Gahnite-bearing marbles and their significance for regional classification of the eastern part of the Bohemian Massif

Mramory s gahnitem a jejich význam pro regionální členění východní části Českého masivu (Czech summary)

(4 text-figs.)

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Gahnite-bearing marbles in the Polička Unit and in the Hraničná Group were recognized as a distinct mineralogical and geochemical type of the marbles within the Bohemian Massif, typically rich in Zn and Mn (Fe). Gahnite seems to be the important Zn-carrier. Conditions of its origin are not explained sufficiently due to the simple mineral assemblages Cal+Dol+Tr+Phl+Di and its large stability field. The likely process of gahnite formation seems to be its crystallization from Zn, released during metamorphism from carbonate minerals, under conditions of a relatively high activity of Al in metamorphic fluids. Remarkably similar features of the studied marbles - lithology, chemical and mineral compositions, similar sulphide and Fe-oxide minerals, concentration and composition of gahnite - suggest the Polička Unit is closely related to the Hraničná Group (Staré Město Unit). Consequently, the Polička Unit may be lithologically a part of the Lugicum, which includes the Hraničná Group (Staré Město Unit).

Key words: gahnite, marbles, chemical composition, regional classification, Polička Unit, Hraničná Group, Lugicum, Bohemian Massif

Introduction

Marbles of the Polička Unit and the Hraničná Group, Staré Město Unit, are characterized by considerably increased Zn-contents relative to marbles from the other regions of the Bohemian Massif (e.g. Babčan 1962, Mrázek 1987, Novák 1987). Beside very rare sphalerite, which only locally occurs at isolated ore bands, gahnite seems to be the main Zn-carrier in silicate-poor marbles; it may locally compose several vol. % of the carbonate rocks. The composition of Zn-bearing spinels in marbles varies from Zn-poor spinel to zincian spinel with almost 50 mol. % of the gahnite component (Ulrych 1971, Němec 1973, this work), whereas, gahnite from marbles in the Polička Unit (Trhonice Marbles) and Hraničná Group is rather close to the end-member. The gahnite-bearing marbles are discussed in the present paper including their geological position and significance for regional classification of the eastern and northeastern parts of the Bohemian Massif.

Geological setting

Marbles are typical subordinate members of rock sequences in both studied regions. Marble bodies, up to 40 m thick and 1 km long, occur in the Polička Unit in a narrow NW-trending belt about 10 km long, from Ubušínek in the southernmost part through Trhonice and Sedliště to Borovnice in the N (Fig. 1). Due to their lithology, mineral assemblages and particularly chemical composition, these marbles were classified as a lithostratigraphically distinct member of the Polička Unit - Trhonice Marbles (Novák 1987). Marbles are hosted in biotite to muscovite-biotite gneiss with sillimanite and spatially associated with subordinate metabasites and calc-silicate rocks (Mísař 1960, 1963; Slobodník - Hladíková 1994), which may locally form thin bands within the marbles. A significant foliation of marbles is marked by flakes of phlogopite and thin bands of variable silicate rocks. Disseminated and banded sulphide ore consisting of pyrite, sphalerite, galenite, chalcopyrite and baryte was studied from the locality Sedliště (Slobodník - Hladíková 1994), but gahnite was not mentioned in any of the studied mineral assemblages by these authors. Bands and isolated grains of magnetite and rare hematite also were found at some localities of the Trhonice Marbles, particularly in Sedliště.

Massive, mostly silicate-poor marbles with the mineral assemblage Cal+Tr+Phl+Dol+Di are located NE of the Trhonice Marbles near Bystré. They are distinct from the Trhonice Marbles in their lithology, mineral assemblages and chemical composition, and gahnite is typically absent (Novák 1987).

Marbles of the Hraničná Group are similar to those of the Trhonice Marbles. Marble bodies up to 10 m thick and several hundred m long are hosted in quartz-rich biotite gneiss with sillimanite and garnet (Litochleb 1974, Skácel 1981). They form a narrow N-trending belt about 12 km long; typical occurrences are concentrated particularly in the Hraničná vicinity (Fig. 2) (Skácel 1995). Marbles are locally silicate-rich, grading from silicate-poor marbles to banded carbonate-silicate rocks with abundant magnetite and minor to accessory gahnite, franklinite, hematite, sulphides (sphalerite, galenite, pyrhotite, pyrite, chalcopyrite) and baryte. Gahnite also locally occurs in silicate-poor parts of the marble bodies as isolated subhedral grains (Litochleb 1972, 1973, 1974).

