The nature and genesis of greisen stocks at Krásno, Slavkovský les area – western Bohemia, Czech Republic

Stavba a geneze greisenových pňů u Krásna n. T., Slavkovský les – západní Čechy, Česká republika

(15 figs, 3 tabs)

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Apical parts of a Li-F granite intrusion, preserved under gneiss cover at the southern margin of the Krudum Massif in the Slavkovský les area, contain greisen stocks locally bearing low-grade Sn-W mineralization. Greisen varieties pass downwards into leucocratic granite and feldspathite zones. The stocks are underlain at depth by the fresh Li-F alkali-feldspar granite, which is known as the Čistá Granite from outcrops at the present surface. Contacts of the rock types in stocks are not sharp and are partly obscured by younger alterations. The upper parts of the stocks are enriched in minor elements including Li, F, Sn, W, As, Cu, and Zn. The rock sequence in the vertical profile is interpreted as a result of a fractionation from a single parental granite magma, which became gradually enriched in volatiles, mainly water and fluorine. Fluid flow, inner differentiation of the magma as well as cooling resulted in crystallization of granite and greisen bodies. Local oversaturation led to fissure filling and, in the same time, alterations of older minerals. Barren leucogranite and feldspathite zones at depth formed apparently from the residual magma, depleted in silica. Such a model does not need to invoke highly unlikely subsolidus (post-magmatic) autometasomatic processes (e.g. albitization and K-feldspathization), which were previously thought to have completely changed the solidified granite.

Key words: Li-F alkali-feldspar granite; greisen; feldspathite; vertical zoning; Erzgebirge Mts; Slavkovský les

1. Introduction

Occurrences of tin and tungsten mineralization have been explored and exploited at the Czech and German parts of the Krušné hory/Erzgebirge Mts. for several centuries. The deposits are hosted in apical parts of strongly evolved Variscan Li-F granites, which represent final fractionation products of the magmatism belonging to the so-called Younger Intrusive Complex (YIC). To the renowned localities of this type belong Krásno, Cínovec/Zinnwald, Altenberg, Sadisdorf, Ehrenfriedersdorf, Geyer and Krupka.

At the end of the 20th century became greisen stocks at Krásno and Horní Slavkov (western Bohemia), besides Cínovec, the best-opened mines in the country. The long vertical profiles and large data set collected in course of the exploration works offer a rare opportunity to study geological setting of greisen bodies and their relation to strongly fractionated Li–F granites. This paper focuses mainly, but not exclusively, on the petrographic and geochemical development of the rocks with depth, as well as the relative role of igneous processes vs. metasomatism in the genesis of the Li–F granites and the related mineralization.

2. Geological setting

Previous work

At the Schöd stock near Krásno (Fig. 1), the exploration started in 1940's (Fiala 1950), being followed by geological mapping of the Slavkovský les Mts. (Fiala *et al.* 1962, Jarchovský 1962b, Fiala 1969) together with exploration and mining (Drozen 1969, Jarchovský *et al.* 1994). Košatka (1988) and René (1996) described the main greisen varieties. In the stock surroundings a series of boreholes "K" (Kušnír – Jarchovský 1969) and "HU" (Najman *et al.* 1988) were drilled. All these boreholes contributed to the findings of some new low-grade greisen ore bodies and brought a detailed knowledge of the hidden granite relief. At the same time, a widespread

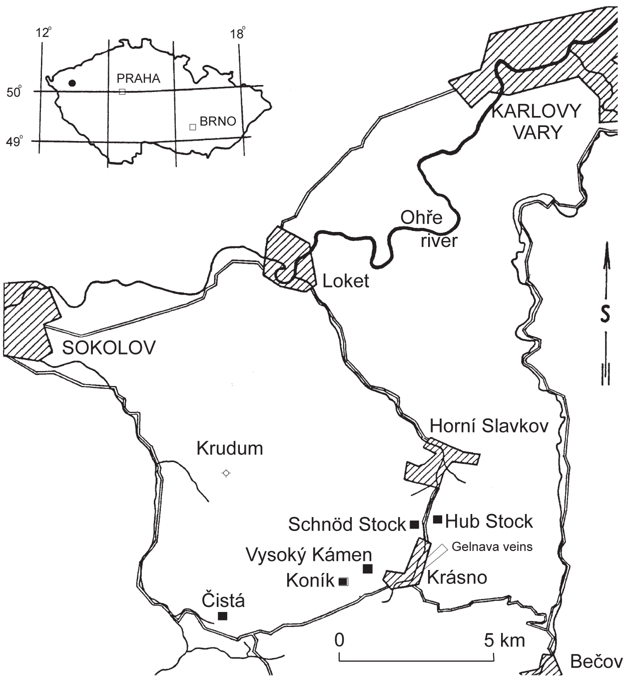

Fig. 1 The geographical position of the main localities in the northern part of the Slavkovský les area.

presence of feldspar-enriched rocks was recognized at the depth. Chemical analyses of drill cores threw light upon the behaviour of fluid components in the whole granite intrusion. Lower parts of the stocks crop out on the present surface as leucocratic granites and feldspathites at the nearby Vysoký Kámen deposit (Pácal – Pavlů 1972, 1979).

The information on economic geology and mineralogy of the Krásno area was published by Beran (1995, Beran *et al.* 1999, 2006) and Sejkora et al. (2006). Altogether there were known about 165 mineral species up to 1995, including 70 supergene minerals. During the last decade, additional minerals have been identified thanks to the use of the electron microprobe.

Geological setting of stocks

Granitoids at the Slavkovský les Mts. belong to the large granitoid batholith of Western Erzgebirge Mts. Country rocks in the northern part of the Slavkovský les Mts. consist of a series of intensively folded and migmatized gneisses, which form a large roof pendant near Krásno and Horní Slavkov. The gneisses were intruded by late-Variscan granitoids, corresponding to those from the Nejdek-Eibenstock pluton. Granitoids of the Slavkovský les Mts. were classified according to their petrographic character into three groups (Fiala 1969): a) biotite granites of the Older Intrusive Complex (OIC), b) biotite- muscovite-bearing granites as the Transitional Group, c) Li-mica and topaz-bearing granites of the Younger Intrusive Complex (YIC) including youngest alkali-feldspar granites. Lange *et al.* (1972) proposed a similar division for the western Erzgebirge Mts.

Two OIC granite composite massifs occur in the Slavkovský les area – Krudum in the northern, and Lesný-Lysina in the southern parts of the Slavkovský les area.

Krudum Massif and Krásno ore-district

The Krudum Massif (Fiala 1969, Schovánek *et al.* 1997) is a body of 50 km^2 in size, located NW of Krásno township (Fig. 2). Its central part is formed by porphyritic biotite granite of the Třídomí type (Transitional Group). This facies is surrounded by younger biotite granite (Milíře type, YIC), muscovite- and topaz-bearing. The southern rim of the Krudum Massif is built by the youngest Li-F granite (Čistá type, YIC). The latter forms a laccolith, intruded along the contact of gneisses and the Třídomí granite. The intrusion is elongated in ENE-WSW direction, dipping cca 60°, with a thickness slightly exceeding 1 km. Level contours of the granite surface beneath the gneiss cover are presented on Fig. 3.

The SE border of the Krudum massif is cut by ENE--WSW trending Vysoký Kámen fault. The western block, lifted along this fault, was eroded. Therefore, only root parts of former stocks, including Vysoký Kámen, Klinge, Koník, and Čistá, are preserved. The area to the east of the Vysoký Kámen fault (the Krásno ore-district) sunk by

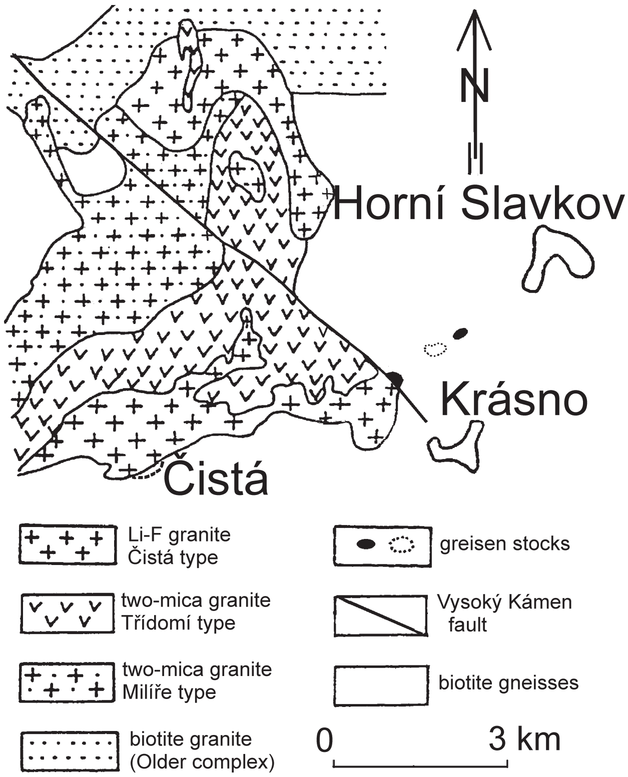

Fig. 2 Geological sketch of the Krudum Massif, Slavkovský les Mts. Modified from René (1998).

about 300–400 meters. Hence the upper part of the Li-F granite intrusion, consisting of two main and some smaller stocks, was preserved under the gneiss cover. The overlying gneisses contain several tin-bearing quartz veins, trending mostly NE-SW. Some of them, up to 50 cm thick, were mined since Middle Ages. This was the case for instance of the Gellnau vein zone (Jarchovský 1969). Beneath them, several thin quartz veinlets formed an aureole containing dispersed Sn-W-Cu-Zn minerals. Their thickness is in millimetre range; the veinlets root in the stocks and fan out into surrounding gneisses. Gneisses at their contact are altered into thin, dark mica greisen rim.

