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Granitic pegmatites and mineralogical museums in Czech Republic

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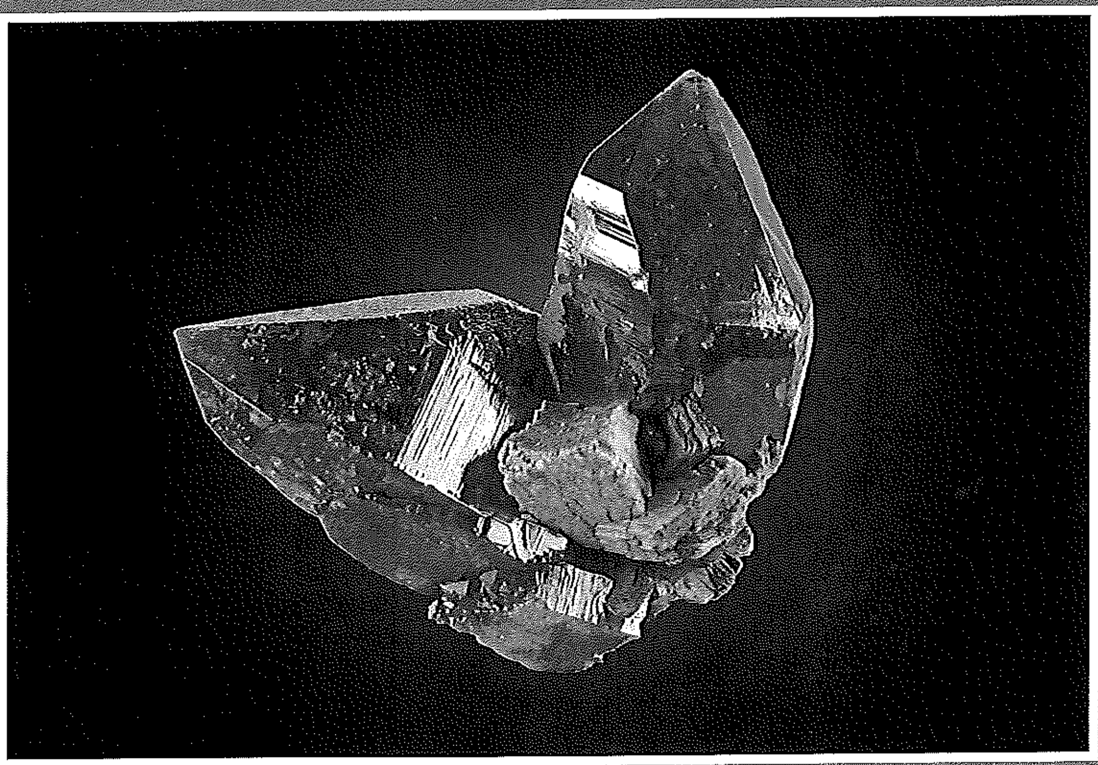

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pegmatite crosscutting muscovite granite → hydrothermal activity – quartz veins with Sn-mineralization, albitization II (very low concentrations of P).

High concentrations of B and P, moderate concentration of Li and mostly low concentration of F in various granitic rocks are of magmatic origin. The relative effects of metamorphic processes on the composition of the individual minerals of the orthogneiss, however, remain an open question. Refractory tourmaline likely underwent minor or negligible compositional changes, whereas muscovite and biotite compositions were probably reset by subsequent metamorphism. The other rocks are not affected by metamorphism, consequently, they may exhibit original magmatic compositions. Tourmaline, micas and other minerals suggest only low to moderate activity of F, but high activity of B (tourmaline, dumortierite), high activity of P (abundant primary phosphates, high P_2O_5 in garnet and in feldspars) and locally high activity of Li (triphylite, elevated Li in some tourmaline and micas). Nevertheless, the degree of fractionation *e.g.*, Fe/(Fe + Mn), Nb/(Nb + Ta) are generally low to moderate. High Fe/(Fe + Mn) values chiefly in garnet may have been controlled by the crystallization of abundant early Mn-rich apatite, which exhausted the major part of Mn from the melt and the associated garnet does not attains high Mn-content, as it is common in evolved pegmatite.

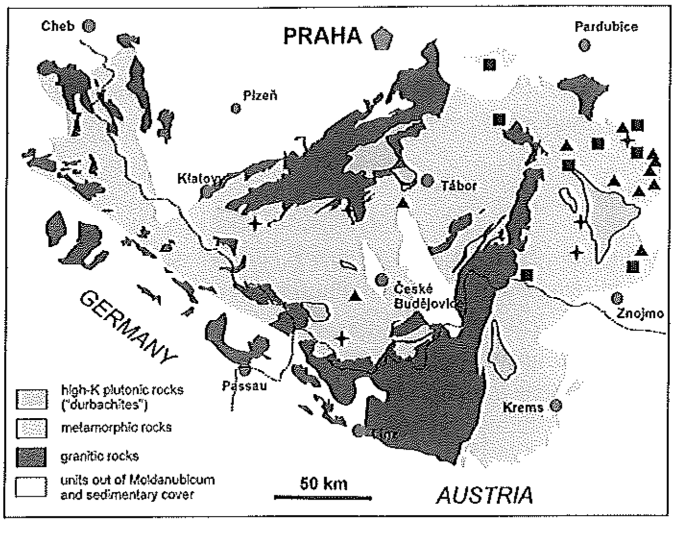

Fig. 6.1. Schematic geological map of the Moldanubian Zone with major occurrences of contaminated pegmatites, crosscutting skarns (squares), serpentinites (triangles) or marbles (stars).

