Contamination in granitic pegmatites; Examples from the Moldanubicum, Czech Republic

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ABSTRACT

Contamination of granitic pegmatites during magmatic to subsolidus evolution was suggested to proceed in three distinct stages: a) Pre-emplacement stage - contamination of pegmatite melts during their propagation from fertile granite to the place of pegmatite solidification; b) Post-emplacement stage - contamination of pegmatite melt from host rock in situ; c) Hydrothermal (subsolidus) stage - alteration of a solid pegmatite by fluids infiltrating from host rocks. Examples of contaminated pegmatites occurring in rocks with contrasting chemical composition from the Moldanubicum are discussed.

Keywords: *granitic pegmatite, pre-emplacement and post-emplacement contamination, tourmaline, Moldanubicum.*

INTRODUCTION

Granitic pegmatites may be contaminated from their host rocks. Contamination is evident particularly in pegmatites enclosed in rocks with contrasting chemical composition. However, detection of such contamination and particularly its degree and time specification of the contamination process are very complicated because we do not exactly know: (i) original composition of pegmatite melts in the time of their separation from fertile granite (granite composition with high amount of volatiles, low amount of FM particularly Mg are generally supposed); (ii) channelways (~ rocks), which pegmatite melts passed through during their propagation from a fertile granite to the place of pegmatite consolidation, as well as a distance of this moving (modeling indicates distances up to ~ 10 km; Baker 1998). Because the bulk compositions of zoned pegmatites are only exceptionally available, we have to focus on chemical composition of individual minerals. From the potential minerals showing: (i) abundance in granitic pegmatites and in individual pegmatite zones, (ii) crystal structure available to incorporate variety of the relevant elements such as Ca, Mg, Fe and F at variable PT conditions, and (iii) refractory behavior, minerals of tourmaline group are the most suitable (cf. Novák 1998, 2000).

Contamination of granitic pegmatites (both melt and solid rock) may generally proceed in three distinct stages (Novák 1997): a) *Pre-emplacement stage* (PRE) when contamination of pegmatite melts proceeded during their propagation from fertile granite to the place of pegmatite solidification. b) *Post-emplacement stage* (POE) involves contamination of pegmatite melt from host rock in situ (London et al. 1996). c) *Hydrothermal (subsolidus) stage* (HYD) operates as an alteration of a solid pegmatite by fluids infiltrating from host rocks largely after thermal and fluid re-equilibration of pegmatite and host rock (London 1990, London et al. 1996). The contamination (both PRE and POE) may generally involve the following major mechanisms: assimilation (dissolution) of fragments of solid rocks in pegmatite melt including more or less perfect homogenization of such contaminated melt, and infiltration (diffusion?) of fluids from host rocks into pegmatite melt. The PRE and POE contamination stages will be discussed in particular in this paper.

THE EXAMINED LOCALITIES

Granitic pegmatites in the Moldanubicum are especially suitable for such study. They cut rocks with contrasting chemical composition (serpentinite, Fe-skarn, dolomite and calcite marbles, metabazite, pyroxene gneiss, biotite gneiss), and tourmaline is a common accessory to minor mineral in most pegmatites. The research was focused on the following examples (localities).

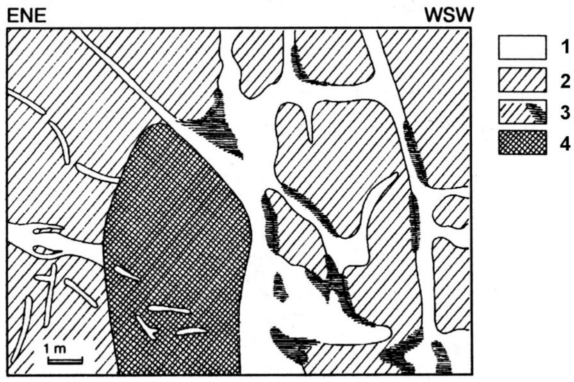

FIGURE 1. Primitive pegmatites cutting Fe-skarn at Vlastějovice; 1 – pegmatite; 2 – Fe-skarn (garnet+pyroxene); 3 – reaction rims rich in amphibole; 4 – massive magnetite; (Novák and Hyršl 1992).