A longitudinal section (Fig. 4) outlines the geological situation. The larger Hub stock is open at its top, smaller Schnöd stock is hidden 70 metres below the present surface. Both stocks are steep elliptical cones, with diameters 450×350 m and 250×150 m. The initially rather steep upper contact slope (65–80°) flattens gradually (of 25–30°) at first at their NW extremity. Both stocks merge at the depth of 450 m a. s. l. Their contact with gneisses is mostly sharp, without any significant thermal metamorphism. Only a few centimetres thick contact aureole of biotite hornfels was formed in the surrounding gneisses; presumably due to the low temperature of the Li-F granite magma. The northern contacts of the stocks are largely tectonic as documented also by occurrences of some gneiss xenoliths enclosed in the granite. The inner structure of the cupolas is well stratified. The distribution of

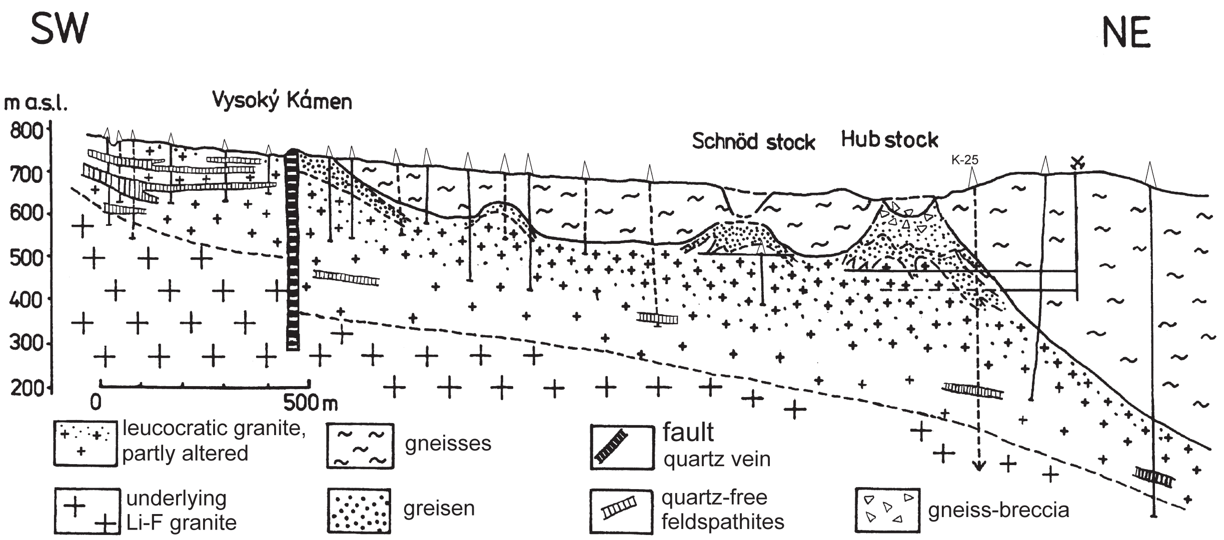

Fig. 3 Level contours (isohypses, metres above sea level) of the granite surface under the gneiss cover (adapted after Najman et al. 1988) and schematic geology of the Vysoký Kámen area, after Fiala (1962). The straight line shows position of the longitudinal cross section.(Fig. 4).

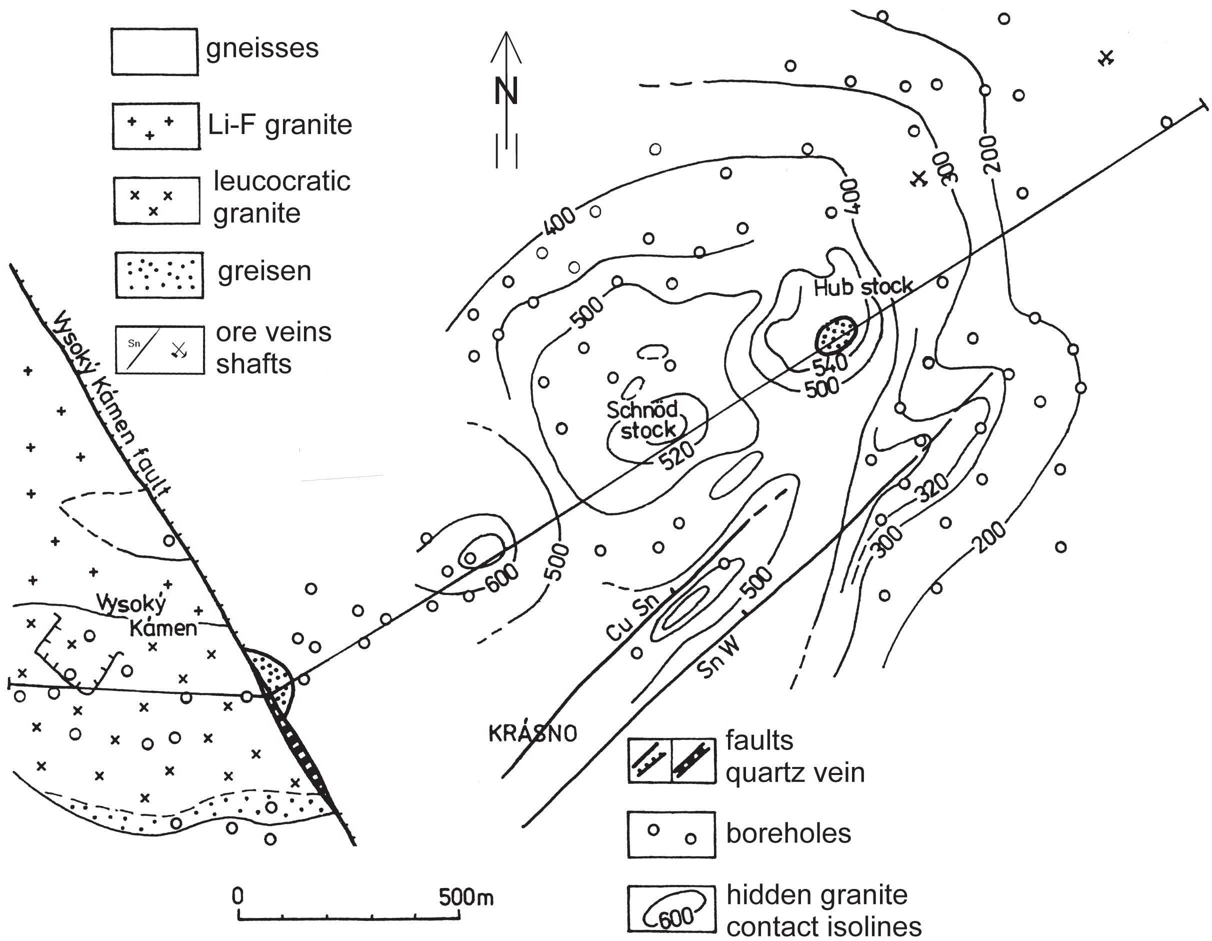

Fig. 4 Longitudinal section of the Krásno stock area (after Jarchovský et al. 1994).

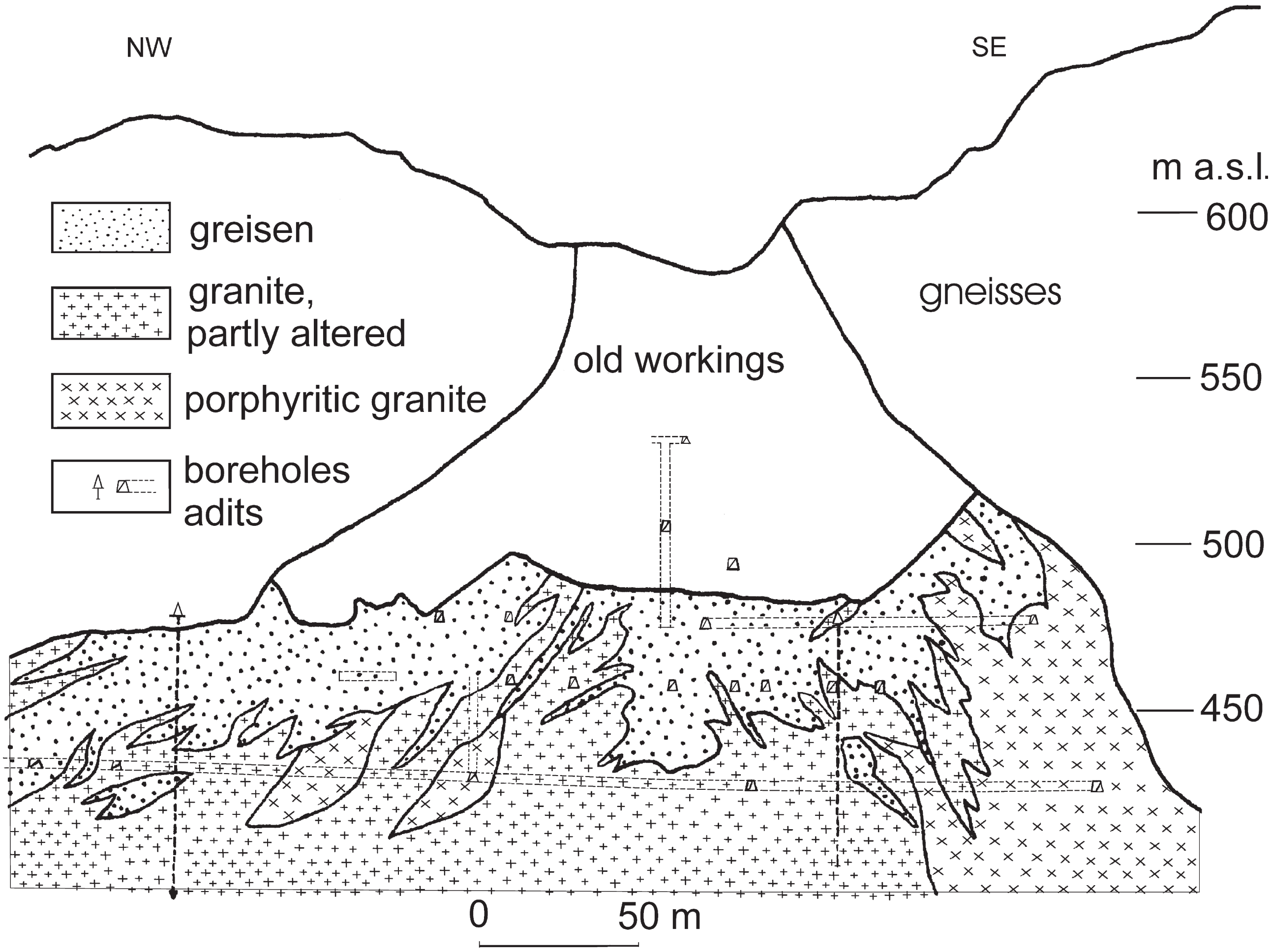

Fig. 5 Schematic section of the Hub stock.

