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# THE RICHTERITE MINETTE FROM BUKOWIEC (THE KARKONOSZE – IZERA BLOCK): PETROLOGICAL CHARACTERISTICS

**Abstract:** The richterite minette in a dike cutting the eastern part of the Karkonosze granite shows petrographic, mineralogical and geochemical characteristics gradational between typical minettes and lamproites. The parental magma of this rock probably originated due to melting of a metasomatised mantle source and further evolved due to polybaric crystallisation and hybridisation processes. Late crystallisation involved formation of blue amphiboles (ferriwinchyte-riebeckite).

**Keywords:** minette, lamproite, richterite, riebeckite, the Sudetes

## SCOPE AND METHODS OF THE STUDY

A rare variety of lamprophyre with abundant Na-Ca and Na amphiboles was found in the eastern part of the Karkonosze-Izera Block, east of the village of Bukowiec near Kowary. This rock, previously mapped as kersantite, forms ca. 0.6 km long dike within a dike swarm cutting the Karkonosze granite intrusion (Awdankiewicz *et al.* 2005). In this paper, petrography, mineral chemistry and geochemistry of this unusual rock are outlined in comparison with other potassic rocks (minettes, lamproites), and magma origin and crystallisation are briefly discussed. The methods applied include: 1) observations in thin sections (3 samples), 2) determination of whole-rock major and trace element contents at ACME Analytical Laboratories Ltd., Canada (the ICP-ES and -MS methods, 1 sample), and 3) determination of mineral chemical composition using the electron microprobe (55 quantitative analyses at Université B.Pascal, Clermont-Ferrand, France, and at Wrocław University, Poland).

## PETROGRAPHY AND MINERAL CHEMISTRY

The lamprophyre from Bukowiec is a porphyritic, flow-foliated rock with abundant, 2-3 mm long, aligned, dark mica phenocrysts. The fine grained to aphanitic groundmass is composed of alkali feldspars (Kfs>>Nafs), amphiboles (mainly richterite), dark micas (phlogopite/biotite), ilmenite, augite, titanite and minor apatite (see Awdankiewicz *et al.* 2005, Tab. 1, for volumetric data).

The mineral assemblage of the described lamprophyre, due to abundant dark micas and alkali feldspars, is generally similar to that found in minettes (Rock 1991), although the presence of phlogopite, richterite and K-feldspar is particularly characteristic of lamproites (Mitchel, Bergman 1991). However, the EDS search did not confirmed any minor phases

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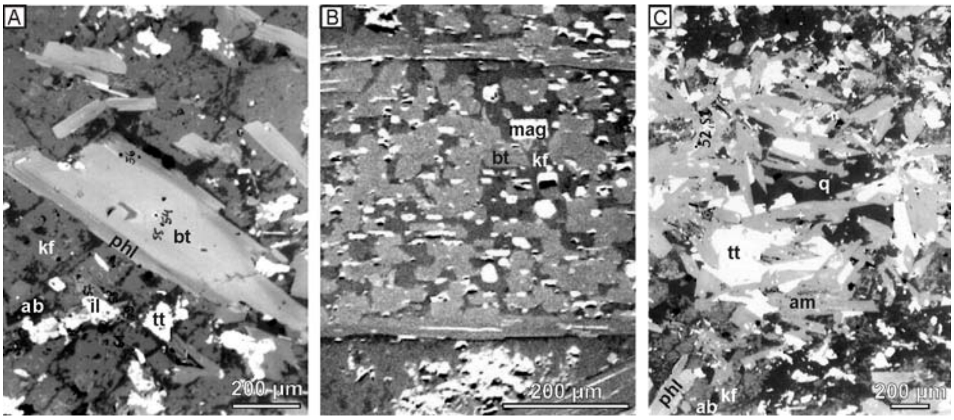



Fig. 1. BSE images of the richterite minette showing a zoned biotite-phlogopite phenocryst (A), sieve-textured biotite phenocryst (B) and a quartz-titanite-amphibole cluster (C). (ab- albite, am- amphibole, bt- biotite, il- ilmenite, kf- K-feldspar, mag- magnetite, phl- phlogopite, q- quartz, tt- titanite). Comments in the text.