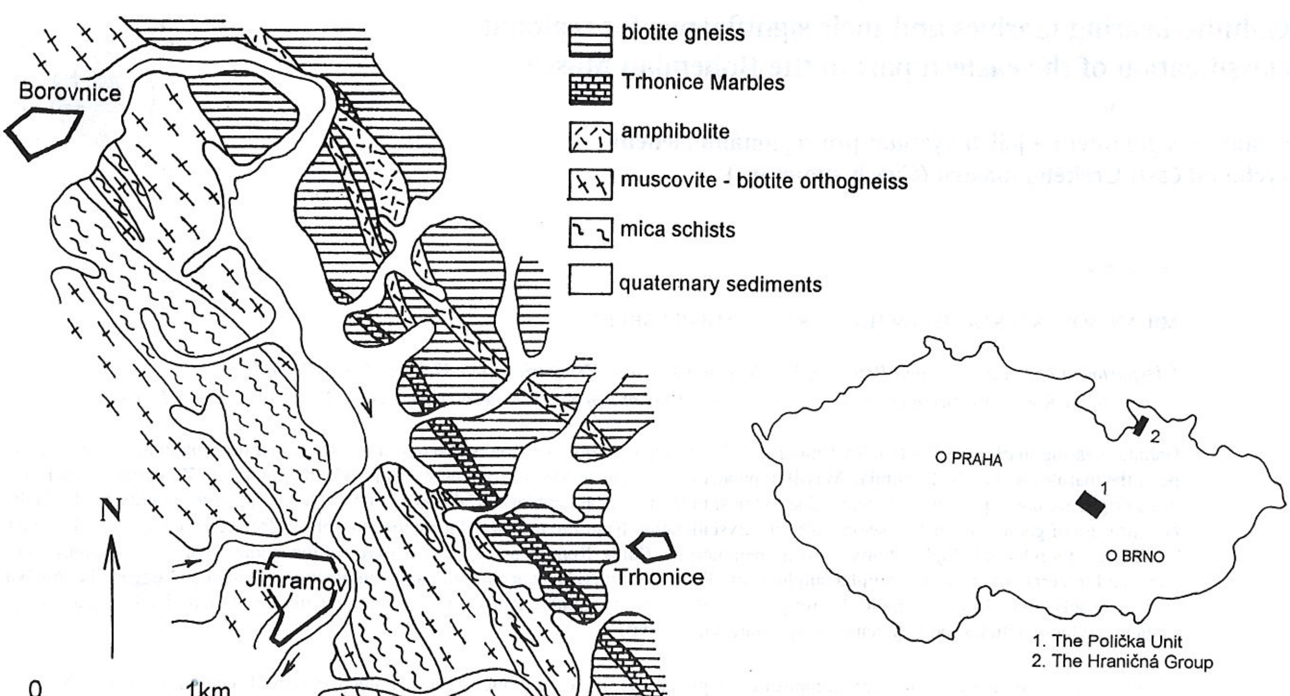

Fig. 1. Geological setting of the Polička Unit. Modified from Mísař (1963)

A distinct type of marbles with the mineral assemblage Dol+Cal+Tr+Phl+Di is located in the eastern part of the Hraničná Group (locality Skorošice). They are massive to banded, mostly silicate-poor and gahnite-free. They fairly resemble in their lithology, mineral assemblages and chemical composition the marbles from Bystré (Polička Unit) described above.

Chemical composition of the gahnite-bearing marbles

The Trhonice Marbles typically show calcite-dominant composition (MgO < 2.5 wt. %), only locally dolomite predominates over calcite (Vocilka 1956, Novák 1987). Low SiO_2 (2-5 wt. % SiO_2) and Fe contents (FeO < 0.36 wt. %) are typical; minor elements include Mn (up to 0.15