greisen bodies and their downward transition into leucocratic granite in the Hub stock portrays Fig. 5. Porphyritic granite facies with a fine-grained matrix is developed at its northeastern contact. Vertical development of the Schnöd stock, with hidden apex almost undisturbed by old workings, is represented in Fig. 6. The upper part of the stocks was filled by massive greisen varieties, alternating deeper in the stock centres with partly or intensively altered granite. The greisen bodies are locally oriented parallel to the elongation of stocks, however, their form is usually irregular and without sharp contacts.

Profiles constructed using numerous boreholes in the neighbourhood of the stocks (Najman *et al.* 1988) show that greisen bodies in the stocks are very seldom located immediately at the gneiss contacts. In most boreholes appears a granite layer first, which is separated from gneisses by a marginal pegmatite body several cm to one-metre wide. The distances of greisen bodies from contact vary in tens of metres and their dips in vertical sections mimic the shallow dip of the contacts. About one third of boreholes contain feldspathite zones in leucocrat-

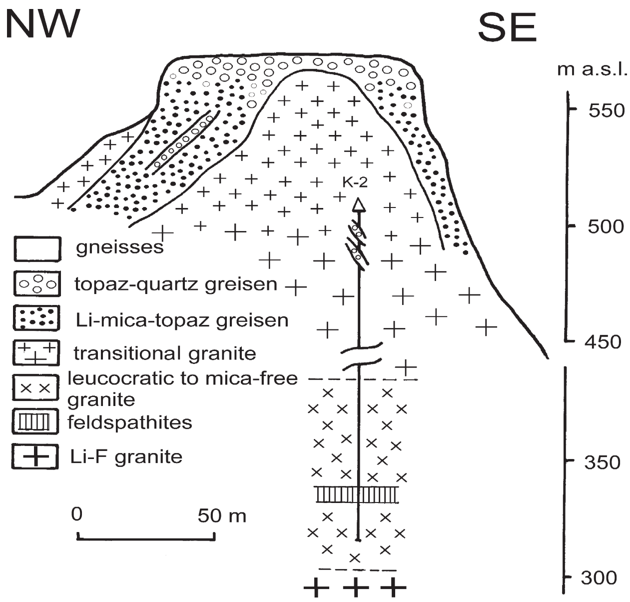

Fig. 6 Schematic section of the Schnöd stock. The top of the stock is 70 m below the present surface.

ic alkali-feldspar granite, located approximately 30–70 metres beneath the greisen bodies. Some of the feldspathite lenses are doubled, as are the greisen zones. The underlying Li-F granite was encountered only in a handful of the deeper boreholes.

3. Vertical zoning and petrography

A complete vertical profile could have been obtained from the Schnöd stock, less affected by the old mining than the Hub stock was. In turn lower parts between 475 and 425 m a. s. l. were accessible at the Hub stock. At these depths is still up to 20 vol. % of the rock altered by argillitization. Comparatively fresh lithologies were encountered mainly in boreholes. In the following paragraphs are described the main rocks types in the order, in which they appear with increasing depth; the degree of fractionation decreases simultaneously.

Early fractionation products: microgranite and marginal pegmatite (Stockscheider**)**

The first fractionation product of emplaced magma were injections of microgranite into gneisses at the Hub stock exocontact, where folded and migmatitized gneisses were converted into intrusion breccias. In these, the gneiss fragments were cemented by ore-free, quickly cooled topaz granite matrix (Jarchovský – Pavlů 1991). Gneiss fragments were at their margins altered to dark mica greisen and at a later stage cut by greisenizing quartz veinlets. Comparable brecciation is known from other localities in the Erzgebirge Mts., where the apical stock parts were preserved, as in Krupka, Geyer and Sadisdorf (Seltmann *et al.* 1988).

Another early magmatic rock is a marginal pegmatite (Stockscheider), up to a few metres thick, located at the flat stock contacts (Jarchovský 1962a). The marginal pegmatites pass gradually into fine-grained granite.

Greisens

The uppermost parts of stocks are built by greisen facies of varying grain size. The vertical extent of greisens reaches maximally 150–200 metres below the stock's top. At this depth only isolated greisen bodies formed in prevailing granite. Both rock types in this zone are locally altered (argillitized). These alterations are definitely younger than greisenization, because they affected both granite and greisen components. The alterations disappear with the increasing depth and the prevailing rock type becomes fresh leucocratic Li-mica bearing alkali-feldspar granite. Borehole profiles show gradual decline in mica content and even more conspicuous lack of quartz. Hololeucocratic granite then contains lenses of quartz-free feldspathites. An underlying Li-F granite, cropping out elsewhere as the Čistá type granite, was penetrated by some deeper boreholes. Several geological sections constructed by Najman *et al.* (1988) show greisen layers as zones up to few metres thick, located usually in a certain distance from the gneiss contact. They run parallel to it, without connection to any (vertical) supply structures. A non-invasive origin of such bodies (greisen I) formed from accumulated fluids and certain analogy with flat lying greisen zones at Cínovec-south/Zinnwald is apparent (Bolduan *et al.* 1967).

Rocks observed in stocks include some stable mineral assemblages (Table 1).

The main greisen type *Greisen I* has the association quartz-topaz-zinnwaldite (Fig. 7A). It is mostly medium-grained, only at gneiss contacts it becomes finer grained. Its modal composition is changing in the vertical profile. In the upper parts of the stock (above 530 m a.s.l.) prevails a quartz-rich facies, composed of 70–85 vol. % of quartz, 10–30 vol. % of subhedral topaz and 10–15 vol. % by zinnwaldite flakes. Quartz aggregates are formed of anhedral grains of variable size, 0.5–2.0 mm across, with streaks of fluid inclusions. Some quartz grains enclose clusters of fluid inclusions only in their centres and limpid rims are evidence of a later quartz growth or its subsequent recrystallization. Quartz contains rare tiny euhedral albite laths (0.05 mm and smaller). According to their size and perfect shape, they probably represent "armoured" relics of the primary crystallization stage, rather than a vestige of any former granite. They indicate local albite stability just at the beginning of the crystallization. At lower level (below 530 m a. s. l.) darker, micaceous greisen facies prevails. Quartz aggregates (50–75 vol. %) enclose topaz (9–23 vol. %) and zinnwaldite (15–30 vol. %). Accessory minerals in both Greisen I varieties are apatite, zircon, and brownish cassiterite.

This greisen type is locally hosting sharply-bound bodies of light-coloured *Greisen II*, which contains prevailing quartz and topaz. Besides a small amount of mica (relics of zinnwaldite) it differs by the presence of euhedral topaz and by the character of accessory minerals. Along with common chalkopyrite, dark sphalerite, and arsenopyrite occur rarer molybdenite, bornite and bismutite. Interstitial space is sometimes filled by fluorite and apatite. Greisen II was defined by Košatka (1988) on the

Table 1 Mineral assemblages in stocks.

mineral phase	main	subordinate	accessoric
marginal pegmatite	Q Or	Tp Ab Mu	Ap
greisen I	Q Tp Zi	Ap	Cs W As Sp
greisen II	Q Tp	Zi Ap Fl Chl	Chp W Sp
transitional granite	Q Tp Ab	Zi	Cs, W
leucocratic granite	Q Ab Or	Tp, (Zi)	Ap Be
feldspathites	Ab Or	Tp	Ap Be

Abbreviations: Q – quartz; Or – K-feldspar; Tp – topaz; Ab – albite; Mu – muscovite; Zi – zinwaldite; Ap – apatite; Cs – cassiterite; W – wolframite; As – arsenopyrite; Sp – sphalerite; Fl – fluorite; Chp – chalkopyrite; Chl – Li-chlorit (cookeite); Be – beryl basis of quartz grains variability. It included also local bodies of almost pure quartz greisen with accessory muscovite and other extreme monomineralic greisen types such as lenses of micaceous quartz-poor greisen, cassiterite-bearing "pockets", or topazites containing euhedral topaz and wolframite needles cemented by cookeite (Melka *et al.* 1991). Such bodies are apparently younger than the surrounding greisens, being irregular in shape and without definable tectonic elements.

Another greisen type is replacing granite at rims of the quartz veins at the Gellnau-system. It differs in structure and mineral composition. The alteration zone is a few centimetres thick, prevailing minerals are zinnwaldite, muscovite and quartz. Common feature are rectangular outlines remaining in quartz after original albites, marked by sericite and fluid inclusions. Dark greisen zones formed around quartz veins, that entered the overlying gneisses, are distinctly narrower, and are made of brown Li-mica, quartz and muscovite.