a) Primitive pegmatites (Plg_{An0-35}>Qtz~Kf) form dikes and complicated bodies with homogeneous internal structure, from 20 cm to 2 m thick. They cut Fe-skarn (andradite+hedenbergite+magnetite) at the locality Vlastějovice (Fig. 1) but these pegmatites have not been found outside of the skarn body. Coarse-grained pegmatites locally contain abundant hastingsite, fluorite, annite, hedenbergite, garnet, accessory allanite-(Ce), titanite and very rare axinite as the only B-bearing mineral. Abundant and thick reaction rims (Fig. 1) consist of dominant amphibole and locally also fluorite, biotite, garnet, allanite and Ca-rich $plagioclase_{An6-35}$ relative to Ca-poor $plagioclase_{An0-20}$ from the central portions of pegmatite (Ackerman et al. 2007). Overall Ca,Fe,F-rich mineral assemblage concentrated especially along contacts of the pegmatites suggest strong POE contamination in situ. Calcium and Fe obviously come from host Fe-skarn, and F was very likely derived from F-rich early garnet ($Grs_{79-87}And_{12-18}$; F = 0.82-1.18 wt.% F; Žáček 1997, Žáček et al. 2003). It was almost completely replaced by F-poor garnet

(And>>Grs) during early stage of regional metamorphism (Žáček 1997) and this metamorphic event very likely produced also the primitive pegmatite melt. Ackerman et al. (2007) suggested, based on the fluid inclusions study and feldspars thermometry, the conditions of pegmatite crystallization at P = 420-580 kbar and T = 600-640 °C. These conditions are slightly lower than the conditions of regional metamorphism at P = 450-650 kbar and T = 590-680 °C estimated by Žáček (1997).

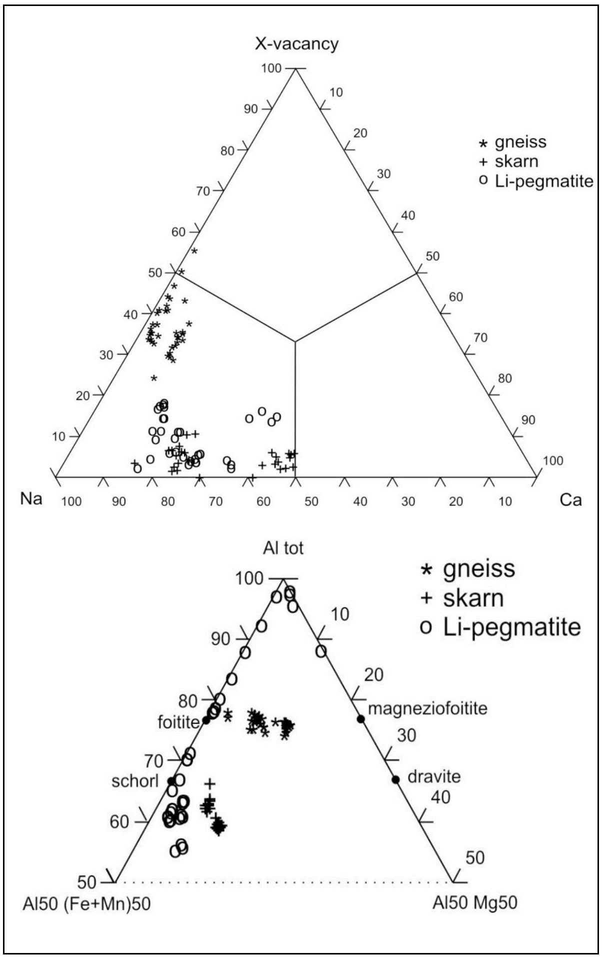

FIGURE 2. Tourmaline compositions from the different pegmatites at Vlastějovice.

