Hybrid I/S nature of Prašivá granite type, Low Tatra pluton: Evidence from mineralogical data

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Abstract:. This study focuses on two facies of Prašivá granitoid: (1) Magurka settlement and (2) Liptovská Lužná village. The both facies are biotite monzogranites with porphyrocrysts of K-feldspar. Apart from textural and petrographic similarities, mineral assemblages show significant differences. In both facies rapakivi and anti-rapakivi intergrowths of feldspars and plagioclase are common but characteristic specific mineral assemblage from Magurka area represent annite and monazite-(Ce) on the other hand, from Liptovská Lužná shows presence of Mg-biotite and primary allanite-(Ce) with monazite relics. The mineral assemblage suggests mixing or different input and interaction of more mafic Ca^{2+} and H_2O rich melt portion into former magma batch resulted in compositional variability within the Prašivá granite body.

Introduction

The mixing and mingling of magmas is reagarded as one of the essential processes in magma evolution responsible for formation of the so-called hybrid granitoids. The interaction of mafic and felsic melts is mirrored in zonal structure of granite bodies, their fabrics and composition.

Meso-Variscan granitoids exposed in the Western Carpathians are subdivided into S- and I-types (e.g. Petrik et al. 1994): geochemical differences between S- and I- types are underlined by set of typological mineralogical phases, especially the ilmenite+monazite versus magnetite+allanite paragenesiss, recpectively. However, the several features, including Rb–Sr and Nd–Sm isotope systematics (Kohút & Nabělek 2008), or presence of mafic enclaves (Petrík & Broska 1989) indicates that I- type should be influence by melt mixing.

This contribution focus on distribution selected typhomoprhic accessory minerals suggesting the inhomogenous nature of the parental granite.

Geological Setting

The Low Tatra pluton includes two main granitoid types: Prašivá granodiorite to granite located on northwest from the Demänovská Dolina and Ďumbier tonalite to granodiorite occurring in more eastern part of the mountain range. Both are classified as calc-alkaline metaluminous granitoids with transition to peraluminous type, however the Prašivá type is richer in alkalis, especially K_2O (Putiš et al. 2003). Apart from these two major types, several distinct, predominantly peraluminous granite bodies occur within the granite pluton and roof metamorphic complexes (e.g. Dupej & Siegl 1981). Nd–Sm, Rb–Sr and Pb–Pb isotope characteristics of Prašivá granite in contact zone with dioritic MME implies predominant role of mantle-derived mafic melt mixed with crustal one (Poller et al. 2005). Zircon U–Th–Pb dating yielded ages 353±3 Ma (Broska et al. 2013).

Sample localities and methods

Investigated representatives of different facies of Prašivá granitoid were taken in area of Magurka settlement (on the trail to the Ďurková saddle) (NTM-7) and in valleys close to the Liptovská Lužná (NTM-12 and NTM-16).

The petrographical decription is based on transmitted and reflected light microscopy. Mineral composition was carried out using SEM and microprobe at the Earth Science Institute SAS in Banská Bystrica.

Results

Petrography

The Prašivá granite type from both localities is porphyritic with heterogranular structure, medium to coarse grained. The composition varies from quartz monzonite (18 % Q, 31 %Fld, 49 % Pl) to monzogranite (25 % Q, 33 % Fld, 42 % Plg) .

Presence of up to 1cm large perthitic K-feldspar porphyrocrysts is very typical textural pattern of the Prašivá granite type. Kfs occurs as smaller microcline grains in intersticial position, and as rims on plg and older Kfs is often altered in various degree. Pl (An 38–41) is present in two generations: smaller, euhedral, highly sericitized and saussuritized crystals with corroded margins, often enclosed in K-feldspar porphyrocrysts, and larger, polysynthetic twinning or normal zonatal, rimmed by albite or orthoclase overgrowths. On the boundaries between feldspars, quartz and myrmekite intergrowths are widespread.

The dark-brown biotite (annite) is present often as aggregates or cloths. It shows variable effect of alternation (chloritisation), replacement along cleavage plains by fibrous prehnite (NTM-7) or by epidote, ilmenite and garnet (NTM-12, 16; Fig. 1a). Muscovite only as a secondary phase occurs.