Transitional granite (free of K-feldspar)

This rock type formed as a transition between Greisen I and the underlying granitic rocks. In contrast to the common stock granite type, it does not contain K-feldspar and its structure is represented by abundance of fine albite tablets enclosed in quartz, topaz and zinnwaldite (Fig. 7B). Its composition was constrained using some rather rare, less argillitized samples. Close to the external contact with the gneiss, this rock sometimes acquires a layered structure, whereby a few centimetres thick white albite layers alternate with darker layers, dominated by quartz and mica. Layers are aligned along the exocontact and albite crystals show subparallel orientation. This phenomena can be explained as local melt enrichment in fluid during crystallization of albite (which proceeded without consumption of water and fluorine), up to certain fluorine (F/OH) level. The crystallization of albite could continue after drop of temperature and/or fluid concentration.

Transitional granite is composed of quartz (20–30 vol. %), albite (30–50 %), zinnwaldite (10–15 vol. %) and topaz (3–8 vol. %). Clay mineral and sericite (about 5–20 %) replaced former albite and topaz. Quartz forms anhedral grains, containing parallel oriented streaks of fluid inclusions, similar to those in greisen. Mica is light brownish zinnwaldite. Topaz occurs as isolated grains, which show intense argillitization along cleavage planes.

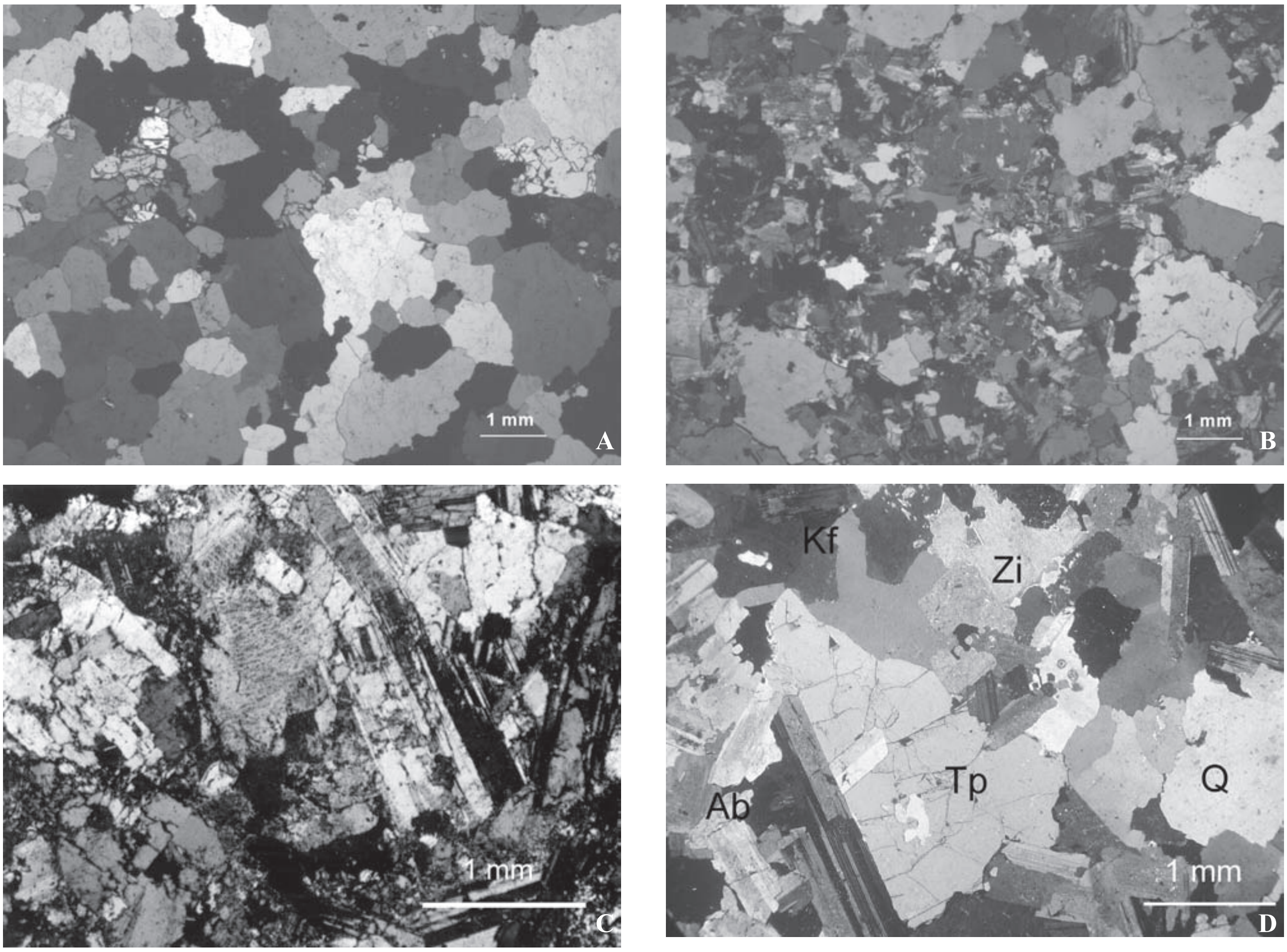

Fig 7 A – Quartz-topaz greisen, crossed polars. Hub stock, outcrop; B – small albite laths in transitional granite, crossed polars. Hub stock, 475 m a. s. l. level.; C – quartz-free feldspathite. Krásno, crossed polars. Borehole K-22, 294 m a. s. l.; D – underlying medium-grained Li-F granite, Čistá type. K-feldspar (Kf, dark), albite enclosed by topaz (Tp) = topaz, quartz (Q) colorless. Borehole Ct-2, 215 m a. s. l.

Albite ($An_{0–6}$) is present in the form of fine, thin euhedral laths, 0.3–1.0 mm long. The albite crystals show simple twinning but lack polysynthetic lamellae (Fig. 7b). Common accessories are apatite and zircon. Locally wolframite needles up to 0.1 mm long, enclosed by mica and topaz were found. The K-feldspar is absent. However, below about 450 m a. s. l. its contents increase as the Transitional granite passes gradually into the leucocratic stock-granite facies. Argillitization gradually disappears at this depth, as well.

Effects of intensive argillitization destroying feldspars and, to a large extent, topaz and mica in greisen, are concentrated where the greisen bodies alternate with Transitional granite. Argillitization is therefore considered as a younger process, accompanied by recrystallization of quartz, and not as a low-degree greisenization. Topaz both in greisen and granite is altered along cleavage planes and its rounded grains are enclosed by clay mineral and sericite. Zinnwaldite is altered in a similar way and hematite is exsolved along its cleavages. Fine-grained aggregate of clay minerals is replaced by neighbouring quartz and by apatite with fluorite or carbonate. This younger alteration stage is not accompanied by any ore mineralization.

Leucocratic granite and feldspathites

These rocks, unlike the preceding types, are comparatively fresh in boreholes in the stock neighbourhood. Prevailing type is a medium-grained granite, containing variable amount of zinnwaldite. At 450 m a. s. l. the mica disappears and granite becomes holo-leucocratic. Key information on these rock types comes from the quarry located SW of the Vysoký Kámen fault. The whole feldspar-enriched zone is 100–200 metres wide (Pácal – Pavlů 1972). The area represents actually the lower part of yet another stock, which was originally much larger than both stocks at Krásno. As confirmed by deeper boreholes, this granite facies forms a continuous horizon under the whole Krásno stock area.

Leucocratic granite from the Vysoký Kámen quarry is whitish to pinkish, composed mostly of albite (30–40 vol %, $An_{3–5}$) and K-feldspar (30–40 vol. %). The mean Ab/Or ratio is about 3:2. The remaining component is quartz (20–40 vol. %). Zinnwaldite (0–5 vol. %), muscovite, sericite and topaz are subordinate. Apatite, rutile, fluorite, opaque minerals, pink garnet and rare beryl represent accessory components.

Quartz-free feldspathites, composed almost exclusively of alkali feldspars, were described originally as metasomatic syenites (Fiala 1962). Several boreholes revealed, that feldspathite bodies form subhorizontal layers (lenses), several decimetres to tens of metres in thickness (Fig. 8). Their contact with leucocratic granite is unsharp. Proper feldspathites are white, fine- to medium-grained rocks. Besides both feldspars (in roughly balanced proportion, or with K-feldspar slightly prevailing) they contain accessory micas, topaz, apatite, rutile and opaque mineral (Fig. 7C). Monomineralic feldspathites are rare, representing probably products of inner differentiation. Variability in K_2O content is higher than that in Na_2O and both oxides are not correlated in vertical profiles. Thin sections show mutual intergrowths of both feldspars and at the granite contacts, skeletal relics of quartz. Both phenomena were originally described as products of metasomatism. However, the whole complex has a character of a magmatic system, because both leucocratic granite and feldspathites are cut by discordant pegmatoid schlieren up to 10 centimetres wide, with a shallow dip (20–40°). They are composed of large crystals of K-feldspar, quartz, and less common albite. Typical pegmatitic intergrowths structures are missing. Feldspars are apparently of low-temperature type (Barth 1969, Dietrich 1962). Brownish mica is subordinate, among accessories were observed topaz, fluorite, and apatite, with rare beryl and columbite. Rims of fine-grained quartz feldspathites have formed at the transition of these schlieren into the neighbouring granite (Pácal – Pavlů 1979). Uniform distribution of both feldspars in feldspathites, similar feldspar ratio to that in granites, and the subparallel orientation of their zones make the existence of younger albitization II questionable.