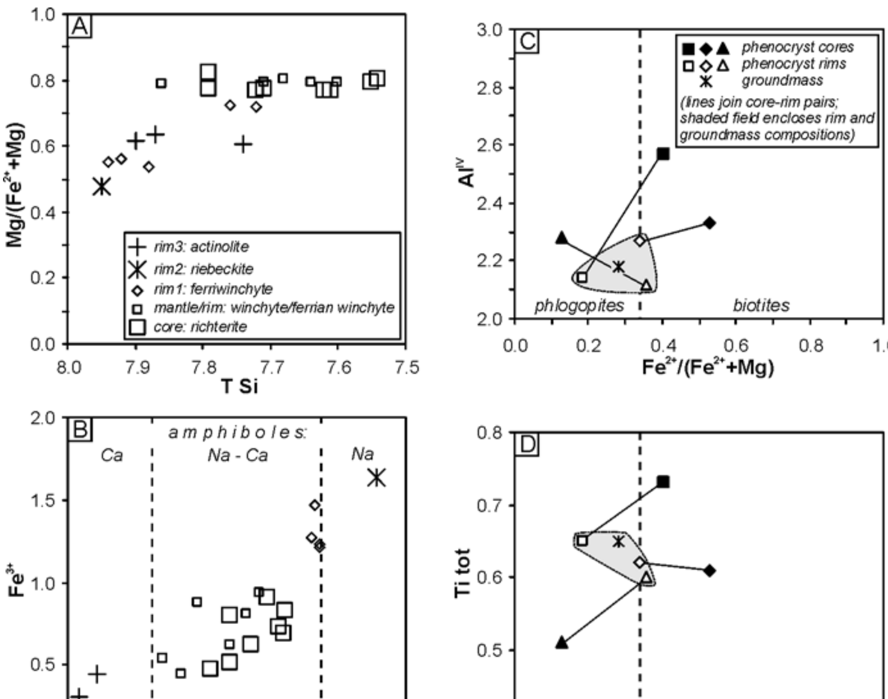



Fig. 2. Selected diagrams illustrating the chemical composition of amphiboles (A, B) and dark micas (C, D) of the richterite minette. Cations normalised to 23O and 13CNK (amphiboles) and 22O (micas). Comments in the text.

typical of lamproites, and also the high $Al_2O_3$ content (>12%) in the dark micas, together with the low $TiO_2$ and $K_2O$ contents (<3% and <4% respectively) in richterite, are unlike those in lamproites (*cf* Mitchell, Bergman 1991). In conclusion, the mineral assemblage and mineral chemistry of the lamprophyre from Bukowiec is considered transitional between minettes and lamproites and this rock is classified as a richterite minette.

The dominant alkali feldspar of the discussed richterite minette is almost pure orthoclase (Or98Ab2) which forms subhedral and tabular groundmass crystals (Fig. 1A). In many places, larger (1-3 mm in size) K-feldspar crystals poikilitically enclose flow-aligned dark mica plates. K-feldspar is densely stained with haematite and intergrown by small (0.01-0.02 mm) patches of chlorite (diabantite), smectite(?) and pure albite. The latter mineral is also an interstitial component of the groundmass (Fig. 1A). Larger patches (0.1-0.2 mm) of Na-K feldspar (Ab<34%) are found within some K-feldspars.

The amphiboles occur in clusters of prismatic crystals associated with subhedral titanite and interstitial quartz (Fig. 1C). The amphiboles are distinctly pleochroic, zoned and vary widely in composition comprising members of the three principal groups: Na-Ca, Na, and Ca (Fig. 2A and B). Typically, light green to olive-brown amphibole cores grade into pale coloured rims with a shift in composition from richterite to winchyte/ferrian winchyte. Some crystals show also incomplete overgrowths, patches and veins of deep-blue (indygo) amphiboles, ranging in composition from ferriwinchyte to riebeckite. The blue amphiboles are further overgrown by acicular, greenish actinolite.

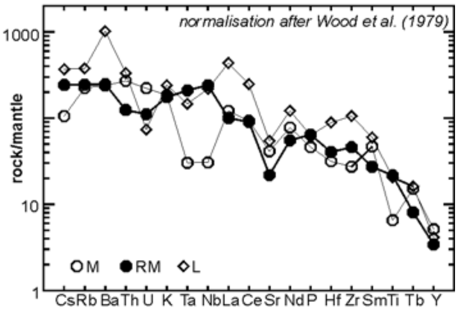
The dark mica phenocrysts typically show euhedral to subhedral, partly embayed habit (Fig. 1A). Sieve-textured phenocrysts densely intergrown by K-feldspar and magnetite are much less common (Fig. 1B). Groundmass micas are usually euhedral plates. The micas are phlogopites and Mg-biotites relatively poor in tetrahedral Al and rich in Ti (2.1-2.6 and 0.5-0.8 cations per formula unit, respectively; Fig. 2C and D). However, the texturally distinct phenocrysts show also different composition at cores and, towards the rims, the compositions converge towards that typical of groundmass mica plates (Fig. 2C and D).

