the following information (further abbreviations are explained in the Appendix).

TABLE 2. DESCRIPTION OF COLUMN HEADERS OF THE DATA TABLES

Column header	unit	Definition
massif/pluton		Name of the massif/pluton
subintrusion		Name of the sub-intrusion (<i>cf.</i> Table 1)
Sample No.		Sample number
Latitude	DD, WGS 84	Latitude of the sample location (DD = decimal degree)
Longitude	DD, WGS 84	Longitude of the sample location (DD = decimal degree)
Rechtswert	m, GK DHDN	Gauss-Krueger East coordinate of the sample location in [m], DHDN (Deutsches Hauptdreiecksnetz)
Hochwert	m, GK DHDN	Gauss-Krueger Nord coordinate of the sample location in [m]
Spot number		These numbers indicate how many spots were conducted within a grain. For instance, 1/1 and 1/2 mean that two spots were conducted in grain 1
host mineral		Host mineral of the respective grain
remarks		This column contains additional information, i.e., the position of the spot within the grain, the back-scattered electron (BSE)-contrast of the domain, in which the spot was conducted (bright, dark), spatially associated minerals, <i>etc.</i>
WR - SiO ₂ , TiO ₂	wt%	Whole-rock (WR) concentrations of SiO ₂ and TiO ₂ in weight-% (wt%), both monitoring the degree of evolution/fraction of the granite magma
WR – P ₂ O ₅	wt%	WR concentration of P ₂ O ₅ , indicating whether the rock belong to the low-P or high-P class of granites
WR – F	wt%	WR concentration of F, addressing the importance of F in the respective granite
WR - A/CNK	wt%	WR alumina-saturation index A/CNK = molar ratio of Al ₂ O ₃ /(CaO + Na ₂ O + K ₂ O), highlighting whether the granite is met- (A/CNK < 1) or peraluminous
P ₂ O ₅ , SiO ₂ , ...	wt%	Concentrations of the measured elements in the minerals in oxide wt%
total	wt%	Total after subtraction of the oxygen equivalents of F from the analytical total. The oxygen equivalent of F is calculated by multiplying moles of F by 0.4211
P, Si, ...	wt%	Respective elemental concentrations in wt%
FU P, FU Si, ...	-	Formula units (FU) of the elements, with the cation proportions calculated on the basis of 16 oxygen atoms
sum		Sum of FU
La-CN, Ce-CN, ...	-	Chondrite (CN)-normalized concentrations of the measured resp. calculated (in case of Tm) rare-earth elements [only for monazite-(Ce) and xenotime-(Y)]. Chondrite values are from Anders and Grevesse (1989)
reference		The reference, in case that a listed result of a spot analysis has been published previously either partly or wholly

4. Analytical methods

Mineral analyses were performed using the Cameca CAMEBAX SX-50 (*cf.* Förster 1998a, b) and CAMEBAX SX-100 electron microprobes, employing a PAP correction procedure (Pouchou and Pichoir 1985). The operating

conditions involved an accelerating potential of 20 kV, a beam current of 40–60 nA, and a 1–3 μm beam diameter. The counting times on the peak were 300 s for Pb and 200 s for Th and U, and in each case, half that time for background counts on both sides of the peak. For the REE and other elements, counting times were 60 s and 40 s on peak, respectively.

X-ray lines and background offsets were selected to minimize interferences and their correction. Wavelength-dispersion spectral scans done on complex natural monazite and xenotime grains were used to determine the peak and background positions of each element and to identify overlapping peaks. $K\alpha$ -lines were used for P, Si, Al, Sc, Fe, Ca, and F; $L\alpha$ -lines for Zr, Y, La, Ce, Yb and Lu; and $L\beta$ -lines for Hf, Pr, Nd, Sm, Gd, Tb, Dy, Ho and Er. The interferences of Th-M β on U-M α and Y-L α on Pb-M α were eliminated by using the Th-M α , U-M β and Pb-M β lines. Minor interferences of Th-M γ on U-M β were corrected by the procedure of Åmli and Griffin (1975). Thulium concentrations in xenotime-(Y) were not measured because both the $L\alpha_1$ and $L\beta_1$ lines of Tm suffer strong interferences with lines of other REE. Instead, they were calculated by interpolation from chondrite-normalized abundances of the neighbouring elements Er and Yb [marked by Tm₂O₃* resp. Tm* in the excel spreadsheet for xenotime-(Y)]. The concentrations of Gd in xenotime-(Y) were empirically corrected for interference of Gd $L\beta_1$ by Ho $L\alpha_1$. The concentration of F was calculated by empirical correction for the major interference of Ce-L α on F-K α . The following analysing crystals were used: LIF for Hf, REE and Fe; TAP for Si, Zr, Al, and Y; PET for P, Th, U, Sc, Ca, and Pb; and PC1 for F.

