PRIMARY (MAGMATIC) MANGANOAN SIDERITE AND ITS ALTERATION PRODUCTS FROM A GRANITIC PEGMATITE AT STRZEGOM, POLAND

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INTRODUCTION

Carbonates (chiefly calcite) are very rare constituents of granitic pegmatites and they typically occur as late hydrothermal minerals commonly associated with epidote, zeolites, chlorites and/or clay minerals. Primary hydrothermal and secondary REE-fluorcarbonates crystallized in open vugs or replaced primary REE-bearing minerals (e.g., allanite) in some NYF pegmatites. Primary magmatic carbonates such as microscopic grains of calcite or euhedral crystals of bastnaesite associated with Ca,Mg-enriched elbaite from contaminated elbaite pegmatite Bližná I (Novák et al., 1999) are exceptional. Siderite as other carbonates is a typical late hydrothermal phase. The examined manganoan siderite from pegmatite at Strzegom represents a new example of carbonate with obvious primary origin closely associated with perthitic K-feldspar, quartz and biotite. Chemical composition of siderite, its mineral assemblage and alteration products are described as well as discussion of the siderite-bearing pegmatite origin.

GRANITIC PEGMATITES

Siderite-bearing pegmatite occurs at the Żółkiewka quarry near Strzegom, Lower Silesia (SW Poland). The pegmatite cuts hornblende-biotite monzogranite pluton belonging to the Variscan Strzegom-Sobótka massif. Granite solidified under low pressure (~150 MPa, Puziewicz, 1990), which led to formation of abundant miarolitic pegmatites (Janeczek, 2007) characterized by primary K-feldspar (microcline), quartz, albite, and annite as well as large pockets lined with hydrothermal minerals of two distinct paragenetic types: (i) Ca-rich (green) paragenesis - epidote, Fe-rich chlorite, axinite, bavenite and fluorite, and (ii) alkali-Fe-rich (black) paragenesis - cleavelandite, stilpnomelane, milarite, tourmaline, zinnwaldite and fluorite. Low-temperature hydrothermal assemblages involving stilbite, chabazite, calcite and siderite are similar in both paragenetic types. Along with dominant miarolitic pegmatites, rather rare, intrusive, flat-lying lenticular to sheet-like fayalite-bearing pegmatites composed of microcline, albite, quartz, annite, and minor Mn-rich fayalite (Janeczek, 1989) occur in hornblende-biotite granite. Fayalite underwent a multi-stage hydrothermal alteration with the internal assemblage (Mn-grunerite+magnetite+quartz) and the external assemblage (Mn-greenalite+Mn-grunerite+Mn-minnesotaite+stilpnomela

ne+magnetite). Miarolitic pegmatites belong to miarolitic class, MI-REE subclass, and are close to the gadolinite-fergusonite type (Černý and Ercit, 2005).

GEOLOGY, INTERNAL STRUCTURE, MINERAL ASSEMBLAGES, ALTERATION PRODUCTS AND CHEMICAL COMPOSITION OF MINERALS

The siderite-bearing pegmatite formed intrusive, sheet-like, homogeneous dike (~ 5-7 cm thick, ~1 m long) with rather sharp contacts with host medium-grained hornblende-biotite monzogranite. The pegmatite dike consists of dominant subhedral grains of perthitic K-feldspar and subordinate interstitial smoky quartz (both ≤ 5 cm large), and minor flakes (≤1 cm in size) of annite $X_{Mg} = 0.21$. Isolated, subhedral to euhedral grains of olive green siderite (≤ 2 cm in size) are randomly distributed within the dike. Minor albite and small isolated grains of magnetite I represent additional primary minerals of the pegmatite closely associated with siderite. Small pocket lined with smoky quartz and dark mica was exceptionally observed in this pegmatite dike as well. In the same exposure thin elongated but rather irregular dike of miarolitic pegmatite with large pocket lined with abundant K-feldspar, albite, quartz, epidote, stilbite, chabazite and fluorite (green paragenesis) occurs at the distance of ~1-2 dm from the siderite-bearing pegmatite. Irregular shape of a miarolitic pegmatite in contrast to linear (intrusive) character of the siderite-bearing dike indicates that the host granite was more elastic during formation of miarolitic pegmatite relative a solid nature of host granite during emplacement of siderite-bearing pegmatite. It seems to crystallize later; however, both types of pegmatites do not cut one another and their temporal relation remains somewhat uncertain.