b) Primitive, tourmaline-bearing pegmatites (Kf~Qtz> Plg_{An0-24}) form dikes with homogeneous to simply zoned internal structure, 2 to 4 m thick, cutting biotite and pyroxene gneisses and Fe-skarn at the locality Vlastějovice. They contain minor to accessory biotite, tourmaline, fluorapatite, whereas muscovite, garnet, rutile, titanite, monazite and xenotime were found only in the pegmatite bodies hosted in gneisses. The pegmatites from Fe-skarn locally have very thin reaction rims with amphibole. Tourmaline (schorl) from pegmatites in Fe-skarn is apparently Ca,Fe,F-enriched (0.15-0.47 apfu Ca, 2.56-2.70 apfu Fe^{2+}_{tot}, 0.22-0.47 apfu F; Fig. 2), whereas tourmaline (schorl to dravite) from pegmatites in gneisses yielded the composition (0.01-0.10 apfu Ca, 1.63-1.70 apfu Fe^{2+}_{tot}, 0.01-0.21 apfu F). This is comparable to the tourmaline from other primitive pegmatites in the Moldanubicum (Novák et al. 2004). The chemical composition of the tourmaline suggests moderate POE contamination in situ of pegmatites cutting Fe-skarn, whereas POE contamination of pegmatites from gneisses is negligible and perhaps less evident due to less contrasting composition of host rocks. PRE contamination was not confirmed, but slightly higher Ca (0.03-0.10; # 0.07 apfu Ca) in tourmaline from pegmatite enclosed at biotite gneiss relative to the tourmaline (0.01-0.10; # 0.03 apfu Ca; Fig. 2) from the pegmatite in pyroxene gneiss indicates, that some contamination older than the weak POE contamination in situ discussed above may have occurred. However, such a weak difference in Ca contents may be controlled by abundance of plagioclase occurring in the pegmatite bodies. Surprisingly, the contents of Ca in plagioclase from the tourmaline pegmatites enclosed in gneisses and in Fe-skarn, respectively, are very similar.

c) Simply zoned, elbaite subtype pegmatite (Kf>Qtz> Plg_{An0-23}), up to 2 m thick, cuts Fe-skarn at the locality Vlastějovice and shows sharp contacts. Tourmaline (schorl-elbaite) is a typical, accessory to minor mineral along with rare annite, magnetite, fluorite, danburite, pyrochlore and manganocolumbite. Datolite and bavenite were found in pockets associated with elbaite, albite, K-feldspar and quartz. Ca,Fe,F-enriched tourmaline (0.18-0.44 apfu Ca, up to 2.98 apfu Fe^{2+}_{tot}, 0.20-0.58 apfu F; Fig. 2) and abundance of Ca-rich minerals (danburite, datolite, fluorite) suggest minor to moderate but evident contamination similar to the primitive, tourmaline-bearing pegmatites described above. However, the contamination may have the PRE contamination origin, which is indicated by evident homogenization of assimilated material, almost entire absence of reaction zones at contact and zoned internal structure of the pegmatite. Ackerman et al. (2007) suggested, based on the fluid inclusions study and feldspars thermometry, the conditions of pegmatite formation at P = 310-430 kbar and T = 500-570 °C.

d) Homogeneous to simply zoned, elbaite-subtype pegmatites (Kf>Qtz>Plg_{An0-33}) at the locality Bližná form dikes, 4 to 6 m thick, hosted in calcite-dolomite marble (Bližná I; Fig. 3) or in biotite gneiss (Bližná II; Černý 2004), both cropping out in the abandoned graphite mine Václav. The pegmatites contain abundant tourmaline, but they differ in abundance and composition of some major to accessory minerals: Bližná I – $plagioclase_{An0-27}$, diopside, titanite, calcite and bastnaesite-(Ce); Bližná II (underground outcrop) – muscovite, $plagioclase_{An0-18}$, spessartine, niobian rutile, manganocolumbite and manganaxinite; Bližná II (surface outcrop) – $plagioclase_{An0-33}$, dumortierite and thortveitite. Accessory rutile and fluorapatite are common at both outcrops the Bližná II pegmatite. Tourmaline (schorl-elbaite-liddicoatite, uvite-dravite) from Bližná I is typically Ca-enriched (0.26-0.79 apfu Ca; Fig. 4). Tourmaline from the surface outcrop at Bližná II is similar to Bližná I showing Ca-rich dravite and rare schorl and olenite (0.02-0.48 apfu Ca; Fig. 4).

Ca-poor tourmaline (dravite and schorl-elbaite; 0.00-0.04 apfu Ca) from the underground outcrop at Bližná II exhibits the composition similar to zoned elbaite pegmatites in the Moldanubicum disregarding their host rocks (Novák and Povondra 1995, Novák et al. 1999, Novák 2000).