The most widespread accessory phase is apatite occuring as relatively large, prismatic crystals in biotite.

Monazite is abundant in Mg granite, often as relatively large crystals enclosed in biotite and associated with apatite. Granites from Liptovská Lužná area contain much smaller and dispersed grains of monazite.

Zircons are present as inclusions in biotite or apatite and within feldspars. In all samples Zr/Hf ratios are between 20–33; it is typical value for Variscan granites in the Western Carpathians.

Magnetite is widespread as euhedral crystals, often with thin titanite rims in Liptovská Lužná but in Magurka is present in lower amount and partly replaced by hematite. Ilmenite was found as lensoidal inclusions in biotite and as a skeletal, strongly oxidised relicts with inclusions of rutile overgrown by titanite.

Apatite

Apatite in all samples forms euhedral, prismatic, in lesser extent stubby crystals and represents almost end-member fluorapatite. Some crystals are homogenous, when the other show well-developed concentric zonation.

In both facies of investigated granites apatite show generally low Mn and Fe content — 0.06–0.17 and 0.02–0.17 wt. %, however the NTM-7 apatite is slightly richer in Mn (Fig. 2). The most distinguishing feature is elevated SO_2, REE_2O_3 and Na_2O contents in NTM-12 and NTM-16. The REE+Y content in some grains correlates with Na and with Si, what suggest two mechanisms of coupled substitution.

Monazite-(Ce)

Monazite-(Ce) is abundant in NTM-7, where it occurs as inclusions in biotite. It forms sub- to anhedral, cracked heterogenous crystals up to 250 µm. The monazites show complex zonation, with patchy irregularly distributed lighter and darker patches (especially when they are located on biotite margins), or concentric zonation (Fig. 1b,c). The lighter patches or cores in monazites are generally enriched in Th and Y, what suggest higher degree of huttonite and xenotime substitution. The irregulary distributed Th-rich zones are thought to be a result of dissolution–reprecipitation of primary monazite causing secondary Th enrichment or depletion in distinct areas; a typical phenomenon of fluid-aided metasomatism (Poitrasson 1996).

In Liptovská Lužná samples, monazite was found only in sample NTM-12. It occurs as inclusions in apatite and skeletal relicts in allanite, All monazites are slightly depleted in P (28–29 wt. %) and REE and show enrichment in SiO_2 (2–2.5 wt.%), ThO_2 (11–14 wt. %) and CaO (0.8–1 wt. %). It suggests the advanced dissolution–reprecipitation process and/or their secondary origin.

Allanite-(Ce)

Allanite-(Ce) was found in NTM-12 and 16 (Liptovská Lužná), as fine crystalline aggregates in biotite and as a interstitial large euhedral- to subhedral grains rimmed by epidote.

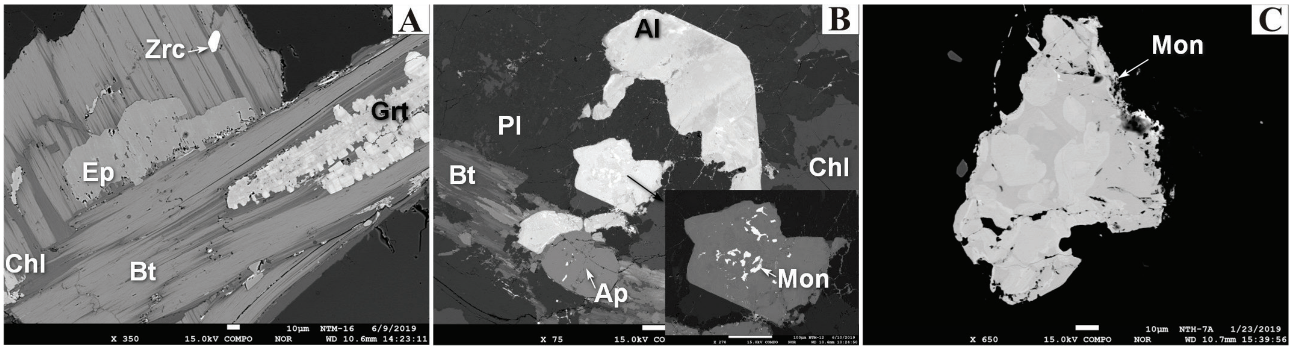

Fig. 1. Eaxmple of mineral assemblages in Prašivá granitoids: **A** — Garnet and epidote lenses in chloritised biotite NTM-12; **B** — Subhedral zoned allanite-(Ce) in plagioclase with enclosed relicts of monazite NTM-16 (Liptovská Lužná area); **C** — patchy monazite from NTM-7 (Magurka area)