3.6 Field stop 6: Vlastějovice near Zruč nad Sázavou – Contaminated anatectic pegmatites and tourmaline-bearing granite-pegmatite system cutting Fe-skarn

(Milan Novák & Tomáš Kadlec)

3.6.1 Introduction to contaminated pegmatites in the Moldanubian Zone

Contamination from a host rock is a common feature of many granitic pegmatites. It is evident particularly in those pegmatites, which are enclosed in rocks with contrasting chemical composition (*e.g.*, Martin-Izad *et al.*, 1995; Novák *et al.*, 1999c; Ackerman *et al.*, 2007; Novák, 2007), nevertheless, low degree of contamination of pegmatite melts is likely in most pegmatites (Novák, 2007). Contamination may generally proceed in three distinct stages (Novák, 2007): (i) Pre-emplacement stage (PRE) – contamination of pegmatite melts proceeded during their propagation from fertile granite to the place of pegmatite solidification; (ii) Post-emplacement stage (POE) – contamination of pegmatite melt from host rock *in situ*; (iii) Hydrothermal (subsolidus) stage – an alteration of a solid pegmatite by fluids infiltrating from host rocks largely after thermal and fluid re-equilibration of pegmatite and host rock. The pre-emplacement and post-emplacement contaminations may generally involve the following major mechanisms: assimilation (dissolution) of fragments of solid rocks in pegmatite melt followed by more or less perfect homogenization of such contaminated melt, and infiltration (diffusion?) of fluids from host rocks into pegmatite melt.

Granitic pegmatites in the Moldanubian Zone are very illustrative to demonstrate contamination of granitic pegmatites because they quite commonly cut rocks with highly contrasting chemical compositions. Pegmatites cutting serpentinite with evident Mg- and minor Ca-contaminations are the most abundant. They commonly form small bodies with thick reaction rims composed of anthophylite, actinolite, phlogopite, chlorite and/or vermiculite. Oligoclase is a dominant mineral in these pegmatites, whereas quartz and chiefly K-feldspar are minor, rare to absent. Quartz is commonly at least partly dissolved or replaced by clay minerals (*e.g.*, Dosbaba & Novák, 2007). Additional primary minerals include biotite, cordierite, and tourmaline – all typically Mg-rich. Widespread late hydrothermal alteration processes produced prehnite, scapolite, carbonates, clay minerals and zeolites (see Table 1). Typical localities of contaminated pegmatites include beryl-columbite pegmatites Věžná I and II, and barren pegmatites Drahonín and Utín, all from western Moravia, and Stupná, southern Bohemia (Novák et al., 2003; Novák, 2005; Dosbaba & Novák, 2007). Pegmatites cutting dolomite and calcite marbles with evident Ca- and Mg-contaminations are less common and the degree of contamination is commonly lower as compared to that in pegmatites from serpentinites. Reaction rims between pegmatite and host marble, if present, are usually thin and include diopside, tremolite, grossular, epidote, vesuvianite, and/or wollastonite. The most interesting locality contaminated by carbonate rocks is elbaite pegmatite Bližná I near Černá v Pošumaví, southern Bohemia with Ca,Mg-rich elbaite, dravite, uvite, diopside, andesine, titanite, allanite–dissakisite and primary bastnaesite (Novák *et al.*, 1997a, 1999c; unpubl. data of the authors). Pegmatites cutting Fe-skarn with Ca-, Fe-, F- and REE-contaminations are also quite common and they are known from several localities such as Rešice and Líšná, western Moravia and chiefly from Vlastějovice nad Sázavou, central Bohemia (Vavřín, 1962; Žáček *et al.*, 2003; Ackerman *et al.*, 2007; Kadlec, 2007; Novák, 2007), where well-exposed, numerous pegmatite dikes with dominant oligoclase, amphibole, biotite, fluorite, and allanite, and less common tourmaline-bearing pegmatites occur in a large quarry. Barren pegmatites typically exhibit much higher degree of contamination as compared to more evolved beryl and complex pegmatites (Novák, 2007). Representative occurrences of contaminated pegmatites in the Moldanubian Zone are given on Fig. 6.1 to manifest their distribution and abundance within the Moldanubian Zone.

Tourmaline-bearing granite-pegmatite system at Vlastějovice represents a unique example, where pegmatites are derived directly from their fertile granite and they are moderately contaminated from host Fe-skarn. Amphibole-bearing pegmatites of anatectic origin, abundant in Fe-skarn, are discussed in contrast to demonstrate their higher degree of contamination. Chemical compositions of selected minerals – indicators of contamination – from both types of contaminated pegmatites are briefly discussed as well as the geological position of the pegmatites.