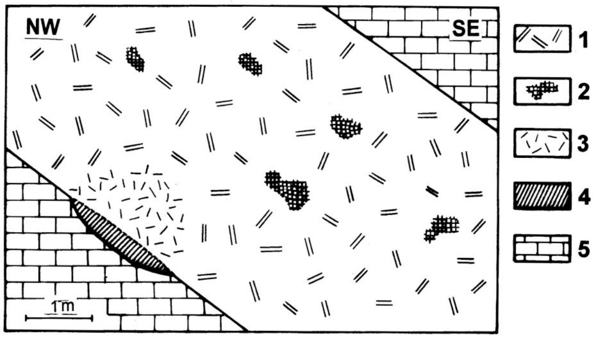

FIGURE 3. Cross section through the elbaite pegmatite Bližná I; 1 – pegmatite with schorl; 2 – pegmatite with elbaite-liddicoatite; 3 – pegmatite with elbaite-uvite-dravite; 4 – tourmaline-rich contact zone with uvite-dravite-elbaite; 5 – marble; (Novák et al. 1999).

The chemical composition of tourmaline (Fig. 4) and plagioclase as well as presence of some accessory minerals at both pegmatite dikes from Bližná suggest PRE contamination documented by Ca-rich tourmalines, dravite and thortveitite in the pegmatite enclosed in gneiss (Bližná II) and common Ca-rich tourmaline, diopside, titanite, calcite and accessory bastnaesite-(Ce) in the pegmatite from marble (Bližná I). REE, Ca, Mg and CO_2 were very likely derived from the carbonatite-like marble body rich in Mo (1930 ppm), Nb (75 ppm), REE (915 ppm) (Drábek et al. 1999), underlying the rock complex with both pegmatite dikes. Similar carbonatite-like marbles were also found at other localities in this region (Houzar and Novák 2002). The POE contamination in situ was very likely weak to minor because of almost entire absence of reaction zones between the Bližná I pegmatite and marble, and particularly between the Bližná II pegmatite and gneiss. Occurrence of Ca-rich minerals at the surface outcrop at Bližná II, although this pegmatite body is completely hosted in biotite gneiss, also strongly supports this idea. The units with different mineral assemblages and chemical composition of the relevant minerals (tourmaline) at Bližná I (compare units with schorl and elbaite-liddicoatite versus the unit with elbaite-uvite-dravite; Fig. 3), and at Bližná II (compare the surface outcrop versus underground outcrop) suggest that homogenization of contaminated melt is poor at both pegmatite dikes relative to the contaminated zoned elbaite pegmatite from Vlastějovice (see above).

e) Complexly zoned, lepidolite-subtype pegmatite dikes (Kf>Qtz>Ab>Msc~Lpd), 2 to 8 m thick, cut serpentinite commonly with narrow reactions rims at the localities Nová Ves near Český Krumlov and Radkovice. They exhibit textural and mineralogical features typical for lepidolite pegmatites elsewhere and contain abundant tourmaline (schorl-elbaite-rossmanite; Selway et al. 1999, Novák 2000). Low to moderate concentrations of Mg were found in biotite and tourmaline from outermost pegmatite zones (Novák 2000, unpubl. data of the author). Disregarding Mg-rich host rock, no indications of evident POE contamination in situ by Mg were found, and potential PRE contamination is not possible to reveal.