Darker and brighter domains are distributed subordinately or the latter are developed along the cracks due to oxidation process. The ThO_2 content is highly variable from 0.7 in darker zones to 1–2.7 wt. % in brighter and correlate with lower concentration of REE, higher oxidation state of iron and enrichment in Ca. The plot REE+Th+U vs Altot (Petrík et al. 1995) suggests that most of the allanites were formed in higly oxidised metaluminous melts during moderate-pressure conditions (Broska et al. 2021).

Garnet

Garnets were found only in Liptovská Lužná as an anhedral, streak or lens-like aggregates in chloritised biotite (Fig. 1a). Its composition correspond to andradite (91–68 mol. %) with variable grossular component (>30 to 13 mol. %). Depletion in silica and excess in Fe^{3+} suggests high degree of hydratation and oxidation.

Conclusions

The mineral assemblages and rock textures suggest spatial compositional heterogenity within Prašivá intrusion. They show features of both metaluminous and peraluminous magmas. It seems that the magmas before the mixing event intruded as a crystal mush containing phenocrysts of biotite with enclosed accessory apatite and REE phases as well as older populations of K-feldspar. The most important factors which governed the development of new mineral phases or modifications of accessory minerals content of volatiles and redox conditions. The fluctuations and changes in these parameters resulted in interaction of transferred phenocrysts and hybrid melt as well as growth of the new phases.

The facies in more eastward Magurka areas of the pluton, indicate larger input of felsic crustal magmas to existed metaluminous melt. The more reduced character of melt is recorded in lower ratio of Mg/(Fe+Mg) in