Primary standards included pure metals for Th and U (also synthetic UO_{2.15}), vanadinite and a synthetic glass (0.79 wt% PbO) for Pb, synthetic phosphates prepared by Jarosewich and Boatner (1991) for the REE, and natural minerals and synthetic oxides for other elements. The calibration was checked routinely using the synthetic glass SRM 610, which contains low contents of Th, U, and Pb, and the REE glasses prepared by Drake and Weill (1972).

The analytical errors for the REE depend on the absolute abundances of each element. Relative errors were estimated to be < 1% at the > 10 wt% level, 5–10% at the > 1 wt% level, 10–20% at the 0.2 to 1 wt% level, and 20–40% at the < 0.1 wt% level. The analytical uncertainties for the actinides and Pb amounted to about 10%, even for concentrations below 0.1 wt%. Detection limits were approximately 100–400 ppm for all measured elements, except lead ($\approx$ 100 ppm).

5. Acknowledgements

The author thanks Dieter Rhede and Oona Appelt, GFZ Potsdam, for their valuable assistance in the electron microprobe work and their efforts to optimize the analytical routines.

6. References

Åmli, R. and Griffin, W.L. (1975) Microprobe analysis of REE minerals using empirical correction factors. *American Mineralogist*, **60**, 599–606. URL: http://www.minsocam.org/ammin/AM60/AM60_599.pdf

Anders, E. and Grevesse, N. (1989) Abundances of the elements: meteoric and solar. *Geochimica et Cosmochimica Acta*, **53**, 197–214, [http://doi.org/10.1016/0016-7037\(89\)90286-X](http://doi.org/10.1016/0016-7037(89)90286-X)

* Förster, H.-J. (1998b) The chemical composition of REE–Y–Th–U-rich accessory minerals from peraluminous granites of the Erzgebirge–Fichtelgebirge region, Germany. Part II: Xenotime. *American Mineralogist*, **83**, 11–12, 1302–1315. URL: http://www.minsocam.org/msa/AmMin/TOC/Articles_Free/1998/Forster_p1302-1315_98.pdf

* Förster, H.-J. (1998a) The chemical composition of REE–Y–Th–U-rich accessory minerals from peraluminous granites of the Erzgebirge–Fichtelgebirge region, Germany. Part I: The monazite-(Ce)–brabantite solid solution

series. *American Mineralogist*, 83, 3–4, 259–272. URL:
http://www.minsocam.org/msa/AmMin/TOC/Articles_Free/1998/Forster_p259-272_98.pdf

* Förster, H.-J., Tischendorf, G., Trumbull, R.B. and Gottesmann, B. (1999) Late-collisional granites in the Variscan Erzgebirge, Germany. *Journal of Petrology*, 40, 11, 1613–1645,
<https://doi.org/10.1093/petroj/40.11.1613>

Drake, M.J. and Weill, D.F. (1972) New rare earth elements standards for electron microprobe analysis. *Chemical Geology*, 10, 179–181, [https://doi.org/10.1016/0009-2541\(72\)90016-2](https://doi.org/10.1016/0009-2541(72)90016-2)

Jarosewich, E. and Boatner, L.A. (1991) Rare-earth element reference samples for electron microprobe analysis. *Geostandards Newsletter*, 15, 397–399, <http://doi.org/10.1111/j.1751-908X.1991.tb00115.x>

Pouchou, J.L. and Pichoir, F. (1985) “PAP” (ρ - ρ -Z) procedure for improved quantitative microanalysis. In J.T. Armstrong, Ed., *Microbeam Analysis*, 104–106. San Francisco Press, San Francisco, California.

*key references

7. Appendix: Explanations and abbreviations in the excel data sheets

A	aplite
E	enclave
A/CNK	alumina-saturation index
WR	whole-rock
FU	formula unit
CN	chondrite
0.00	below detection limit
blank box in oxide concentration columns	not measured
Tlh	locality Tellerhäuser
E(b)-EIB 1	granite type “Walfischkopf” entrained in granite EIB 1 (cf. Table 1)
E(a)-EIB 1	granite type “Krinitzberg” entrained in granite EIB 1 (cf. Table 1)
qtz	quartz
fsp	feldspar
plag	plagioclase
kfs	K-feldspar
alb	albite
sid	siderophyllite
Li-mica	Li-rich trioctahedral mica
mnz	monazite-(Ce)
xen	xenotime-(Y)
zrc	zircon
apa	apatite
cord	cordierite
tpz	topaz