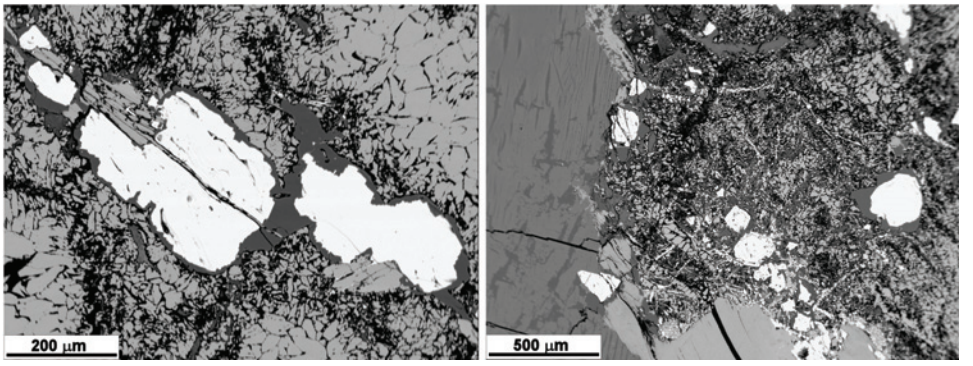

Figure 1- BSE images of a) internal assemblage and b) external assemblage. White – magnetite with quartz rim. Qtz – quartz, Sd – siderite; Gru – grunerite; Kfs – K-feldspar; Bt – biotite, Chl - chlorite. Note a narrow rim of chlorite on contact with K-feldspar.

Zoned siderite with Mn-enriched rim (0.12-0.25 apfu Mn; Table 1) is strongly altered particularly at the grain margins. Two distinct mineral assemblages of alteration products were distinguished. Internal one is represented by less altered central part of siderite grains with the mineral assemblage - magnetite II + quartz ± grunerite - as randomly distributed microscopic aggregates (Fig. 1a). Grunerite is enriched in Mn (0.50-0.72 apfu) and chiefly in Mg (0.64-0.81 apfu). Magnetite II is locally cut by siderite II slightly Mn-depleted (0.11-0.10 apfu Mn; Table 1). External assemblage on contact of siderite and K-feldspar (±biotite), as narrow black zone (~ 1-2 mm thick), involves fine-grained chlorite I with small grains of magnetite III and irregular mostly interstitial masses of nontronite (Fig. 1b) and minor stilpnomelane. Locally needle-like (or platy?) mineral replaced by small grains of magnetite III is present. Representative analyses of the individual minerals are given in Table 1.

COMPARISON OF SIDERITE- AND FAYALITE-BEARING PEGMATITES

Both siderite- and fayalite-bearing pegmatites exhibit similar shape and internal structure of pegmatite bodies – intrusive, sheet-like with rather sharp contacts to host monzogranite and presence of rare pockets; although, in fayalite-bearing pegmatites narrow transitional border zone of fine-grained granite is developed and dikes are up to 50 cm thick (janeczek, 1989). the mineral assemblages of primary and secondary fe,mg-minerals from both pegmatite types at strzegom also are similar. the earliest primary minerals - siderite/fayalite - exhibit similar textural and paragenetic position in the pegmatites as well as chemical composition with only trace amounts of mg disregarding the principal difference carbonate/silicate; although, siderite is rather mn-enriched. the assemblage magnetite+quartz±grunerite developed exclusively in the internal assemblage also is similar to that of fayalite-bearing pegmatites. however, grunerite is mg-enriched similarly as primary biotite relative to fayalite-bearing pegmatites, where this assemblage represents breakdown product of fayalite. the textural relations of this assemblage to host siderite (Fig. 1a) do not indicate whether this assemblage is a product of breakdown of fayalite or it represents a product of simultaneous crystallization with siderite; however, no relics of fayalite have been found and primary origin of the assemblage magnetite+quartz±grunerite is possible.

Chlorite and nontronite are dominant minerals along with magnetite III and rare stilpnomelane in the external assemblage developed along margins of siderite crystals with host K-feldspar (and biotite). This system is evidently Al-enriched relative to the internal assemblage. However, this mineral assemblage is different from the external assemblage of fayalite-bearing pegmatites with greenalite, minnesotaite common stilpnomelane and magnetite. Nevertheless, pseudomorphs of magnetite III after unknown fibrous (platy?) mineral suggest that this assemblage was more or less overprinted by low-T processes and it may have previously contained at least some minerals (e.g., greenalite and/or minnesotaite) from the external assemblage of the fayalite-bearing pegmatites.