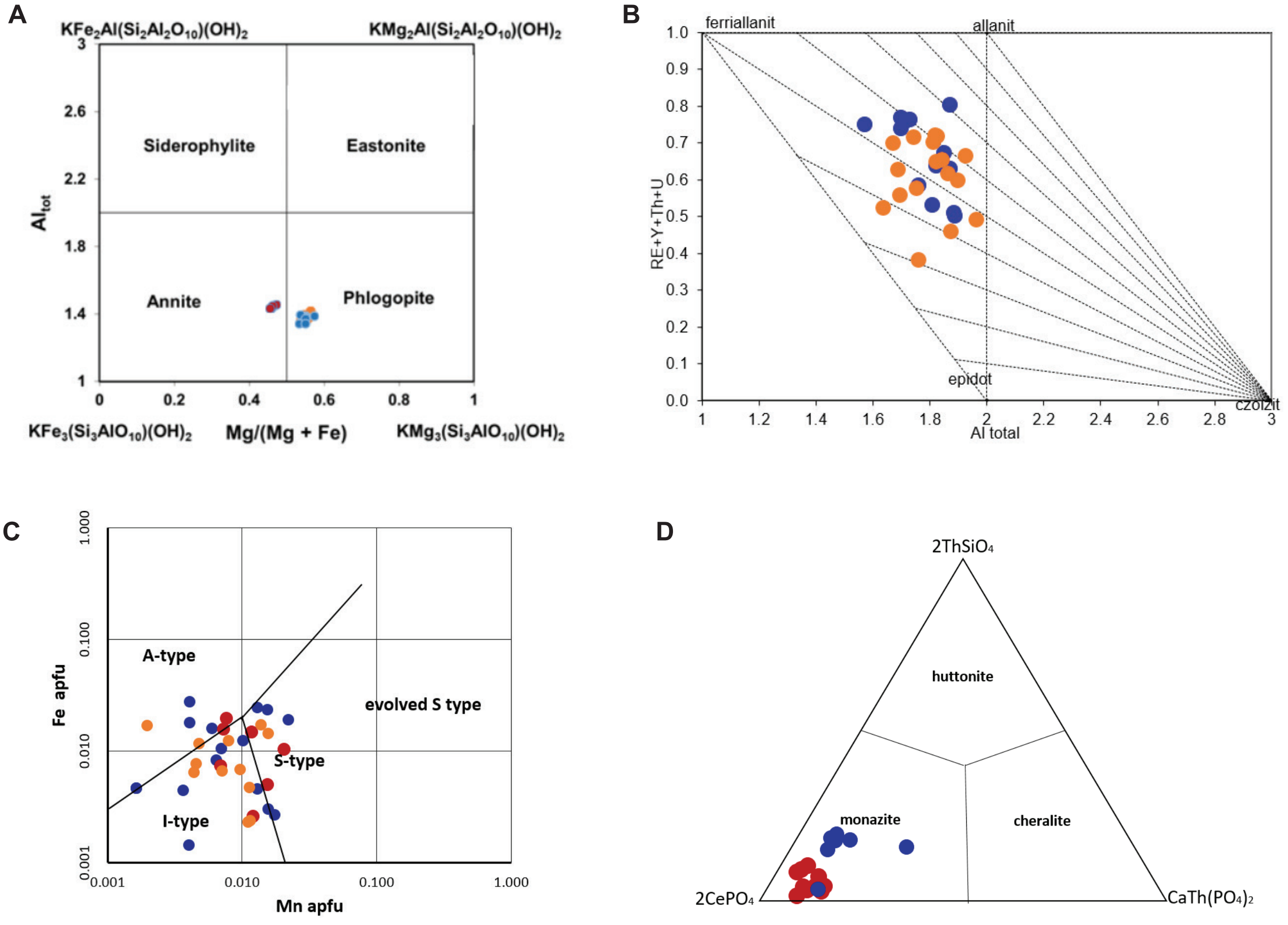

Fig. 2. Composition of main and accessory minerals in the Prašivá granite: **A** — Classification of biotites from Prašivá granitoids; **B** — REE+Y+Th+U vs Al tot (apfu) diagram for NTM12 and NTM16 allanites (after Petrík et al. 1995); **C** — Fe vs Mn discrimination diagram for apatites from different granite suites in WC (Broska & Petrík 2008). **D** — Cheralite–Huttonite–Monazite plot for samples NTM7 and NTM12.

biotite and abundance of monazite-(Ce) as main REE carrier along with general absence of minerals typical for hybrid rocks, like magnetite or primary titanite In Liptovská Lužná area, biotite is Mg richer and allanite is main REE-bearing phase, when monazite-(Ce) occurs as tiny relicts within some allanite grains showing more metaluminous character of melt.

In samples from Liptovská Lužná, the presence of resorbed monazite relicts in some allanite crystals suggest its formtion at the expense of the phosphate from presented REEs. The replacement relationship between monazite and allanite could be described by fluid-aided alternation processes (see e.g. Regan et al. 2019).

Mn and Fe (apfu) contents in apatites from all localities are in coincidence with I-type characteristics (Broska & Petrik 2008), some subtle differences are connected with concentration of S and, REEs. Higher content of S generally suggests more oxidised character of crystallization (Sha & Chappell 1999). Low REE contents in sample NTM-7 apatite may be explained by coeval precipitation of monazite (Sha & Chappell 1999).

The changes of Ca and Al activity influenced also micas, causing the replecement of biotite by Ca-Al rich phases towards prehnite, hydrogarnets and chlorite (Tulloch 1979) and exsolution of titanite (Frost et al. 2001), However these secondary phases may also have been formed during post magmatic or sub-solidus alternation in Alpine orogeny.

The presence of K-feldspar and albitic rims (similar to antirapakivis structures) and myrmekitic intergrowths manifest interaction of alkalis rich fluids from residual magmas. It cannot be excluded, that in some cases these alkaline fluids overprinted also the REE minerals (Poitrasson et al. 1996; Poitrasson 2002) and triggered monazite exsolutions from apatite (Harlov & Forster 2003).

Summarising all the differences within Prašivá granite facies, from Magurka and Liptovská Lužná, suggests different input and degree of melt mixing within the Prašivá magmatic body. Proposed model of hybridisation for Prašivá granite body indicate differences in evolution of the different amount of melt injection the mafic melt into partially-solidified differentiated magma in propagation from NW to SE. It may suggest that mafic input, evidenced by isotope data (Poller et al. 2005) did not result in total mixing of melts.

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