Whole-rock and mineral REE patterns: Providing a better insight into rock histories

(2 figs, 1 table)

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Igneous whole-rock REE signatures are often interpreted using discrimination diagrams that are based upon large numbers of analyses from specific tectonic settings (e.g., Pearce 1984). One of assumptions for the use of these diagrams is that the discriminating elements are immobile. This need not be true for rocks which have undergone post-magmatic and/or sub-solidus alteration.

We have attempted to assess the applicability of whole-rock discrimination diagrams for studying altered rocks by studying the mineral trace element chemistry of rocks from one of the igneous massifs of the Variscan collisional belt – the Třebíč Massif (SW Moravia). This batholith is formed by rocks of the durbachite suite – K-feldspar-phyric mela-granites through mela-syenites. They consist of biotite, actinolite, K-feldspar, plagioclase, and variable amount of quartz. Primary accessory minerals comprise apatite, zircon, titanite, allanite, thorite, sulphides, and in some cases altered monazite group minerals and ilmenite.

As part of a much larger research project, which is focused on the occurrence of radionuclides, rock samples were taken from 48 different locations. The whole-rock samples were analysed for major- and trace elements by solution ICP-MS. In order to assess the distribution of U, Th, and REE, the main rock-forming and accessory minerals were analysed by electron microprobe and laser ablation ICP-MS[†].

The durbachites display poorly fractionated REE patterns (Ce/Yb_N = 8–15) with negative Eu anomalies (mean Eu/Eu* = 0.6). The REE patterns of individual samples have very similar slopes; although the less mafic varieties show flatter REE patterns, whereas rim-granites and aplitic dykes are HREE-enriched.

Actinolites from various durbachites have almost identical, concave-upwards REE pattern, irrespective of the modal composition of the host rock (Fig. 1). This may be due to the fact that horblende in the durbachite series rocks is of secondary origin, formed in a late magmatic stage. In contrast, the granodiorite from Dobroutov (Northern margin of the massif) has an almost flat REE pattern that can be explained by possible contamination of the magma by metamorphic country rocks. Biotite is very low in U, Th and REE. Feldspars, however, contribute significantly to whole rock REE budgets (typically 7–13%) due to relatively high total REE contents (between 10 and 60 ppm) and high modal abundances.

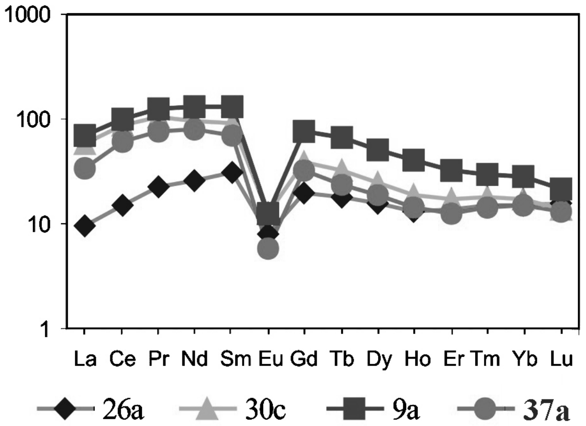

Fig. 1 Chondrite-normalised REE patterns of hornblende from durbachites; diamonds – granodiorite

The chemistry of the most abundant accessory mineral, apatite, was compared with the classification criteria of Sha – Chappell (1999). We were able to confirm that central Hroznatín and Tasov blocks of the massif are very similar to the northern Zhoř block. All three correspond to mafic I-type granites, while apatites from rocks of the southern Boňov block have REE patterns that correspond to those of felsic I-type or S-type granite – see Table 1. Apatite seems to be very valuable in this respect, as it appears to be unaffected by postmagmatic alteration processes. This is not true for other significant hosts of REE's in durbachites – allanite, zircon, thorite and monazite family minerals. All of them are to some extent metamict and/or altered by fluids highly enriched in F (released by chloritisation of biotite) and CO_2. Due to this alteration, significant elemental redistribution and mobilization of U, Y, the HREE and MREE relative to the LREE has occurred on a range of length scales.

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Table 1 Comparison of REE-based parameters of apatites from different blocks of the Třebíč durbachite massif with classification criteria of Sha – Chappel (1999)

Parameter	Mafic *I*-type	Felsic *I*-type	*S*-type	Zhoř block	Hroznatín & Tasov block	Boňov block
Nd anomaly	Nd-undepleted	Often Nd-depleted	Often Nd-depleted	Nd-undepleted	Nd-undepleted	Nd-depleted
$(Sm/Nd)_{cn}$	<0.80	>0.80	>0.80	0.71	0.72	0.98
$(La/Lu)_{cn}$	>5	mostly <4	mostly <4	19.80	20.60	13.40
$(La/Sm)_{cn}$	>1.10	<1.10	<1.10	1.82	1.82	1.20
La/Y	>0.20 (0.20–3.25)	similar to S-type	<0.30 (0.05–0.29)	1.31	1.84	0.32
Sm/Nd	<0.27 (0.12–0.26) Ø 0.17	>0.27 (0.29–0.58) Ø 0.36	>0.27 (0.28–0.62) Ø 0.42	4.92	0.22	0.32
LREE/HREE	1.90–7.90	<1.9, mostly 0.40–1.30	<1.90, mostly 0.50–1.85	3.80	5.74	1.42
Eu/Eu*	0.12–0.94	0.02–0.16, average 0.11	0.03–0.23, mostly <0.15	0.18	0.13	0.05

Note: Grey fields denotes affiliation to felsic I-type (in most parameters the same as for S-type)

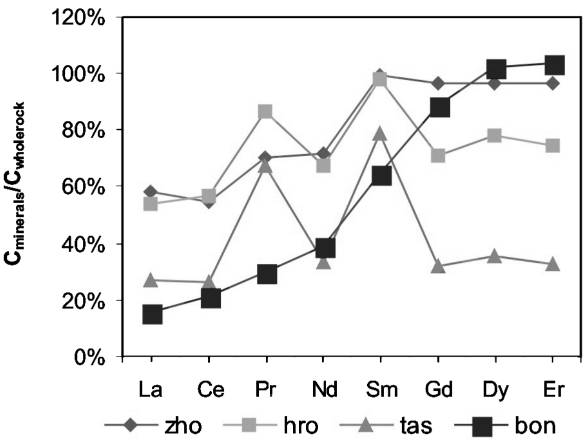

Fig. 2 Contribution of zircon, apatite, amphibole, feldspars to the whole-rock REE contents. The remaining portion to 100% accounts for allanite, thorite and products of their alteration (involving REE fluorocarbonates).

The above mentioned blocks have been affected to different degrees by sub-solidus alteration (see Fig. 2). Whilst the central blocks (-hro and -tas in Fig. 2) are most affected and display similar trends in the proportions of stable minerals (plus zircon), the Boňov block is characterised by the HREE being mostly concentrated in the rock-forming minerals and apatite and zircon. The Zhoř block shows transitional behaviour between these extremes.

References

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