3.6.2 Geological setting

The locality Vlastějovice is situated in the Ledeč-Chýnov belt of Variegated Group (Drosendorf terrane), Moldanubian Zone (Fig. 6.2). Dominant two-mica to locally migmatized biotite-sillimanite gneisses contain common intercalations of amphibolite, pyroxene gneiss, quartzite, marbles, and common two-mica tourmaline-bearing orthogneisses. Several lenticular bodies of Fe-skarns, up to several tens m thick and several hundreds m long, occur in the NE–SW trending synclinal structure at Vlastějovice. Small bodies of leucocratic granites and simple tourmaline-bearing pegmatites with garnet (*e.g.*, Březina, Nosatá skála; Kadlec, 2007) are common in this region as well. The Fe-skarn body is highly heterogeneous and consists of: skarn *s.s.* – monomineralic massive garnetites and banded garnet-clinopyroxene (andradite-grossular + hedenbergite-diopside + magnetite ± allanite); clinopyroxene-garnet-epidote rock; lenses of massive magnetite, up to several m thick; and minor hybrid rock (hastingsite + almandine + biotite + quartz + K-feldspar + plagioclase) located between Fe-skarn and surrounding gneisses. These Fe-skarns were regionally metamorphosed at the conditions $T \approx 590$–680 °C and $P \approx 4.5$-6.5 kbar corresponding to the main Variscan metamorphic event (Žáček, 1997).

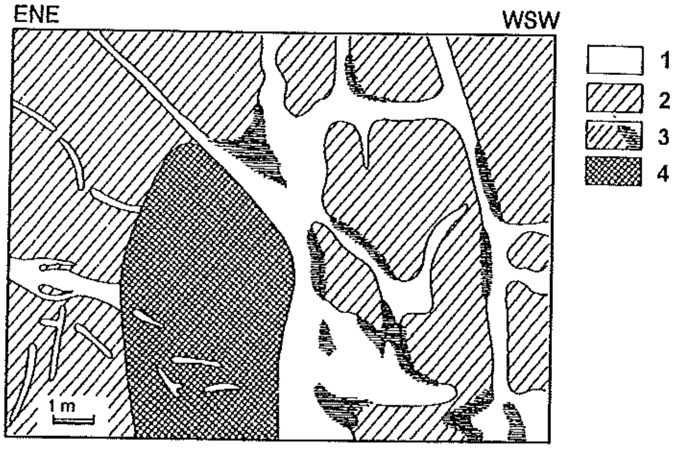

Fig. 6.3. Amphibole-bearing pegmatites cutting Fe-skarn.
1 – amphibole-bearing pegmatite, 2 – Fe-skarn, 3 – contact rock with abundant hornblende, 4 – massive magnetite (from Novák & Hyršl, 1992).

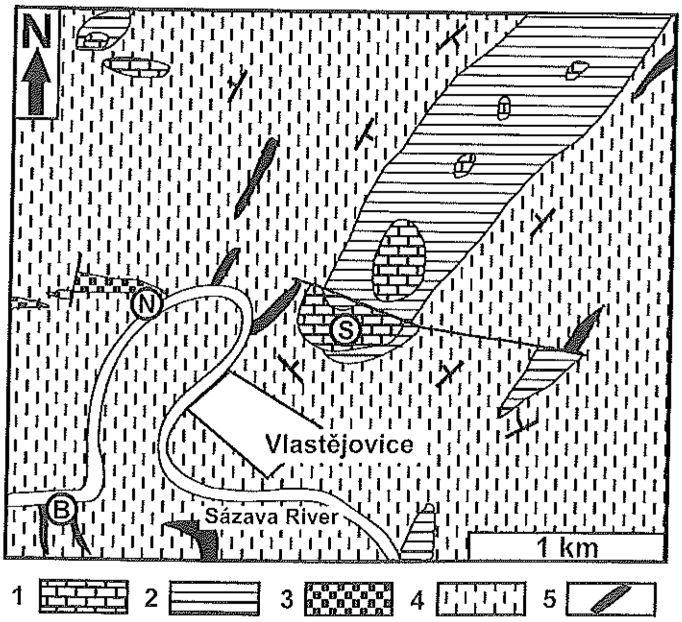

Fig. 6.2. Geological sketch of the Vlastějovice region.
1 – Fe-skarn, 2 – orthogneiss, 3 – calc-silicate rock, 4 – biotite paragneiss, locally migmatized, 5 – amphibolite. B – Březina, N – Nosatá skála, S – Holý vrch (modified from Koutek, 1950).

3.6.3 Amphibole-bearing pegmatites and the tourmaline-bearing granite-pegmatite system

Two principally distinct types of pegmatites were distinguished at the Vlastějovice region (see Žáček *et al.*, 2003; Ackerman *et al.*, 2007; Kadlec, 2007). ***Amphibole-bearing pegmatites*** (Plg_{An0-35} > Qtz > Kfs) form numerous (up to about 100) dikes and complicated bodies (Fig. 6.3), from 10 cm to 1 m thick, with homogeneous to subhomogeneous internal structure. They cut Fe-skarn and have not been found outside of the skarn body including hybrid rock on the contact. Coarse-grained pegmatites locally contain abundant amphibole, fluorite, biotite, hedenbergite, garnet, accessory allanite-(Ce), titanite and very rare ferroaxinite as the only B-bearing mineral. Monomineralic grey quartz forms locally irregular masses and veins located along the contact with host skarn and enclosing its fragments. Abundant reaction rims (Fig. 6.3), up to 30 cm thick, consist of dominant amphibole and locally also fluorite, biotite, and

