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GAHNITE FROM SIEDLIMOWICE, STRZEGOM-SOBÓTKA GRANITIC MASSIF, SW POLAND

Abstract. Green spinel was found in a vein pegmatite in Siedlimowice (Strzegom-Sobótka massif, SW Poland). X-ray diffraction and electron microprobe analyses allowed defining the mineral as gahnite with the formula $(Zn_{6.1}Fe_{1.8}Mn_{0.1})(Al_{15.8}Fe_{0.2})O_{32}$ and unit cell parameters a = 8.1018 ± 0.008 Å, V = 531.787 ± 0.156 Å^3. Its chemical composition is typical of gahnites of igneous association. Formation of the zincian spinel was most probably controlled by local variations of crystallization conditions, e.g. the variations of a Zn/Fe ratio in a pegmatitic fluid or of oxygen fugacity.

Key-words: gahnite, zincian spinel, Siedlimowice, Strzegom pegmatite

INTRODUCTION

Gahnite belongs to the spinel group minerals with the general formula AB_2O_4, where A stands for Mg^{2+}, Mn^{2+},Fe^{2+}, Ni^{2+}, Zn^{2+} and B for Al^{3+}, Cr^{3+}, Fe^{3+}. It is an end member of the gahnite ($ZnAl_2O_4$) — hercynite ($FeAl_2O_4$) solid solution, occurring as an accessory mineral in rare-element pegmatites, peraluminous granites and certain metamorphic rocks as well as a heavy mineral in sedimentary rocks. Polish localities where gahnite has been reported are confined to the Sudety area (SW Poland) and comprise Przecznica and Kotlina near Mirsk, Szklarska Poręba, Jordanów Śląski and alluvia of the Izera Mts (Lis, Sylwestrzak 1986). The mineral has not been described from the Strzegom-Sobótka granite pegmatites yet.

The Siedlimowice granite quarry is located about 10 km north-east of Świdnica (SW Poland). The granite crops out in the eastern part of the Strzegom-Sobótka granite massif, a complex Variscan intrusion of the Fore-Sudetic Block whose petrography and mineralogy have been a matter of extensive research (e.g. Majerowicz 1972; Pin et al. 1989; Janeczek 1985; Puziewicz 1990). The rock quarried here is a two-mica granite crystallized from magma close to water saturation at a depth deeper than 15 km.

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The locality is well known for its rare-element vein pegmatites, which were a subject of several mineralogical reports, either as a separate subject (Janeczek, Sachanbiński 1989) or a part of larger monographies (Janeczek 1985). The following phases were described from the Siedlimowice pegmatites by Janeczek and Sachanbiński (1989): feldspars (microcline, albite, oligoclase), quartz, muscovite, biotite, chlorite, Fe-Mn garnets, beryl, columbite, zircon, apatite. No zincian phase has been reported so far from the location. However, a few data presented by Janeczek and Sachanbiński (1989) indicate the presence of zinc as a trace element in some muscovites and garnets (550 and 1,750 g/t, respectively). The paper presents the results of the studies of the zincian spinel from this locality.

SAMPLE DESCRIPTION

Gahnite crystals were found in few boulders containing fragments of a vein pegmatite on the second exploitation level in the Siedlimowice quarry. Despite the abundance of pegmatite fragments, the gahnite-bearing rock is extremely rare and detailed observations did not result in finding the mineral *in situ*, i.e. in the quarry walls. The thickness of the gahnite-bearing veins may only be roughly estimated as not lower than 20 cm. They are built of a mineral assemblage typical of the Siedlimowice pegmatites, i.e. major K-feldspar, plagioclase, quartz and muscovite, minor chlorite and biotite, and accessory garnet, beryl, columbite and zircon. Comparing gahnite-devoid and gahnite-bearing pegmatite fragments, the latter contain noticeably lower amount of garnet which forms crystals smaller (up to 3 mm) than elsewhere in the quarry.