	1	2	3	4	5	6	7	8	9
SiO_2	0.00	0.00	0.00	47.99	0.14	34.41	43.38	25.74	57.06
TiO_2	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.03	0.08
Al_2O_3	0.00	0.00	0.00	0.43	0.15	12.90	3.90	12.55	7.82
Fe_2O_3*	-	-	-	-	68.44	-	-	-	22.89
FeO*	45.34	54.09	54.72	39.38	30.79	33.13	31.45	47.01	-
MnO	15.43	7.04	6.07	5.21	0.37	1.44	10.83	0.99	0.18
MgO	0.15	0.10	0.10	3.32	0.02	4.87	1.12	2.53	1.86
ZnO	0.04	0.00	0.00	0.17	0.11	0.20	0.18	0.21	0.07
CaO	0.35	0.31	0.10	1.01	0.00	0.03	0.00	0.32	3.08
Na_2O	0.00	0.00	0.00	0.15	0.00	0.00	0.06	0.03	0.02
K_2O	0.00	0.00	0.00	0.01	0.00	8.67	2.87	0.40	0.02
H_2O*	0.00	0.00	0.00	1.83	0.00	3.13	3.99	10.30	4.37
CO_2*	37.82	37.85	37.48	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	99.18	99.39	98.48	99.51	100.03	99.58	98.13	100.10	97.46

Si	0.00	0.00	0.00	7.86	0.01	2.83	8.00	3.00	3.92
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Al	0.00	0.00	0.00	0.08	0.01	1.25	0.85	1.72	0.63
Fe^{3+}	-	-	-	-	1.98	-.	-	-	1.18
Fe^{2+}	0.73	0.88	0.89	5.40	0.99	2.28	4.85	4.58	-
Mn	0.25	0.12	0.10	0.72	0.01	0.10	1.69	0.10	0.01
Mg	0.00	0.00	0.00	0.81	0.00	0.60	0.31	0.44	0.19
Zn	0.00	0.00	0.00	0.02	0.00	0.01	0.02	0.02	0.00
Ca	0.01	0.01	0.00	0.18	0.00	0.00	0.00	0.04	0.23
Na	0.00	0.00	0.00	0.05	0.00	0.00	0.02	0.01	0.00
K	0.00	0.00	0.00	0.00	0.00	0.91	0.68	0.10	0.00
OH^-	0.00	0.00	0.00	2.00	0.00	1.72	4.90	8.00	2.00
C	1.00	1.00	1.00	-	-	-	-	-	-
∑CAT	2.00	2.00	2.00	17.12	3.00	6.28	16.43	18.00	6.17
∑AN	3.00	3.00	3.00	23.00	4.00	12.00	27.00	14.00	11.00

DISCUSSION

The primary mineral assemblage of siderite-bearing pegmatite (siderite+magnetite+K-feldspar+annite+albite+quartz) is indicative of $f(O_2)$ higher than that under which the fayalite-bearing pegmatites have crystallized. Biotite and grunerite occurring in the siderite-bearing pegmatite are more magnesian than their analogues occurring in the fayalite-bearing pegmatites, also indicating higher $f(O_2)$. Since $f(O_2)$ during crystallization of fayalite-bearing pegmatites is defined by the FMQ buffer, the siderite-bearing pegmatite originated under $f(O_2)$ higher than those defined by FMQ but lower than those defined by HM buffer. Analysis of phase relationships in the system Fe-Si-C-O-H (Frost, 1979) shows that in the presence of CO_2 – H_2O at temperatures close to those of the fayalite stability siderite is stable under CO_2-rich conditions, whereas grunerite under H_2O-rich ones. Since siderite coexists with silicate assemblage assumed to originate under temperatures of ~600 to 500 ºC (Janeczek, 1989), the evolution of host pegmatite started probably at this temperature range under abundance of CO_2, giving assemblage K-feldspar+siderite. The grunerite-bearing assemblages originated due to increase of H_2O activity but

not necessarily at significantly lower temperatures.

The siderite-bearing pegmatite, exhibiting intrusive relationship to the surrounding granite, comes from "external" source as opposite to the miarolitic pegmatites, which have originated in situ by H_2O unmixing from the crystallizing magma. The cross-cutting relationship to host granite might have originated at the same time and similar P/T conditions to those of miarolitic cavities origin, due to brittle response of almost solidified visco-elastic granite to the stress generated by intruding pegmatite melt. The description of fayalite-bearing pegmatites (Janeczek, 1989) suggests that they also originated from the "external" melt. Both the pegmatites show that at the late- to post-magmatic stage local displacement of mobile volatile-rich melts took place in the pluton leading to the formation of intrusive pegmatites. The varying mineral compositions might be due to differences in intruding melt composition as well as crystallization course. The siderite-bearing pegmatites as well as the fayalite-bearing ones are magnetite/K-feldspar/quartz saturated, and the interplay between temperature and CO_2/H_2O proportions led to fayalite or siderite crystallization, possibly with fayalite originating under slightly higher temperatures (see Frost, 1979).

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