Ca-rich plagioclase$_{An6-35}$ as compared to Ca-poor plagioclase$_{An0-20}$ from the central portions of pegmatite (Ackerman *et al.*, 2007). Allanite, hedenbergite, garnet, epidote, calcite, wollastonite, magnetite, chlorite, prehnite, apophyllite and pyrite occur in minor amounts in marginal parts of pegmatite dikes or as products of late hydrothermal processes and/or contamination (Vavřín, 1962; Žáček & Povondra, 1991; Novák & Hyršl, 1992; Žáček *et al.*, 2003).

Tourmaline-bearing pegmatites form rare dikes, 20 cm to 4 m thick, with homogeneous to simply zoned internal structure, cutting Fe-skarn and also biotite and pyroxene gneisses at the Vlastějovice region. They contain minor to accessory biotite, tourmaline, fluorapatite, whereas primary muscovite and garnet (except the spessartine dike) were found only in the pegmatite bodies hosted in gneisses. The pegmatites enclosed in Fe-skarn locally have very thin reaction rims, 1 mm to commonly 1–3 cm thick, with amphibole and less commonly also with biotite, garnet, fluorite and allanite. They are members of the granite-pegmatite system represented by ***footwall granite*** (Fig. 6.4) and several tourmaline-bearing pegmatite dikes (about 15 dikes were observed during the last 25 years). Granite body occurs along the footwall contact of the Fe-skarn body and underlying orthogneiss as a tectonically broken dike, about 200-250 m long and up to ~6 m thick in current outcrops (Fig. 6.5). It texturally evolves from medium- to coarse-grained and locally porphyric granite to coarse-grained granite with large blocks of K-feldspar, locally up to 30 cm in size. Accessory tourmaline is locally present. Footwall granite evidently generated several pegmatite dikes (Fig. 6-6.4) varying from texturally and mineralogically simple dikes (Kfs ≈ Qtz > Plg_{An0-31}) with rare tourmaline and locally amphibole, biotite and chlorite (**dikes No. 12 and** 4) to more evolved ***spessartine pegmatite***. It forms a zoned dike, up to 0.5 m thick and ~20 m long, mined out in 2008. It consists of dominant coarse-grained unit with locally developed graphic unit, blocks of K-feldspars, small quartz core and fine-grained albite locally with small masses of fluorite and several accessory minerals. The most evolved ***elbaite pegmatite***, which occurred in the western part of the Fe-skarn body and was very likely derived from footwall granite, was completely mined out in mid 1980s. This pegmatite dike, up to 2 m thick, exhibited simply zoned internal structure with fine- to medium-grained outer zone, coarse-grained inner zone with abundant graphic intergrowths (quartz + K-feldspar, quartz + tourmaline), blocky K-feldspar, albite and rare pockets with red elbaite, bavenite and datolite (Čech, 1985).

Very rare crosscutting dikes of amphibole-bearing and tourmaline-bearing pegmatites found recently confirmed that highly contaminated amphibole-bearing pegmatites crystallized earlier. Based on the detailed study of fluid inclusions and geological constraints (geothermal gradient, haplogranite solidus with 4.5 wt% B_2O_3, feldspars thermometry), Ackerman *et al.* (2007) suggested the following conditions for the amphibole-bearing and elbaite pegmatite formations: H_2O-CO_2 low salinity fluids (H_2O–CO_2 / N_2–H_3BO_3–NaCl fluids); P = 4.0–5.8 (3.1–4.3) kbar; T = 600–640 (500–570) °C (elbaite pegmatite in parentheses). The host rock temperature during elbaite pegmatite emplacement was estimated at ~300 °C. The P estimated for the elbaite pegmatite is slightly higher as compared to the complex pegmatites in the Moldanubian Zone, where presence of primary petalite and locally abundant andalusite suggests P < ~3.0 kbar (Novák, 2005).

3.6.4 Mineralogy

In order to demonstrate evident differences in contamination between amphibole-bearing pegmatites enclosed exclusively in Fe-skarn and tourmaline-bearing pegmatites cutting both Fe-skarn and gneisses, we focused on the chemical composition of the individual minerals (tourmaline and garnet) as well as overall mineral assemblages.