The grains of gahnite are dark green, translucent at edges. They occur in central parts of the pegmatite as idiomorphic octahedral crystals (rarely with subordinate dodecahedron faces) up to 5 mm large, embedded in grey quartz, more rarely in white K-feldspar, subordinately in muscovite and exceptionally in beryl (one sample). The crystals are generally not twinned although often intergrown. An intergrowth of gahnite and garnet was also noted. A single spinel crystal found within a mica aggregate was flattened in a similar way to garnets described by Janeczek and Sachanbiński (1989).

METHODS

Spinel grains were separated from the pegmatite mass by handpicking and inspected under a binocular microscope. About 20 mg of the material was used for XRD measurements which were carried out at room temperature on a powdered sample by means of a Siemens D500 X-ray diffractometre with Co-K_{α} Fe-filtered radiation, over the range: 20–145°2θ with a step 0.02°2θ. The results are shown in Table 1. Unit cell parameters were calculated using a WIN-METRIC programme and based on 13 lines with a tolerance of 0.01°2θ.

A thin section was prepared from a few grains and after observations under a standard E600-Pol polarizing microscope it was coated with graphite for microprobe

TABLE 1

Observed and calculated diffraction lines of gahnite from Siedlimowice

hkl	*d* (obs.)	*d* (calc.)	I/I_o
220	2.8628	2.8644	72
311	2.4417	2.4428	100
400	2.0249	2.0254	13
331	1.8583	1.8587	11
422	1.6535	1.6538	14
333	1.5591	1.5592	83
440	1.4317	1.4322	84
620	1.2808	1.2810	10
533	1.2356	1.2355	11
642	1.0826	1.0826	10
553	1.0549	1.0548	11
800	1.0127	1.0127	6
822	0.9549	0.9548	20

analyses. The WDS analyses were conducted by means of a Cameca SX100 electron microprobe with a beam current of 20 nA and acceleration voltage of 15 kV using the following standards: synthetic corundum (Al), sphalerite (Zn), rhodonite (Mn), rutile (Ti), diopside (Mg, Ca), haematite (Fe), chromite (Cr). The representative chemical analyses of five spinel crystals carried out in edge and/or central parts of separate crystals are presented in Table 2. They were recalculated basing on 32 oxygens and a part of Fe was assumed to be trivalent from overall stoichiometry.

RESULTS AND DISCUSSION

The X-ray diffraction pattern (Table 1) corresponds well with that of gahnite and allows calculation of the unit-cell parameter for 13 peaks indexed: a = 8.1018 ± 0.008 Å, and the volume V = 531.787 ± 0.156 Å^3. The a value is intermediate between those of gahnite and hercynite (8.086 and 8.149 Å, respectively), closer to the gahnite end member (Hill et al. 1979).

The spinel crystals investigated seem to be fairly homogenous and neither optical observations nor BSE image analysis have revealed any mineral inclusions or a clear zoning pattern. Chemical analyses (Table 2) do not show any important variations in the gahnite composition and give the spinel formula $(Zn_{6.1}Fe_{1.8}Mn_{0.1})(Al_{15.8}Fe_{0.2})O_{32}$ for the averaged values. A low MgO content (not exceeding 0.12% with an average of 0.09%) is typical of rare-element granite pegmatites (Batchelor, Kinnaird 1984;