The other minerals analysed show rather weak compositional variation. Augite is partly chloritised and relatively rich in Mg and Ca (En44Wo44Fs12). Ilmenite contains up to 0.3 $Fe^{3+}$ cations per formula unit. Titanite composition is close to the ideal formula. Chalcopyrite strongly replaced by a fine-grained, haematite-rich mineral aggregate is occasionally found.

## GEOCHEMISTRY

The richterite minette from Bukowiec is an intermediate, mildly alkaline rock (trachyandesite in terms of the TAS classification; Awdankiewicz *et al.* 2005) showing a potassic ($K_2O$>$Na_2O$) and subaluminous (molecular $K_2O+Na_2O \approx Al_2O_3$) composition (Fig. 3). It is characterised by a moderate Mg/(Mg+Fe) ratio and high contents of both compatible and incompatible elements (*e.g.* Ni, Zr, Nb, Ti). High Ba/La, La/Lu, Nb/Y and Zr/Y ratios indicate enrichment in large-ion litophile elements, light rare earth elements, Nb and Ta relative to heavy rare earth elements and Y. Unlike typical mintettes, characterised by Nb, Ta and Ti depletion in the mantle normalised trace element plots, the richterite minette shows high Nb, Ta and Ti abundances more similar to lamproites. However, Ba, La, Ce or Zr do not reach such extreme concentrations as those found in lamproites. Thus it is considered that the geochemical features of the richterite minette from Bukowiec are transitional between typical minettes and lamproites.

| | M | RM | L |
|---|---|---|---|
| $SiO_2$ | 51.50 | 53.62 | 51.10 |
| $TiO_2$ | 1.30 | 4.31 | 4.10 |
| $K_2O$ | 5.60 | 5.32 | 7.30 |
| $Na_2O$ | 2.00 | 2.63 | 0.65 |
| Mg/(Mg+Fe)* | 0.66 | 0.56 | 0.74 |
| $K_2O/Na_2O$* | 1.84 | 1.33 | 7.39 |
| $(K_2O+Na_2O)/Al_2O_3$* | 0.73 | 0.90 | 1.18 |
| Ni | 210 | 215 | 452 |
| Ba | 1887 | 1912 | 8008 |
| Nb | 20 | 153 | 140 |
| Zr | 315 | 515 | 1206 |
| Nb/Y | 0.76 | 9.01 | 6.75 |
| Zr/Y | 12 | 30 | 58 |
| La/Lu | 319 | 443 | 1409 |
| Ba/La | 21 | 26 | 25 |




M - mean minette, RM - richterite minette from Bukowiec, L - mean lamproite
* - molecular ratios

Fig. 3. Selected geochemical characteristics and primitive mantle normalised diagram of the richterite minette from Bukowiec compared to a mean minette and lamproite (after Rock 1991, Tab. 5.1).

## PETROGENESIS: GENERAL INTERPRETATION AND OPEN QUESTIONS

The origin of lamproite and minette magmas is linked with low degrees of partial melting of mantle sources metasomatically enriched in trace and volatile elements due to subduction processes, often tens to hundreds million years before the onset of magmatism (*e.g.* Wilson 1989; Rock 1991; Mitchel, Bergman 1991). Based on the petrological characteristics presented above, such a general interpretation can also be applied to the richterite minette from Bukowiec. However, the chemical and mineralogical distinctness of minettes and lamproites implies quite different source characteristics and melting conditions and these, together with the extent of fractionation and crustal influence on the melt composition, remain a matter of debate (*e.g.* Rock 1991). The textural and compositional variation of dark mica in the Bukowiec minette suggest that an early, polybaric crystallization of this mineral and, possibly, hybridisation of distinct magma batches were both involved in this case. The lack of Nb-Ta depletion argues against a significant crustal contamination. The composition and zoning of amphiboles possibly reflect the specific melt composition and changing crystallization conditions: from magmatic (richterite-winchyte), through late magmatic (ferriwinchyte-riebeckite) to post-magmatic (actinolite). Other minerals (K-feldspar, titanite, quartz, albite, chlorite, smectite) formed successively in late- to post-magmatic conditions.

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