3.6.4.1 Amphibole-bearing pegmatites

Their mineral assemblages involve along with major oligoclase to andesine, quartz and locally K-feldspar and the following minor to major primary minerals – **amphibole > fluo-**

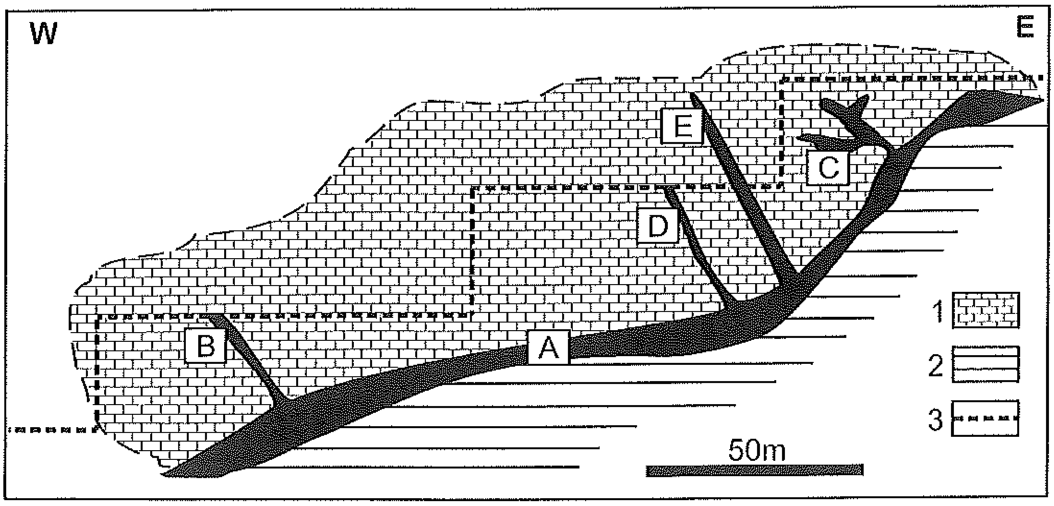

Fig. 6.4. Idealized section through the Fe-skarn with footwall granite and tourmaline-bearing pegmatites.
1 – Fe-skarn,
2 – orthogneiss,
3 – quarry floor levels,
A – footwall granite,
B – dike no.4,
C – dike no.12,
D – spessartine pegmatite,
E – elbaite pegmatite.

Fig. 6.5. Spessartine pegmatite derived from the footwall granite, cross-cutting the Fe-skarn body. Pegmatite dike thickness is ~50 cm.

rite > biotite > hedenbergite > andradite–grossular ≈ allanite ≈ epidote ≈ titanite ≈ calcite ≈ magnetite. Black to green-black amphibole as euhedral to subhedral phenocrysts, up to ~10 cm in size, and massive, coarse-grained aggregates, which belong to **hastingsite** (potassic to potassian) to **edenite** showing Fe^{3+} > ^{VI}Al (Fe^{3+} 0.70–1.07 apfu, ^{VI}Al = 0.18–0.30 apfu), high X_{Fe} (0.84–0.72), and highly variable ^{A}K (0.23–0.66 apfu) and ^{A}Na (0.22–0.41 apfu). Moderate F (0.69–0.72 wt%; 0.35–0.37 apfu) and 1.61–1.72 wt% H_2O (1.74–1.85 apfu OH; Žáček & Povondra, 1991) are typical. Subhedral to euhedral crystals of yellowish-brown **titanite,** ≤ 10 mm in size, occur in black hastingsite and fluorite chiefly from reaction zones between pegmatite and skarn. Titanite is Al-rich wt.% (7.81–9.75 wt% Al_2O_3, ≤ 0.31 apfu) and contains also elevated Fe ≤ 1.71 wt% of FeO = 0.05 apfu; 1.59 wt% F (0.16 apfu) and 0.74 wt% H_2O (0.16 apfu OH) (Vrána & Mrázek, 1985; unpubl. data of the authors). Abundant dark violet, purple to rare colourless **fluorite** forms coarse-grained aggregates, up to several dm in size, in pegmatite or in the exocontact zone. Fluorite locally predominates over quartz and feldspars. It is closely associated with allanite with deep violet to black rims around allanite grains. Ackerman (2005) presented REE-geochemistry and fluid inclusions study and suggested that fluorite crystallized under magmatic-hydrothermal transition conditions. Quite common **allanite-(Ce)**, present in amphibole-bearing pegmatites and host skarn, is often replaced by secondary fluorocarbonates (*e.g.*, **bastnaesite**).

3.6.4.2 Tourmaline-bearing pegmatites

Mineral assemblages of tourmaline-bearing pegmatites are very different from that of the amphibole-bearing pegmatites except for the presence of quartz, plagioclase, K-feldspar, and biotite. Also several very rare accessory minerals (fluorite, titanite, amphibole, allanite), occurring in minor to major amounts in amphibole-bearing pegmatites, are present in tourmaline-bearing pegmatites. Along with tourmaline and biotite, simple pegmatites contain accessory **fluorapatite, zircon, rutile, titanite, monazite-(Ce), xenotime-(Y), allanite-(Ce), arsenopyrite** and **pyrite**, whereas **uraninite, cassiterite, niobian rutile, Sn-rich titanite**, a gadolinite–hingannite related mineral close to **minasgeraisite** and **Y-rich milarite** are known only from the spessartine pegmatite. Tourmaline (**schorl** to **elbaite**) is a typical minor mineral along with rare primary **danburite, annite** and accessory **magnetite, fluorite, zircon, pyrochlore-group minerals** and **manganocolumbite** in the elbaite pegmatite. Late **datolite** and **bavenite** were found in pockets associated with red elbaite, albite, K-feldspar and quartz. Tourmaline and garnet, accessory to minor minerals in pegmatites cutting Fe-skarn and associated gneisses, were selected to demonstrate the degree of contamination in tourmaline-bearing pegmatites.