TABLE 2

Representative compositions of gahnite from Siedlimowice

Component	Grain 1	Grain 2		Grain 3		Grain 4			Grain 5		Mean
		edge	centre	edge	centre	edge		centre	edge	centre	
Al_2O_3	55.68	55.88	55.11	55.65	54.83	55.17	55.36	55.40	54.88	54.78	55.27
Fe_2O_3	0.65	1.29	2.03	1.47	1.64	1.91	1.81	1.61	1.87	1.79	1.61
MgO	0.08	0.12	0.11	0.08	0.11	0.07	0.07	0.07	0.08	0.07	0.09
MnO	0.21	0.44	0.41	0.49	0.46	0.39	0.39	0.39	0.47	0.43	0.41
FeO	8.39	9.04	8.57	9.33	9.29	8.66	8.47	8.73	8.84	9.05	8.84
ZnO	34.88	34.28	34.65	33.92	33.34	34.62	34.91	34.58	34.05	33.74	34.30
Total	99.89	101.05	100.87	100.93	99.66	100.81	101.01	100.77	100.18	99.85	100.50
Cation proportions based on 32 oxygens											
Al	15.84	15.74	15.81	15.79	15.76	15.77	15.80	15.76	15.77	15.80	15.84
Fe^{3+}	0.14	0.22	0.16	0.18	0.20	0.19	0.17	0.20	0.19	0.17	0.14
Mg	0.04	0.04	0.03	0.04	0.02	0.03	0.02	0.03	0.03	0.03	0.04
Fe^{2+}	1.82	1.74	1.88	1.90	1.75	1.71	1.77	1.80	1.85	1.79	1.82
Mn	0.09	0.08	0.10	0.10	0.08	0.08	0.08	0.10	0.09	0.08	0.09
Zn	6.09	6.20	6.04	6.01	6.19	6.23	6.18	6.13	6.09	6.14	6.09
Selected molar proportions											
Zn/Fe	3.67	3.35	3.57	3.21	3.17	3.53	3.64	3.50	3.40	3.29	3.43
(Zn+Mn)/Al	0.79	0.78	0.80	0.78	0.77	0.80	0.80	0.79	0.79	0.78	0.79
(Fe+Mg)/Al	0.22	0.23	0.23	0.24	0.25	0.23	0.22	0.23	0.23	0.24	0.23

Morris at al. 1997; Tindle, Breaks 1998). The presence of Cr has not been detected with the microprobe. On the ternary plot showing molecular proportions of Zn, Fe_{tot} and Mg (Fig. 1), which was used by Batchelor and Kinnaird (1984) to differentiate between igneous and metamorphic gahnites, the zincian spinel from Siedlimowice falls into the first field.

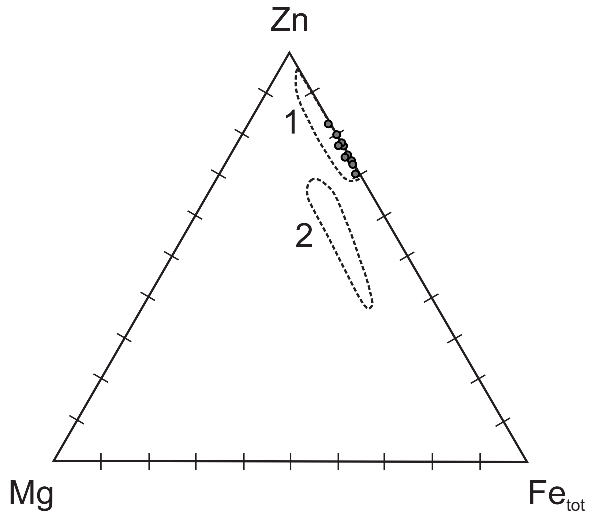

Fig. 1. Composition of gahnite from Siedlimowice in terms of Mg, Zn and total Fe molecular proportions. Fields for igneous (1) and metamorphic (2) associations are marked after Batchelor and Kinnaird (1984)

The molecular (Zn+Mn)/Al ratio was plotted against the molecular (Fe_{tot}+Mg)/Al ratio (Fig. 2); the plot depicts a complex diadochy between (Zn+Mn) and (Fe+Mg) in the mineral structure (Batchelor, Kinnaird 1984). In the gahnite from Siedlimowice the (Zn+Mn)/Al and (Fe+Mg)/Al ratios range from 0.77 to 0.80 and from 0.22 to 0.24, respectively, placing the analyses within the igneous association field on the line of almost perfect diadochy.