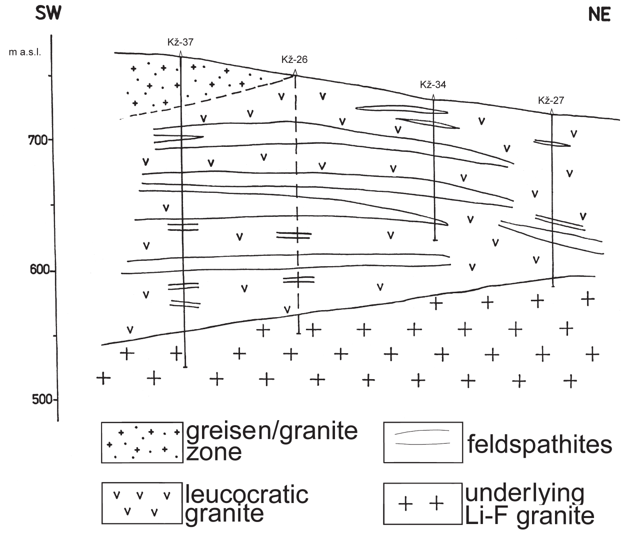

Fig. 8 Leucocratic alkali-feldspar granite and feldspathite lenses in a cross-section through the Vysoký Kámen area (according to Pácal – Pavlů 1979).

Several younger joints and faults of NW-SE direction, i.e. orientation similar to the main Vysoký Kámen fault, cut the whole rock complex. Jasper-like quartz, iron and manganese oxides, fluorite and clay minerals locally fill the fractures.

Underlying Li-F granite

The existence of Li-F granite under the leucocratic complex was first verified at the Vysoký Kámen quarry, where this granite type occurs in boreholes at the depth of 100 metres. The dip of the contact is flat to the SE, and thus this granite crops out in a distance of several hundred metres further to the NW. As a consequence, this so-called Čistá granite type (YIC), which builds parts of the Krudum Massif on the surface, is identical with the underlying Li-F granite. In the Krásno stock area, on the other hand, this Li-F granite occurs at a much deeper level of *c*. 200–300 m a. s. l. (see Fig. 4).

The Li-F (alkali-feldspar) granite is a medium-grained rock of subhedral texture (Fig. 7D). It contains quartz (25–43 vol. %), perthitic orthoclase (20–35 vol. %, triclinicity 1–20 %), nearly pure albite (21–36 vol. %, An_{3-5}), and subordinate protolithionite-zinnwaldite (3–6 vol. %). Common accessories are apatite, zircon, and fluorite; rare are cassiterite, rutile and wolframite. Topaz occurs in the form of irregular grains. Protolithionite-zinnwaldite, is somewhat darker than zinnwaldite from greisens and has lower Li_2O content (1.9 wt. %). In contrast, the beige greisen zinwaldite contains about 2.5 wt. % Li_2O.

4. Notes on mineralogy

Topaz was observed in Hub stock greisen as colourless crystals about 5 mm in size, cemented by whitish cookeite, and filling irregular lenses. Rosický (1916) studied chemical composition and optical properties of topaz from the Gellnau vein. Its composition was close to the fluorine-rich end member (F = 16.87 wt. %), with angle of optical axes 2V = 63°. According to the new measurements of 20 topaz grains from samples scattered throughout the Hub stock, its angle of optical axes varies in the range of 60–62°. There are apparently only insignificant differences in composition of this mineral.

Albite from the transitional topaz-albite granite, the feldspathites and the underlying Li-F granite contains 0–5 mol. % An, according to its optical properties. No internal zoning was observed. Albite in transitional granite and feldspathites shows simple lamellae, without polysynthetic twinning, which is on the contrary common in albite in Li-F granite.

K-feldspar occurs in two forms: a) perthitic microcline of a low triclinicity but without typical microcline cross-hatched twinning, restricted to marginal pegmatite bodies, b) non-perthitic monoclinic orthoclase found in all samples of leucocratic granite, feldspathites and pegmatoid "schlieren". The zero degree of triclinicity and 7–11 % of unexsolved albite-component were determined by X-ray methods (Pácal – Pavlů 1972). According to the geological thermometer (Ryabchikov 1965) based on the molar ratio of albite in the K-feldspar for coexisting alkali feldspars, a minimum temperature of compositional equilibration was about 500 °C. Thermobarometric data for these feldspar-bearing rocks are missing, but the strictly monoclinic structure of orthoclase in feldspathites indicates low temperatures (less than 500 °C) for its origin (Ferguson 1960, Senderov 1976, Senderov *et al.* 1981), i.e. above the hydrothermal range.

Micas are present in all rock types studied. Their composition and empirical formulae are given in Table 2. In the classification diagram (Fig. 9), data points from granites and Greisen I fall to the zinnwaldite field close to the boundary with the protolithionite domain. Compositional changes of Li-micas with the depth are depicted in Fig. 10. There is a distinct drop in Li, accompanied by an increase in F and total Fe. A distinct trend can be

Table 2 Chemical and normative composition (wt.%) of rocks from the Schnöd stock.

m a.s.l.	565	520	510	487	398	353	(300)
No.	**Schn6**	**Schn7**	**Schn8**	**K1/23**	**K1/112**	**K1/157**	**K32/554**
SiO_2	79.31	74.02	70.37	70.48	72.21	72.79	73.26
TiO_2	0.04	0.06	1.77	0.03	0.03	0.03	0.03
Al_2O_3	8.90	15.20	14.28	14.49	15.22	14.74	14.67
Fe_2O_3	1.26	0.07	0.86	1.73	0.29	0.19	0.24
FeO	2.25	2.01	3.53	1.81	0.86	0.67	0.83
MnO	0.22	0.11	0.27	0.10	0.07	0.02	0.07
MgO	0.22	0.18	0.12	0.19	0.35	0.20	0.10
CaO	0.90	2.12	0.73	2.52	1.16	1.12	0.38
Li_2O	0.31	0.37	0.66	0.61	0.22	0.10	0.20
Na_2O	0.17	0.32	0.55	1.15	3.30	4.22	3.13
K_2O	1.18	2.60	2.25	2.10	4.18	4.90	4.59
P_2O_5	0.20	0.16	0.25	0.28	0.25	0.17	0.33
CO_2	0.12	0.34	0.16	0.48	0.23	0.24	0.01
H_2O+	1.20	1.49	1.91	3.42	1.49	0.48	0.84
F	1.60	0.72	1.80	0.27	0.00	0.15	0.81
-F	0.67	0.30	0.75	0.11	0.16	0.06	0.34
Total	100.06	99.65	99.33	100.23	100.32	100.21	99.54
Qz	70.5	54.4	54.1	50.1	33.8	27.4	35.6
Or	0.0	7.7	1.0	0.0	19.9	26.3	23.3
Ab	1.5	2.7	4.8	10.0	28.2	35.9	26.8
An	3.2	9.6	2.0	11.0	4.2	4.5	0.0
Bi	9.4	5.7	7.7	9.1	4.0	2.7	3.0
Tr	5.6	6.7	12.0	11.1	3.9	1.8	3.6
Tp	9.3	12.8	14.5	7.9	5.4	0.9	7.0
Ap	0.5	0.4	0.6	0.7	0.6	0.4	0.7
Be	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Il	0.1	0.1	3.4	0.1	0.1	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Wet analyses were carried out in the laboratory of the Czech Geological Survey Prague.

Explanations:

Schn6 – quartz-topaz greisen, Schnöd stock, 6th level,

Schn7, Schn8 – transitional albite-topaz granite, Schnöd stock, 7th and 8th level respectively,

K1/23 – transitional albite-topaz granite, Schnöd stock borehole K-1,

K1/112, K1/157 – leucogranite. Schnöd stock borehole K-1,

K32/554 – underlying granite, borehole K-32.

Normative minerals:

Qz = quartz, Or = K-feldspar, Ab = albite, An = anorthite, Bi = biotite, Tr = trilithionite, Tp = topaz, Ap = apatite. Be = berlinite, Il = ilmenite.

Table 3 Chemical composition (in wt.%) and empirical formulae of Li-micas from Krásno stocks and the borehole K-25.

Loc.	Schn	Hub	borehole K-25					
m a.s.l.	**509**	**475**	**394**	**355**	**222**	**37**	**-124**	**-161**
SiO_2	43.09	43.59	42.77	43.20	40.92	39.99	39.97	38.56
TiO_2	0.29	0.07	0.44	0.43	0.59	0.53	0.53	0.77
Al_2O_3	22.82	23.65	23.15	24.86	23.94	23.10	24.70	23.52
Fe_2O_3	0.98	2.82	1.51	1.71	3.32	2.81	3.00	6.92
FeO	12.46	10.78	11.96	10.28	10.33	11.74	11.57	10.60
MnO	0.50	0.58	0.54	0.46	0.50	0.74	0.68	0.70
MgO	0.48	0.17	0.04	0.08	0.13	0.10	0.10	0.13
CaO	0.27	0.27	0.21	0.14	0.09	0.06	0.06	0.06
Li_2O	2.52	1.75	2.43	2.13	2.37	2.24	1.83	1.74
Na_2O	0.40	0.33	0.28	0.30	0.42	0.41	0.40	0.43
K_2O	9.68	10.58	10.28	10.58	10.04	9.90	10.29	9.78
Rb_2O	0.00	0.00	0.55	0.27	0.35	0.48	0.28	0.45
Cs_2O	0.00	0.00	0.08	0.06	0.06	0.08	0.05	0.06
H_2O+	3.45	3.24	2.51	2.22	2.23	2.85	2.78	2.30
F	2.60	3.75	2.96	3.18	3.53	4.50	3.64	3.77
P_2O_5	0.07	0.03	0.10	0.08	0.06	0.07	0.08	0.07
Total	99.61	101.61	99.81	99.98	98.88	99.60	99.96	99.86
2F=O	1.09	1.58	1.24	1.34	1.49	1.20	1.53	1.59
Total	98.43	99.99	98.44	98.53	97.31	98.34	98.37	98.21
K	1.780	1.907	1.910	1.947	1.885	1.854	1.917	1.855
Rb	n.d.	n.d.	0.051	0.025	0.033	0.045	0.026	0.043
Na	0.112	0.090	0.079	0.084	0.120	0.117	0.113	0.124
Ca	0.029	0.035	0.014	0.007	0.003	0.000	0.000	0.000
Li	1.461	0.995	1.423	1.236	1.403	1.322	1.075	1.041
Fe	0.209	1.574	1.621	1.423	1.639	1.751	1.743	2.092
Mg	0.100	0.036	0.009	0.017	0.029	0.018	0.016	0.025
Mn	0.060	0.069	0.067	0.056	0.062	0.092	0.084	0.088
Al	3.870	3.938	3.973	4.226	4.152	3.997	4.252	4.122
Si	6.210	6.159	6.228	6.231	6.021	5.870	5.838	5.733
Ti	0.031	0.007	0.048	0.047	0.650	0.059	0.058	0.860
F	1.185	1.676	1.363	1.451	1.643	2.089	1.681	1.773
OH	2.810	2.320	2.616	2.335	2.322	1.911	2.319	2.227

Analyst: Chemical Laboratory, Czech Geological Survey. Wet analyses, formulae are based on 22 oxygen atoms per formula unit. Samples are in the order of their height above sea level.