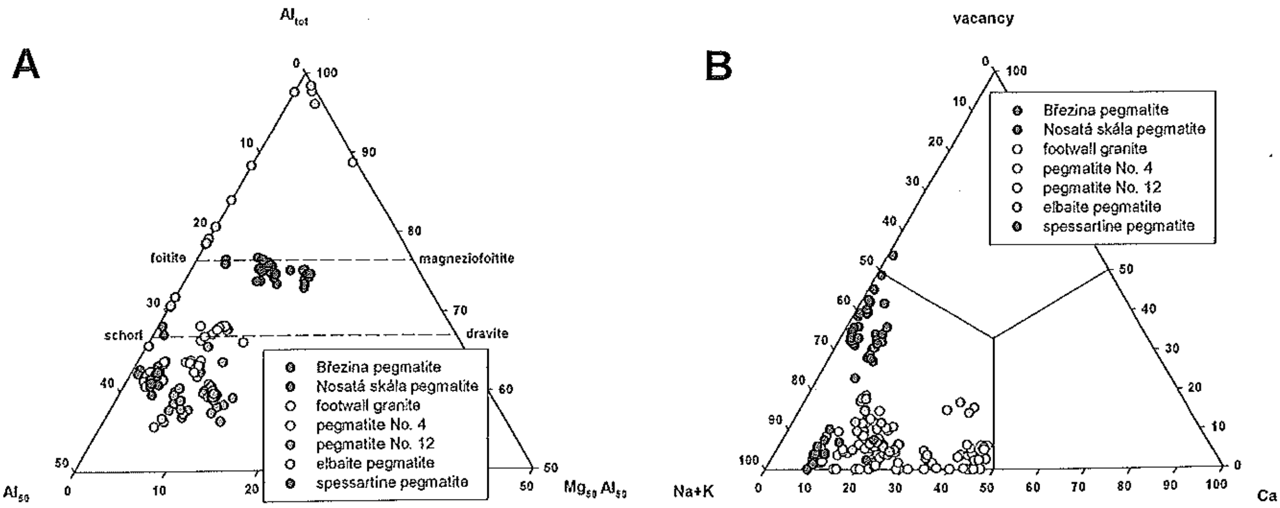

Fig. 6.6. Compositional diagrams of tourmaline from pegmatites of the Vlastějovice region.
A) Y + Z site occupancy (Al–Fe_{tot}–Mg); B) X-site occupancy (vacancy–Na–Ca).

Tourmaline

Tourmaline (**schorl**) from pegmatites in Fe-skarn is apparently Ca,Fe,F-enriched (0.15–0.48 apfu Ca, 2.56–2.70 apfu Fe^{2+}_{tot}, 0.22–0.47 apfu F; Fig. 6.6), whereas tourmaline (**schorl to dravite**) from pegmatites in gneisses yielded the composition 63-1.0.01–0.10 apfu Ca, 1.63–1.70 apfu Fe^{2+}_{tot}, 0.01–0.21 apfu F. The latter has evidently higher contents of Mg with Mg/(Fe + Mg) 0.219–0.521 as compared to that of tourmaline from footwall granite and two primitive pegmatites from Fe-skarn (dikes No. 12 and No. 4), with Mg/(Fe + Mg) 0.203–0.235 (Fig. 6.6), and especially to spessartine pegmatite with Mg/(Fe + Mg) 0.068–0.099 and the elbaite pegmatite with Mg/(Fe + Mg) 0.00–0.156. Also low concentrations of Mn are typical, and they increase, similarly as Fe, from pegmatites in gneiss (0.007–0.026 apfu) through footwall granite (0.023–0.036 apfu), pegmatites No. 4 and No. 12 (0.035–0.061 apfu) and spessartine pegmatite (0.108–0.130) to elbaite pegmatite with up to 0.929 apfu Mn in **elbaite**. High contents of Al (given as total Al in Y-site + Z-site + T-site) are typical for tourmaline from pegmatites from gneisses (6.469–7.040 apfu), whereas tourmaline from the other pegmatite dikes (except Li-enriched tourmaline from elbaite pegmatite) exhibits lower Al: footwall granite (6.012–6.290 apfu Al), pegmatite No. 4 (5.442–6.017 apfu), spessartine pegmatite (5.198–5.593 apfu) and pegmatite No. 12 (5.184–5.523 apfu) (Fig. 6.6). In the elbaite pegmatite extremely high variation in Al_{tot} = 4.806–8.289 apfu was found.

Tourmalines from pegmatites cutting gneisses suggest participation of the following dominant substitutions: $FeMg_{-1}$ and □OH $(NaO)_{-1}$. However, tourmalines from other geochemically primitive pegmatites in the Moldanubicum show quite different exchange vectors (*cf.* Povondra, 1981; Novák *et al.*, 2004b). Tourmalines from pegmatites cutting Fe-skarn are evidently distinct in high contents of Ca and Fe and participation of the general substitutions: CaR^{2+} $(NaAl)_{-1}$, $R^{2+}OH$ $(AlO)_{-1}$ is suggested. However, due to fine-grained intergrowths of tourmaline and Fe-chlorite found in all tourmaline-bearing pegmatites cutting Fe-skarn except for the elbaite pegmatite, determination of Fe^{2+}/Fe^{3+} by Mössbauer spectroscopy was not possible. Consequently, the above-elucidated substitutions are only approximate.