The possibility that earlier investigators and mineral collectors have overlooked the presence of gahnite in Siedlimowice seems highly improbable due to its distinctive appearance. This and the fact that the gahnite-bearing pegmatite fragments are very rare in the quarry suggest its local and spatially restricted occurrence in the pegmatite veins. This hypothesis has arisen from our failure of identifying the garnet-bearing pegmatite in the quarry walls. Most probably it was completely exploited during quarring.

Discussing the origin of the zincian spinel studied, our observations that fragments of the pegmatite containing gahnite are devoid of larger garnet crystals and the data of Janeczek and Sachanbiński (1989) showing elevated contents of Zn in some garnets must be considered. Combination of the two suggests that the formation of the zincian spinel was controlled by local changes in chemistry of the pegmatite fluid, such as variations of Zn/Fe ratio, variations of oxygen fugacity, etc., they may have resulted in the crystallisation of gahnite at the expense of garnet.

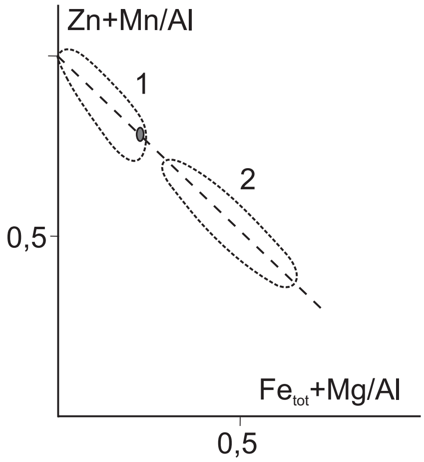

Fig. 2. Plot of the (Zn + Mn)/Al vs. (Fe_{tot} + Mg)/Al molecular ratios depicting a complex (Zn, Mn) – (Fe, Mg) substitution in gahnite from Siedlimowice (dark spot). Fields for igneous (1) and metamorphic (2) associations are marked after Batchelor, Kinnaird (1984)

The presence of a tabular gahnite crystal within a muscovite aggregate may indicate that a part of the spinel was formed in the process of biotite muscovitization, which was described as taking part in the formation of some garnets (Janeczek, Sachanbiński 1989). Nonetheless, further research is needed to unravel the question of detailed geochemical conditions of the gahnite formation; finding the gahnite-bearing pegmatite *in situ* would be especially fruitful in drawing sound conclusions.

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GAHNIT Z SIEDLIMOWIC (MASYW GRANITOWY STRZEGOM-SOBÓTKA, SW POLSKA)

Streszczenie

W czynnym łomie granitu dwułyszczykowego w Siedlimowicach, położonym około 10 km na północny-wschód od Świdnicy, natrafiono na fragmenty pegmatytu żyłowego zawierającego kryształy ciemnozielonego spinelu. Wykształcony w postaci oktaedrów spinel tkwił w środkowej części pegmatytu złożonego ze skalenia potasowego, plagioklazu, kwarcu i muskowitu z podrzędnymi ilościami chlorytu i biotytu oraz akcesorycznym granatem, berylem, kolumbitem i cyrkonem. Badania składu chemicznego oraz analizy rentgenowskie pozwoliły określić minerał jako gahnit o składzie $(Zn_{6.1}Fe_{1.8}Mn_{0.1})(Al_{15.8}Fe_{0.2})O_{32}$ oraz następujących parametrach komórki elementarnej: a = 8.1018 ± 0.008 Å, V = 531.787 ± 0.156 Å^3. Skład chemiczny badanego spinelu jest typowy dla gahnitu z granitoidowych pegmatytów ziem rzadkich. Powstanie gahnitu najprawdopodobniej związane było z lokalnymi zmianami warunków krystalizacji pegmatytu, takimi jak zmiany lotności tlenu lub zawartości Zn/Fe w stopie pegmatytowym.