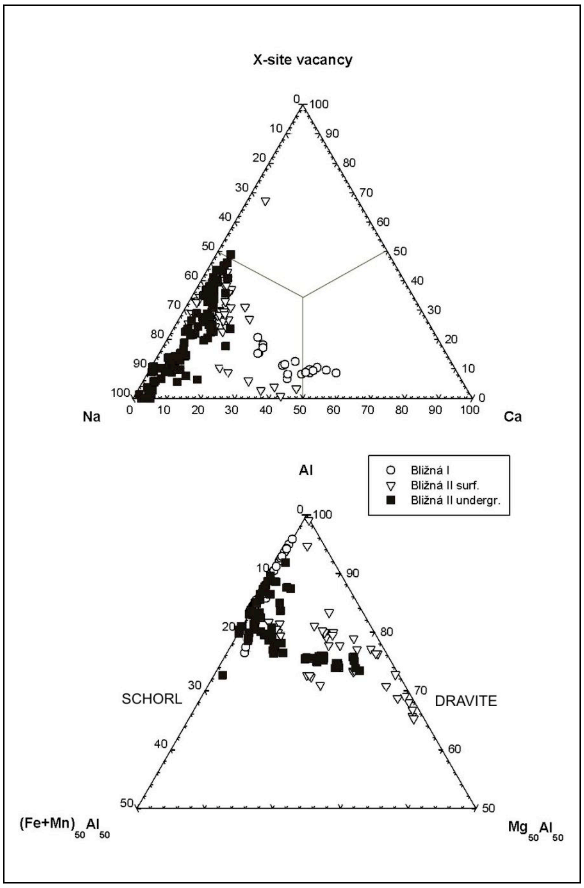

FIGURE 4. Tourmaline composition from the pegmatites at Bližná; (Novák et al. 1999, Černý 2004).

DISCUSSION

Participation of PRE contamination is very complicated to reveal. However, the mineral assemblages in the elbaite pegmatites from Bližná chiefly occurrence of Ca-rich tourmalines, diopside, bastnaesite-(Ce) at the pegmatite Bližná I hosted in ordinary marble, and Ca-rich tourmaline and thortveitite at the pegmatite Bližná II, hosted in biotite gneiss manifest quite clearly that PRE contamination from underlying carbonatite-like marble may have produced such minerals. At the other examined localities, PRE contamination was uneasy to detect due to absence of minerals with such unusual composition like bastnaesite-(Ce) at Bližná I or Ca-rich tourmalines in the pegmatite enclosed in Ca-poor gneiss (Bližná II). Zoned internal structure and absence of reaction rims at the contaminated elbaite pegmatite from Vlastějovice (see Fig. 2) indicate strong homogenization of the contaminated melt; hence, the PRE contamination from Fe-skarn very likely prevails over the POE contamination in situ from the same Fe-skarn.

The POE contamination was documented at many localities. It is strong at primitive, homogeneous pegmatites in Vlastějovice, moderate at simply zoned tourmaline-bearing pegmatite from Vlastějovice, and it seems rather negligible if any at the zoned, highly evolved Li-rich, lepidolite pegmatites from Nová Ves near Český Krumlov and Radkovice. Absence of POE contamination was found also at the complex pegmatite Tanco, Manitoba, Canada interpreted from the composition of columbite-tantalite occurring near host amphibolite (see Van Lichtervelde et al. 2006), whereas a weak contamination of outermost pegmatite unit is suggested from compositions of tourmaline and Nb,Ta,Ti-oxide minerals by several authors (e.g., London et al. 1996, Tindle et al. 2002). Nevertheless, any evidences that the elevated concentrations of Mg, Ca and/or Ti in these minerals are controlled by POE contamination in situ and not by PRE contamination were not discussed. The elevated contents of Mg and Ti were found in tourmaline from outermost pegmatite units of zoned lepidolite pegmatites in the Moldanubicum; however, any relation to the chemical composition of the host rock varying from serpentinite through calcite and dolomite marbles to biotite gneiss was observed (Novák 2000, unpubl. data of the author).

CONCLUSIONS

The examples described above show evidences that both PRE contamination and POE contamination occurred in the granitic pegmatites examined.

To reveal participation of both PRE and POE contaminations, detailed study of chemical composition and distribution of the relevant minerals within a pegmatite body, and reaction rims with host rocks and rock xenoliths are required. Absence or scarcity of reaction rims at many localities of highly evolved (commonly Li-bearing) pegmatites in the Moldanubicum as well as zoned internal structure indicates that POE contamination was weak to negligible. Consequently, PRE contamination of some contaminated pegmatites is very likely more common but largely overlooked.

The factors controlling the degree of PRE contamination include chiefly mechanical properties and reactivity of rocks building chanellways, and distance and velocity of pegmatite melt propagation. The factors controlling degree of POE contamination involve difference in T between pegmatite melt and host rock (time for exchange of matters), contrasting composition and reactivity of host rock, internal structure and thickness of the pegmatite.

This work was supported by the grant MSM 0021622412.

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