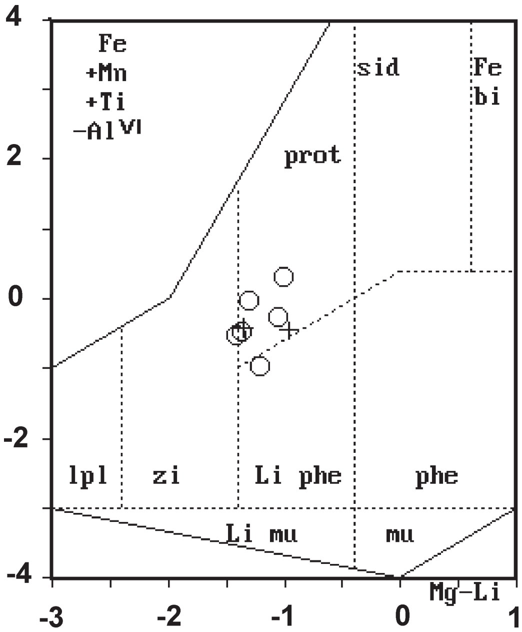

Fig. 9 Li-micas in the classification diagram of Tischendorf *et al.* (1997). Structural formulae based on 22 O were calculated according to Rieder (1977). Explanations: + = greisen mica, o = granite mica. Samples from the Table 3. Diagram: lpl – lepidolite; zi – zinnwaldite; prot – protolithionite; sid – siderophyllite; phe – phengite; mu – muscovite.

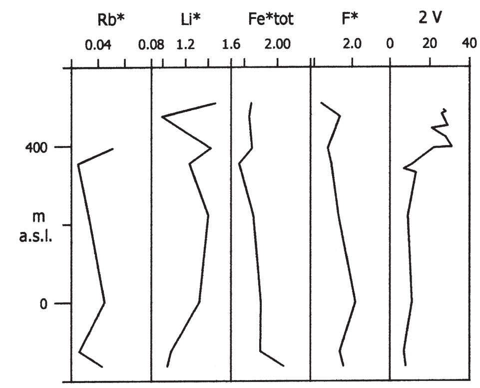

Fig. 10 Composition of Li-micas in vertical profile. Rb*, Li*, Fetot*, F* = atoms per formula unit, 2V = angle of optical axes. Samples from the Table 3.

also seen in the angle of optical axes; the 2V values decrease with the depth from 35 to 10°. Low (close to zero) values of this angle are characteristic of rare brown Li-mica flakes, enclosed in quartz grain centres. Refraction indices of Li-micas vary in the range of 1.584–1.597.

Muscovite in large crystals (5–10 mm) and dark brown *biotite* (5–20 mm) occur at contacts between marginal pegmatite and gneisses. Muscovite is colourless, without pleochroic haloes. Its optical angle 2V = 40°. A younger generation of white mica is fan-like muscovite/sericite in Greisen II.

5. Whole rock chemistry

Chemical analyses of typical rock samples from Schnöd stock are given in Table 2. The major-element data were recast to normative minerals using the programme EVOLGRA (Dolejš – Štemprok 2001). Changes in normative mineralogy with the depth are shown in Fig. 11. The sum of Bi (= biotite) and Tr (= trilithionite) values gives approximate normative amount of Li-mica. There is a gradual drop in quartz content, compensated by increasing amounts of both feldspars (with K-feldspar be-

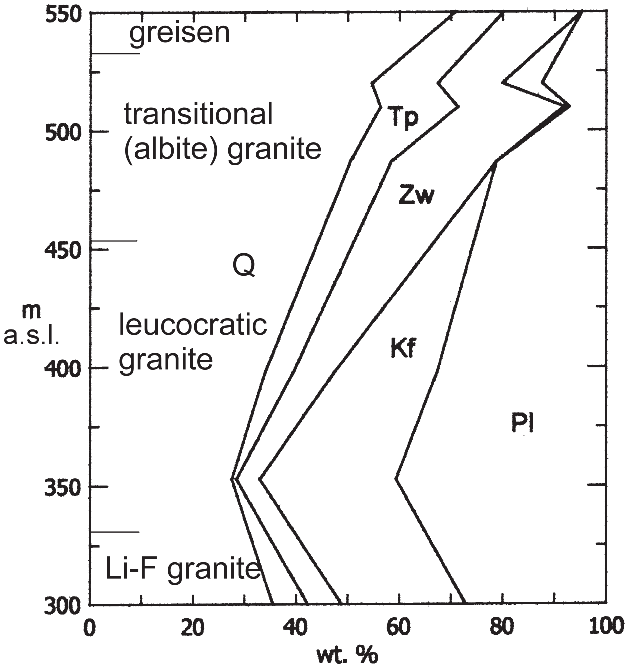

Fig. 11 Normative composition of typical rock samples from the Schnöd stock in vertical profile. Accessoric ilmenite, berlinite and apatite are neglected, remaining normative values were rounded and recalculated to 100 percent prior to the graph construction. Normative values were calculated using computer programme EVOLGRA (Dolejš – Štemprok 2001).

coming more important). In addition, the figure illustrates a distinct composition of the underlying Li-F granite.

Systematic analyses of drill cores, using XRF, AAS and other methods were carried out by Najman *et al.* (1990). Several chemical elements were determined in vertical profiles. The important indicators of petrographic character of rocks are first of all incompatible elements Li and F, besides Sn, Rb and W.

All granite types and feldspathites contain about 30–50 ppm Sn and 5–20 ppm W. Both greisen types – regardless whether rich in quartz or in mica – bear locally higher contents of Sn and W in tenths of percent, but very often are barren. On the other hand, similar Sn and W values occur locally in granite, usually close to greisen zones, but without any visible traces of alteration. In such cases the microscopic study often revealed accessory grains of dark cassiterite. However, prevailing quantities of the ore elements still occur in the greisen bodies themselves.

The fluorine content of granites is commonly 1–2 wt. % F. Mica-bearing granite varieties contain 0.2–0.4 wt. % Li_2O, leucocratic granite only 0.8 wt. % F and 0.05–0.06 wt. % Li_2O. Feldspathites are indicated by minima of both these elements in borehole profiles (< 0.1–0.3 wt. % F and < 0.03–0.04 wt. % Li_2O). Geochemical drill logs have shown, that higher Li_2O and F contents in the granite occur down to 50–100 metres below gneiss contact irrespective the presence of greisen bodies. The concentrations of both these elements then drop monotonously, in accordance with the occurrence of leucocratic rocks. The general trends of some elements can be best demonstrated on an example of a typical borehole profile (HU-41; Fig. 12). It can be seen that compatible element Y, hosted in stable accessories, is more or less independent of the depth, both in the gneiss and granitic rocks.

Underlying Li-F granite contains rather constant concentrations of 0.75 wt. % F and 0.1–0.2 wt. % Li_2O. Remarkable changes in some element contents indicate the contact between leucocratic and underlying Li-F granite, as e.g. in the borehole Kz-22 in the Vysoký Kámen area (Fig. 13). The increased Li_2O, F, and Fe concentrations are in line with the presence of zinnwaldite in the Li-F granite.

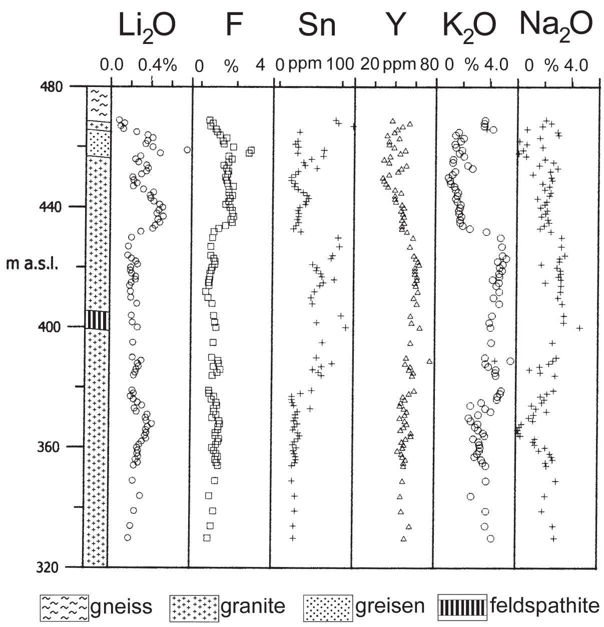

Fig. 12 Variation in some indicative elements in the borehole HU-41, below the gneiss contact. Data from Najman *et al.* (1990).