Garnet

Garnets from two pegmatites in gneisses (Březina, Nosatá skála) are quite homogeneous in the BSE images, but they are slightly heterogeneous, namely in Fe/Mn (Fig. 6.7). Garnet ($Alm_{72-63}Sps_{30-22}Prp_{8-4}Grs_{2-1}$) from the pegmatite Březina exhibits slightly decreased Mg and Ca and increased Fe along rims. Garnet ($Alm_{67-62}Sps_{35-30}Prp_{3-2}Grs_{1-0}$) from Nosatá skála is homogeneous. Garnet ($Alm_{43-35}Sps_{61-51}Prp_{1-0}Grs_{9-3}And_{2-0}$) from the spessartine pegmatite is evidently enriched in Y (0.62 wt% Y_2O_3, 0.033 apfu), whereas Sc and F are below the detection limits. The LA-ICP-MS study confirmed elevated contents of HREE (Ho, Er, Tm, Yb) and Sr in garnet from spessartine pegmatite up to 2 orders higher as compared to the pegmatites (Březina, Nosatá skála) from gneisses. Concentrations of other trace elements including LREE, are very similar.

3.6.5 Concluding remarks

Granite and pegmatite bodies closely related to Fe-skarn (footwall granite, pegmatite No. 12, pegmatite No. 4, spessartine pegmatite, elbaite pegmatite) (Fig. 6.4) represent a unique example of granite-pegmatite system, where individual small pegmatite dikes show unambiguous relationship to well-defined parts of the texturally heterogeneous parental granite body with the exception of the elbaite pegmatite mined out in about 1985. Both pegmatites from gneisses (Březina and Nosatá skála) are very likely related to the same magmatic event as granite-pegmatite system cutting Fe-skarn. Such a parental granite, however, is very small as compared to the size of potential granitic plutons fertile to granitic pegmatites as was modelled by Baker (1998) and as is commonly expect-

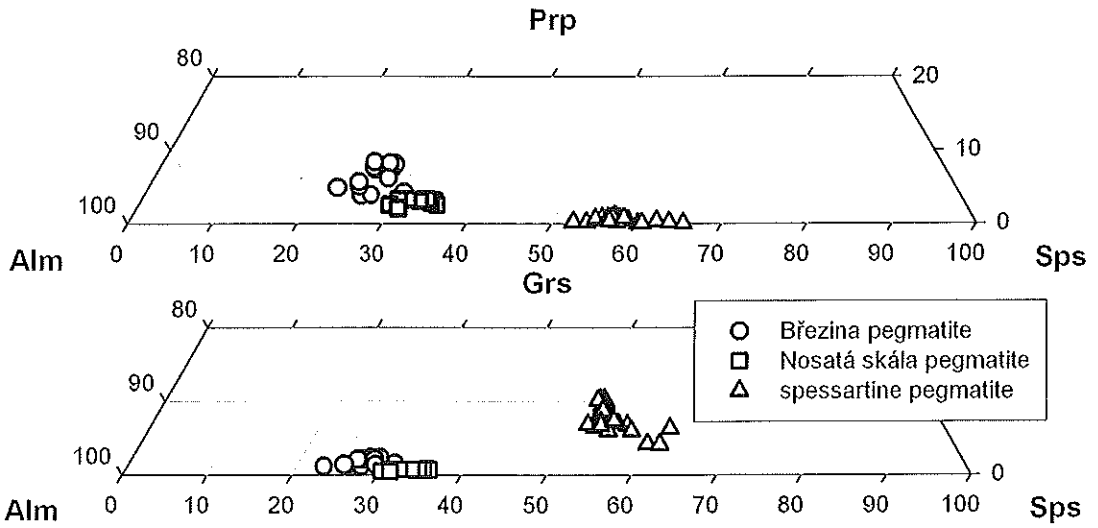

Fig. 6.7. Compositional diagrams of garnet from pegmatites of the Vlastějovice region.

ed (Černý, 1991a; Černý, 1991b; London 2008). Hence, the granite-pegmatite system in Vlastějovice is very unusual and raises the question how granites fertile to granitic pegmatites appear including their size, textures, compositions etc. (see Martin & De Vito, 2005).

Tourmaline (schorl) from pegmatites cutting Fe-skarn is apparently Ca,Fe,F-enriched, as compared to tourmaline (schorl to dravite) from pegmatites enclosed in gneisses. Their composition is comparable to that of tourmaline from other primitive pegmatites in the Moldanubian Zone (Novák *et al.*, 2004b). The chemical composition of tourmaline suggests moderate *in situ* contamination of pegmatites cutting Fe-skarn, which is evidently higher in less fractionated and differentiated pegmatite bodies (dike No. 12) relatively the more evolved to the spessartine pegmatite and chiefly to elbaite pegmatite. High degree of fractionation is indicated also by elevated Li, Mn and F concentrations. Garnet from the spessartine pegmatite is evidently Ca-,Mn-,Fe^{3+}-enriched as compared to garnets from pegmatites enclosed in gneisses, hence, both higher degree of fractionation and Ca,Fe-contamination are evident in this pegmatite. Elevated Y and REE contents as compared to garnet from the pegmatites in gneisses support also introduction of Y and REE from Fe-skarn (with common accessory allanite). Contamination demonstrated by chemical composition of minerals and mineral assemblages is evident in pegmatites cutting Fe-skarn including elbaite pegmatite. It is in contrast with fluid inclusion study (see Ackerman *et al.*, 2007), where no contamination was indicated in evolution of fluid inclusions from the elbaite pegmatite as compared to amphibole-bearing (barren) pegmatites.