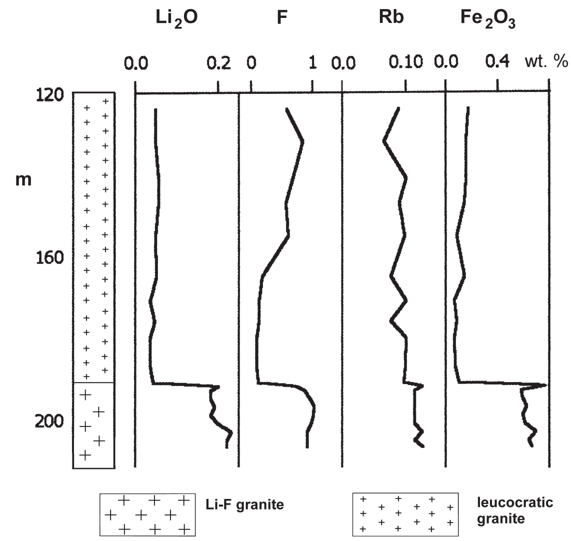

Fig. 13 Variation of some elements at the contact of leucocratic and underlying Li-F alkali-feldspar granites. Borehole Kz-22, Vysoký Kámen quarry (data from Pácal – Pavlů 1979).

6. The origin of stocks in the Krásno area – a discussion

At present, there are little published data on the speciation of fluorine in natural hydrous aluminosilicate melts. Thus the discussions concerned with origin of Li-F granites, greisens and feldspathites are still based mainly on petrographic observations and silicate analyses. Most of interpretations during the last 50 years emphasized the importance of postmagmatic (subsolidus) autometasomatic overprinting. The current literature seems to bring more arguments for "magmatic" models of Li-F granite formation, based, among others, on experiments on silicate systems containing fluorine.

According to the metasomatic ideas, the solidified granites were altered to Li-F granites (apogranites) by a sequence of postmagmatic hydrothermal solutions. A set of processes presented originally by Beus *et al.* (1962) was as follows: albitization I and microclinization I (initial alkaline stage of solutions), then greisenization (acidification stage) and the whole process was terminated by late albitization II and microclinization II (closing alkaline stage). It was at the initial stage of the alkaline metasomatism, when the ore components were mobilized from the country rocks. A review of relevant terminology and ideas published Štemprok (1987).

The "magmatic" model and primary existence of albite and of Li-F granites was defended very early by Kovalenko *et al.* (1970) and Kovalenko (1974, 1978). These authors studied thoroughly in the field the subvolcanic Li-F granite equivalents – ongonites – and stated that fluids were present in the highly fractionated parental magma from its ascent on.

The same view is supported by Beskin (1994) who questioned the metasomatic origin of the Li-F granite in the Orlovka Massif in Transbaikalia, which originally served as a corner stone to the metasomatic theory. Recently, several authors (Lowenstern 1994, Dostal – Chatterjee 1995, Shinohara *et al.* 1995, Taylor – Fallick 1997) accepted the idea of early fluid/melt fractionations and of primary crystallization of granites containing albite and topaz without any early albitization.

We can mention only briefly the main ideas from numerous articles concerning Erzgebirge Mts. area. Most investigations of granite differentiation were based mainly on petrographically established granite types (Lange *et al.* 1972). Geochemical features of granitoids of the Czech part of the Erzgebirge Mts. granite pluton were summarized by Štemprok (1986). He postulated, as one possibility, that the specialization of the youngest Li-F granites (called lithium apogranites) could have been achieved by a major addition of volatile constituents into the already consolidated granite. Albeit the primary existence of albite in Li-F granites was later accepted (Dolejš – Štemprok 2001), the common Erzgebirge Mts. Li-F granite was still interpreted as a product of subsolidus (postmagmatic) albitization (Štemprok *et al.* 2005). Breiter *et al.* (1991) studied geochemical specialization of Erzgebirge Mts. granites and distinguished seven granite types. Five of them, at the western part of Erzgebirge (Nejdek-Eibenstock Massif), represent presumably postorogenic members of the granite series as products of successive differentiation. The remaining two, at the eastern Erzgebirge, seem to be young anorogenic bodies. All types contain more Li, Rb, Cs and Sn with increasing magmatic differentiation.

Geochemical patterns of granites from the Slavkovský les Mts. are compatible with an uninterrupted fractionation from older OIC to younger YIC granite complexes. According to the studies of ongonites (Kovalenko 1974) Breiter et al. supposed that the albite of YIC granites in Erzgebirge is also of primary origin. A detailed investigation of a small stock at Podlesí (e.g., Breiter *et al.* 1997 and Breiter 2002) showed that the initial melt formed at first prevailing stock granite (albite-protolithionite-topaz), then albite-protolithionite granite dykes enriched in Al, P, F with Li and then pegmatite layers enriched in K, but depleted in Si and Na.

Greisenization in published genetic studies is – almost as a rule – interpreted as replacement of solidified granites and their country rocks by postmagmatic solutions. Stoichiometric equations were presented for instance by Heinrich (1990), Schwartz – Surjono (1995) and Halter (1996); thermodynamic equilibria ("fluorination") studied Dolejš – Baker (2004) on data for several minerals. The temperature conditions and concentration ranges of the greisen formation at presence of fluorine were intensively experimentally studied in the last decades. Accumulation of H_2O and F in the magma at the top of the stocks lowered the solidus temperature significantly (to as low as 550–650 °C at 200 MPa; Manning 1982). Attendant substantial decrease in viscosity by several orders was confirmed by experiments (Baker – Vaillancourt 1995). From experimental studies it is known that the solubility of fluids in magma dropped proportionally to the gradual magma cooling. As an example, the solubility of pure water (in weight percent), depending on pressure in granitic melts, is shown in P-X diagram (Fig. 14) valid for temperatures above solidus. These values should further increase in presence of fluorine. As can be seen, the solubility of water in the melt at the pressure prevailing in a supposed emplacement depth of about 2.5 km (approximately 100 MPa) is only 4 wt. %. For the Erzgebirge granites the values of about 4–8 wt. % H_2O found in fluid inclusion studies, are in agreement with these data. The lower limit for the depth of formation of Erzgebirge granites is 20–25 km and pressure of 600 MPa (Thomas 1993). Müller *et al.* (1999) linked quartz cathodoluminescence with microanalytical methods and found, that zoned quartz phenocrysts from the Hub stock topaz microgranite crystallized at depth from relatively dry (3 wt. % H_2O) magma. This magma became progressively enriched with differentiation, reaching 10 equivalent wt. % H_2O and 4 wt. % F (Breiter – Förster *et al.* 1999).

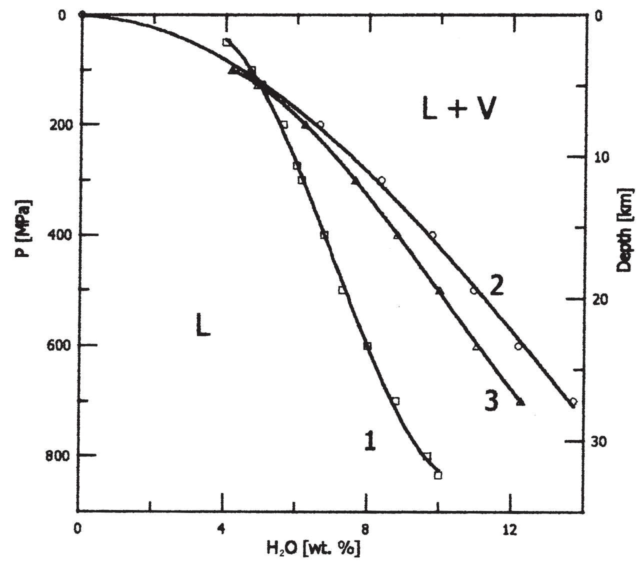

Fig. 14 Water solubility in granitic melt versus pressure. 1 – Burnham (1997) 660–720 °C, 2 – Ryabchikov (1975) 800 °C, 3 – Holtz *et al.* (2001) 800 °C. L = melt, V = fluid phase. Descending pressure axis corresponds to the increasing depth.

According to fluid inclusion study, mineral associations of topaz- and mica-bearing greisens in the Erzgebirge Mts. gave a temperature range of 400–300 °C (Ďurišová *et al.* 1979). The pressure estimated at less than 100 MPa in topaz and cassiterite fluid inclusions indicate subvolcanic (1–2 km) depths. The temperature range of 270–350 °C for stability of lithium chlorite – cookeite (Vidal – Goffé 1991), cementing topaz grains in Greisen II at the Hub stock, is also in agreement with the values spanning from the fluid inclusions.

The stability range of mineral phases in the system granite-fluids was studied in several experiments. Weidner – Martin (1987) found for water-saturated melts solidus temperatures of 660–608 °C at pressures 100–800 MPa. Kovalenko *et al.* (1994) reported results of experimental hydrothermal alterations of granite by H_2O-F containing fluids and Kovalenko *et al.* (1996) studied alteration of granite in the system H_2O-HCl. It was shown that both feldspars are stable above pH 3–4 at temperatures up to 500 °C and a pressure of 100 MPa. Xiong *et al.* (1999) studied experimentally the system granite-H_2O-F and found that greisen association quartz-topaz-mica, containing 2–6 wt. % F and 14–18 wt. % H_2O, may crystallize directly from melts under 800 °C and 100 MPa. This work yielded consistent results during both melting and crystallization experiments. However, no difference in stability of albite and K-feldspar was noticed.

In stocks after emplacement, steep pressure gradient made further spontaneous ascent of volatiles easier. The enrichment of volatiles and especially high fluorine contents of the magma in stocks may apparently promote a direct crystallization of greisen minerals at the late-magmatic stage when the feldspars are no longer stable. Such a case observed Eadington *et al.* (1978), who presumed that topaz- and quartz-bearing rocks in Australia are greisens of magmatic origin.

A metasomatic model was applied by Dahm – Thomas (1985) for the stock evolution at Ehrenfriedersdorf in the German part of the Erzgebirge Mts. Seltmann et al. (1995) proposed a sequence of alterations for the same deposit. They used the scheme of Beus *et al.* (1962), in which the alterations presumably followed the complete granite solidification.

For the Krásno stocks, we can deduce that the crystallization of magmatic melts containing dissolved volatiles, started at solidus temperatures under 600 °C. Composition of resulting phases was governed primarily by fluorine concentrations (or better by fugacity ratio fF/fH_2O, as proposed Tischendorf – Förster 1990). Its lower values lead at first to the constitution of granite, developed in case of undercooling in the form of *marginal pegmatites*. Ongoing crystallization of granitic melt caused a passive enrichment of volatiles in the remaining melt. Thus, at certain level of fluorine concentration the first stable phases were *Greisens I* minerals – topaz and mica, instead of feldspars. Instability of feldspar is explained by destruction of AlO2-tetrahedra by fluorine. Cooling of the system could have supported the decomposition of transported fluorosilicates as well as may have led to formation of greisens and deposition of accessoric ore minerals.

At such conditions in the Krásno area, greisen "layers" might have been formed. They are located in granite at certain distances below the flat gneiss contacts (Najman *et al.* 1988) and parallel to it, in accordance with the presumed shape of isotherms. It is apparently a non-invasive form of greisen, not bound on any steep fissures and formed after certain fluid accumulation. Different conditions ruled at the top of stocks, where the concentration of volatiles, due to their flow from the depth along the pressure gradient, was higher. Such conditions were favourable for immediate growth of greisen minerals. Schröcke (1954) compared several greisen deposits at Erzgebirge Mts. from this point of view, and proposed primary greisen origin solely for the stocks at Krásno. The absence of feldspar relict structures of Greisen I is in accord with this opinion. Metasomatic processes apparently took part later, at the stage of continuing fluid transport into partly solidified stocks. *Greisen II* then was formed along fissures. The repeated fluid transport led to local alteration (recrystallization) of Greisen I, observed as corrosion phenomena on topaz and zinnwaldite. The presence of two greisen phases indicates the differentiation of fluids (F/OH ratio), which is proved in most fluid inclusion studies.

Lower fluorine concentrations (after neutralization of fluids) below greisen bodies led to formation of K-feldspar-free *transitional granite*, containing albite as the main feldspar in equilibrium with topaz. Fluorine at this level was apparently gradually consumed by the formation of topaz and zinnwaldite. Albite appears as the more stable phase of the two alkali feldspars. Temperature estimates for transitional granite, measured on melt inclusions in the quartz and topaz crystals from the Hub stock (475 m a. s. l.), gave Thomas (1993) and Thomas – Klemm (1997). They obtained for the last (3rd) crystallization phase a liquidus temperature of 646° ± 16 °C and a solidus value of 607° ± 9 °C. The total pressure of 119 MPa corresponds to the depth of 4.6 km.

From chemical analyses is apparent, that all greisen varieties are poor in sodium. Convection and advection (Shinohara *et al.* 1995) of low viscosity magma could have distributed this component to the lower parts of stocks. Both alkali feldspars are stable components in mica-free *leucocratic granite* (low in Li), which builds the central parts of the stocks. A comparatively highest enrichment of alkalies is then observed at deeper level in quartz-free *feldspathites*, which are in addition impoverished in silica and fluorine. Crystallization of feldspathites terminated the solidification of stocks.

Analyses of alkalies in Vysoký Kámen feldspathites show a roughly balanced orthoclase and albite proportions (with rare extreme monomineral K- or Na-enriched sections) and so the idea of mere albitization of granite by a late introduction of sodium from the depth (albitization II) is doubtful. Instead, better interpretation is a crystallization of residual magma poor in SiO_2. Similar conclusion was done by Seim – Leipe (1987) for the "inner granite" at the deepest levels of the Altenberg deposit. Inner magma differentiation transported silica, bound with fluorine, into stock apices.

According to this interpretation, the formation of greisen and feldspathites does not represent two contrasting metasomatic trends – greisenization and alkalization (Dolejš – Štemprok 2001), as suggested by the common triangle Ab-Q-Or of normative components. Such diagram depicts consolidated products, after their separation in stock space. More probable is the existence of a single magmatic process, involving inner differentiation of components, during which the main part of SiO_2 and fluid components are accumulated in the apical part of the stock. The magmatic residuum poor in SiO_2 would then remain at the stock's bottom. The stable stock assemblages are illustrated by the mineral equilibria diagram (Fig. 15, from Govorov 1977). At the presence of lithium and iron, the stable mica is zinnwaldite (Zi) instead of muscovite. The general tendency of acidity changes are shown by the arrow. Quartz is present in a large extent of conditions, except the final surplus of alkalies.

Younger argillitization comprising kaolinite, sericite, and locally fluorite, apatite, carbonate and hematite are low-T continuation (below 200 °C) of the main process (Ďurišová *et al.* 1979). Hematite indicates local increase in oxygen activity at the end of alterations.

The *underlying Li-F granite* separated by comparatively sharp contacts from leucocratic rocks lying above, differs in abundance of somewhat darker mica and in iron content. Its solidus is above 800 °C, i.e. higher than for the stock rocks, due to a decreased fluid contents. Its solidification therefore took place possibly earlier than solidification in stocks. This granite type is a product of the same magma as that in the stock filling, but with substantially lower contents of fluids. Its shows a monotonous composition over its whole vertical span (documented from 180 to -162 m a. s. l.).

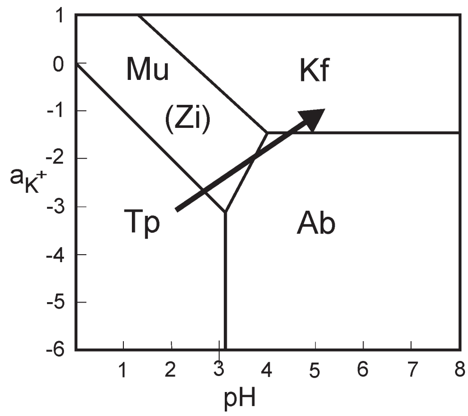

Fig. 15 Mineral equilibria of stock assemblages and their changes in relation to acidity and K activity (after Govorov 1977). Kf = K-feldspar, Ab = albite, Mu = muscovite, Zi = zinnwaldite, Tp = topaz., (T = 400 °C, P = 50 Mpa, a_F = 0.1 m, a_{Na} = 0.4 m).

7. Conclusions

Available field, petrological and geochemical data on Krásno stocks allow the following conclusions regarding their structure, composition and evolution:

1. The stocks represent apical part of an evolved laccolith, which intruded the contact between gneisses and a less evolved granite of the Krudum Massif.

2. The Krásno stocks have a zoned structure, which includes low-grade greisen varieties at the top, largely argillitized transitional (K-feldspar free) granite at their center and feldspar-enriched granitic rocks at the bottom. Underlying Li-F granite, having sharp subhorizontal contact, is alkali-feldspar topaz granite of monotonous composition.

3. The character of rocks formed in vertical profile was controlled by cooling from above and by the fluorine-bearing fluids distributed by inner melt convection in the chamber.

4. The first portion of magma (microgranite) presumably sealed the brecciated gneiss roof and the fluid components accumulated at the upper parts of the cupolas. The largest proportion of fluorine was fixed in topaz and zinnwaldite in greisens at the top of the stocks. Deeper, Na entered albite which became stable. Both feldspars then formed leucogranite at the stock bottom. The spatial separation of SiO_2, fluorine and other elements can be explained by a single continuous cooling process including an early fluid transport and differentiation of the stock content. Silica was transported upwards in the form

of fluorocomplexes, which then broke down in the course of cooling. The leucogranite and feldspathites seem to represent a low-T residual petrogenetic system saturated in alkalies.

5. We can conclude, that with increasing depth, the solidification process proceeded at increasing temperatures and lower fluorine concentrations.

6. For stocks at Krásno, the idea of intensive postmagmatic reworking of primary granite is doubtful. An additional late supply of alkaline postmagmatic hydrothermal solutions, which would completely alter the presumed putative, earlier solidified granite into feldspathites (albitization II) is not necessary. Mica-free leucocratic granite and quartz-free feldspathites apparently represent a magmatic residue, poor in SiO_2 and enriched in alkalies, remaining at the stock bottom.

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Stavba a geneze greisenových pňů u Krásna n. T., Slavkovský les – západní Čechy, Česká republika

Apikální části intruzí Li-F granitu, zachované pod pokryvem rul při j. okraji masivu Krudum ve Slavkovském lese, obsahují greisenové pně, místy s chudou Sn-W mineralizací. Variety greisenu přecházejí do hloubky do leukokratního granitu a zón feldspatitů. V hloubce v podloží pňů se vyskytuje nepřeměněný alkalicko-živcový Li-F granit, známý na povrchu dále k SZ jako typ Čistá. Kontakty různých typů hornin v pních jsou neostré a částečně zastřené mladšími přeměnami. Horní části pňů jsou obohacené o vedlejší prvky jako jsou Li, F, Sn, W, Cu a Zn. Sled hornin ve vertikálním řezu je interpretován jako výsledek frakcionace mateřského magmatu, které bylo postupně obohacené těkavými komponentami, zejména vodou a fluorem. Transport fluid, vnitřní diferenciace magmatu a ochlazování ovlivňovaly krystalizaci granitu a těles greisenu. Lokální přesycení fluid vedlo ke vzniku výplní trhlin a současně k přeměně starších minerálů. Bezrudní leukogranit a zóny feldspatitů v hloubce vznikly krystalizací residuálního magmatu, ochuzeného o SiO_2. Podle tohoto modelu není nutné předpokládat velmi nepravděpodobné postmagmatické autometasomatické procesy jako albitizaci a K-feldspatizaci, jejichž působení se dříve přičítaly silné změny složení původně vykrystalizovaného granitu.