Both tourmaline and garnet from the pegmatites cutting Fe-skarn are evidently Ca- and Fe-enriched (Fig. 6.6, Fig. 6.7), whereas chemical composition of tourmaline and garnet from pegmatites cutting gneisses is very similar to those from primitive pegmatites in the Moldanubicum, (tourmaline – see *e.g.*, Povondra, 1981; Novák *et al.*, 2004b; garnet – see *e.g.* Povondra *et al.*, 1987; Breiter *et al.*, 2005b).

The amphibole-bearing pegmatites with overall Ca, Fe, F-rich mineral assemblage concentrated especially along contacts of the pegmatite bodies suggest strong post-emplacement contamination *in situ* as compared to the tourmaline-bearing pegmatites. Calcium and Fe obviously come from host Fe-skarn, and F was very likely derived from early F-rich 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 in host metapelitic rocks. Ackerman *et al.* (2007) suggested, based on the fluid inclusions study and feldspars thermometry, the conditions of pegmatite crystallization at P = 4.2–5.8 kbar and T = 600–640 °C. These conditions are slightly lower than the conditions of regional metamorphism at P = 4.5–6.5 kbar and T = 590–680 °C estimated by Žáček, 1997).

3.7 Field stop 7: Myšenec near Protivín, Písek region – Tourmaline-beryl pegmatite with late Mg-rich alteration

(Milan Novák & Radek Škoda)

3.7.1 Introduction to the beryl pegmatites in the Moldanubian Zone

Beryl-bearing pegmatites with abundant tourmaline are common in the Moldanubian Zone (Fig. 7.1). Three distinct paragenetic types (all beryl-columbite subtype in the sense of Černý & Ercit, 2005) were distinguished. (i) Beryl pegmatites with common primary muscovite, accessory garnet (spessartine–almandine), apatite and columbite + cassiterite, as typical Nb-Ta-Ti-Sn oxide minerals, are randomly distributed in the Moldanubian Zone. They mostly form small bodies within the individual pegmatite districts, where complex (Li) pegmatites commonly prevail. (ii) Beryl pegmatites with rare primary muscovite, minor to accessory cordierite, apatite and niobian (tantalian) rutile and ilmenite as typical Nb-Ta-Ti oxide minerals are concentrated in two isolated regions. They contain quite a high number of accessory minerals as compared to the first type including common REE-minerals (*e.g.*, monazite-(Ce), xenotime-(Y), *písekite* – metamict mineral close to samarskite, see details below). Localities Věžná I and II, western Moravia (Černý & Novák, 1992) and chiefly localities in the Písek region, southern Bohemia represent typical occurrences of the latter pegmatite type. (iii) Beryl pegmatites with primary Be-bearing phosphates (hurlbutite) and closely related to granites of the Central Moldanubian Pluton (Novák, 1995; Cempírek et. al., 1999; Pavlíček *et al.*, 2009) are very rare.

Pegmatites from the Písek region (*e.g.*, Písek – Obrázek 1, 2, 3, Nový rybník; Údraž; Horní Novosedly; Havírky, Myšenec; (Fig. 7.2) cut migmatized gneisses and amphibole-biotite syenites of the Mehelník Massiv. Small dike-like bod-

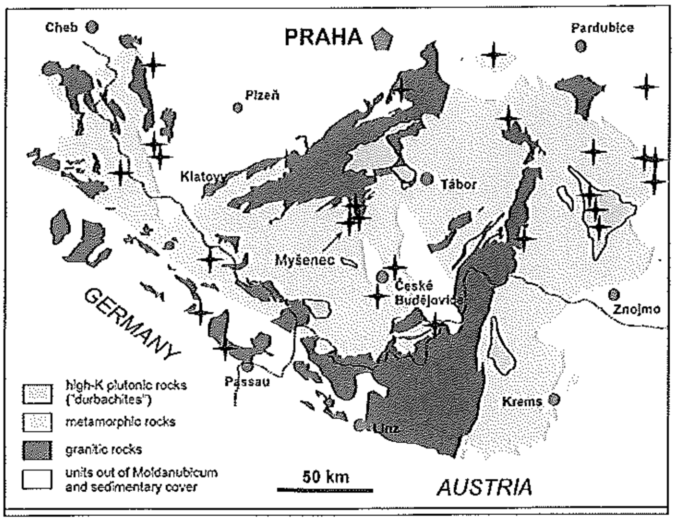

Fig. 7.1. Schematic geological map of the Moldanubian Zone with major occurrences of beryl pegmatites.