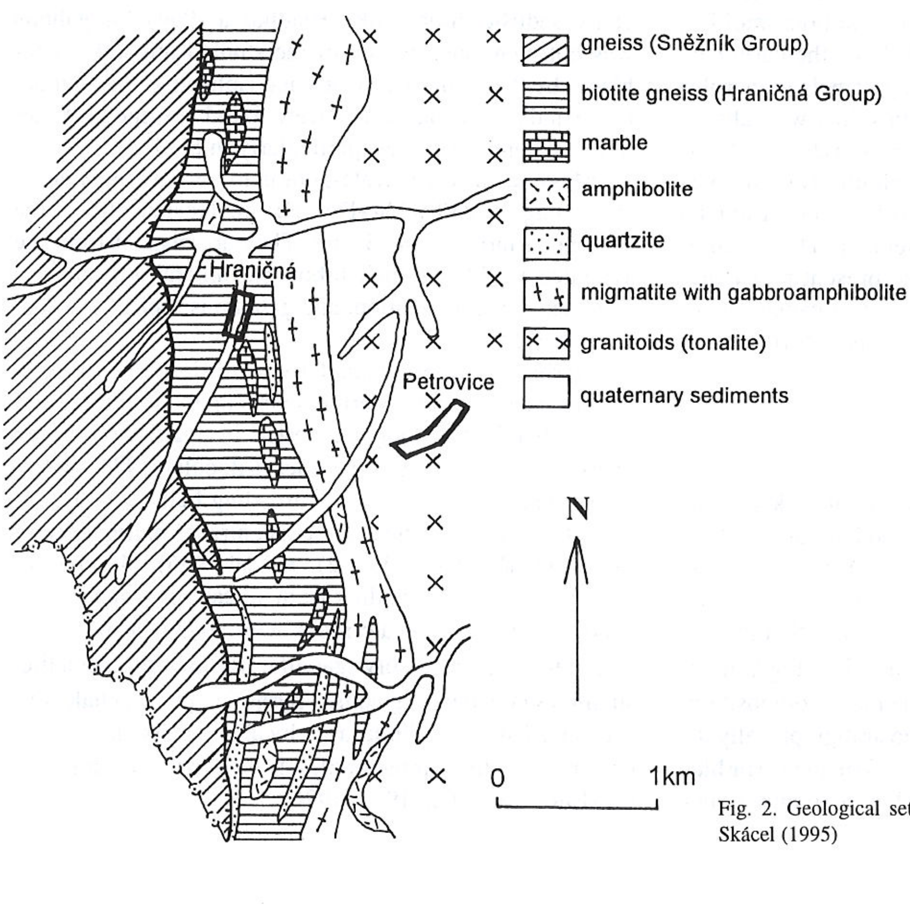

Fig. 2. Geological setting of the Hraničná Unit. Modified from Skácel (1995)

Table 1. Chemical composition of marbles from the Polička Unit

	1	2	3	4	5	6	7
SiO_2	0.43	0.30	2.03	5.03	0.25	0.53	0.74
TiO_2	0.02	0.01	0.01	0.06	0.01	0.01	0.01
Al_2O_3	0.25	0.04	0.22	1.12	0.22	0.25	0.39
Fe_2O_3	0.18	n.d.	0.00	0.27	0.11	0.20	0.28
FeO	0.07	0.27	0.36	0.21	0.07	0.07	0.19
MnO	0.046	0.126	0.132	0.100	0.142	0.127	0.146
MgO	2.06	1.56	2.43	0.79	0.82	1.43	2.23
CaO	52.83	53.65	51.95	50.56	54.50	53.37	52.15
NA_2O	0.03	0.03	0.02	0.05	0.02	0.02	0.03
K_2O	0.04	0.01	0.03	0.44	0.02	0.03	0.03
P_2O_5	0.03	0.02	0.02	0.06	0.01	0.03	0.01
CO_2	43.07	43.61	42.38	40.44	43.64	43.56	42.96
H_2O^+	0.51	n.d.	0.08	0.38	0.06	0.09	0.60
H_2O^-	0.07	0.05	0.06	0.22	0.14	0.07	0.16
TOTAL	99.63	99.77	99.72	99.73	100.01	99.78	100.08
				ppm			
Sr	100	140	140	120	100	110	90
Zn	460	420	3900	1500	2080	2520	1070

1 - Ubušínek
2, 3, 4 - Trhonice
5, 6 - Sedliště
7 - Borovnice
(Novák 1987)

wt. % MnO) and particularly Zn (up to 3900 ppm Zn) (Table 1).

Dolomite marbles (MgO about 17 wt. %) apparently predominate over calcite marbles in the Hraničná Group; SiO_2 content is variable from 2 to 8.5 wt. % SiO_2, the rocks with silicates > carbonates were not investigated in detail. Significantly increased Fe contents (up to 3.28 wt. % FeO and up to 1.61 wt. % Fe_2O_3) relative to the Trhonice Marbles are typical, however, the MnO (up to 0.15 wt. %) and Zn contents (up to 3925 ppm Zn), are almost equal to those in the Trhonice Marbles (Table 2). Chemical composition of marbles in Hraničná published by Babčan (1962) is very similar to the data presented in this paper. A strong pink fluorescence was found in the Trhonice Marbles and in some marbles of the Hraničná Group, indicating presence of Mn and Pb cations in the calcite (dolomite) structure (Slačík 1975).

Diagrams in Fig. 3 illustrate MnO versus Zn ratios in the studied gahnite-bearing marbles; the MnO/Zn ratio was empirically recognized to be useful for such classification (Novák 1987). The gahnite-bearing marbles are significantly distinct from the other marbles in both regions examined, but the positions of the Trhonice Marbles and marbles from the Hraničná Group are almost equal in the diagrams (Fig. 3A, B).

Isotopic compositions of marbles in Sedliště (Trhonice Marbles) and marbles from Hraničná were studied by Slobodník - Hladíková (1994) and Hladíková et al. (1993). The isotopic data fall within $\delta^{13}C$ range typical of sedimentary limestones at both localities. The low $\delta^{18}O$ values (Hraničná) can be ascribed to the metamorphic processes (Hladíková et al. 1993).

Table 2. Chemical composition of marbles from the Hraničná Group - the Staré Město Unit

	1	2	3	4	5
SiO_2	1.66	3.34	8.46	1.75	0.70
TiO_2	0.02	0.02	0.07	0.05	0.01
Al_2O_3	0.74	0.46	1.94	1.28	0.22
Fe_2O_3	0.38	0.19	0.41	1.61	0.11
FeO	1.35	0.96	1.25	3.28	0.21
MnO	0.140	0.106	0.124	0.094	0.04
MgO	17.30	17.20	16.50	17.87	2.22
CaO	33.37	33.46	30.54	29.81	52.51
Na_2O	0.02	0.02	0.07	0.02	0.01
K_2O	0.06	0.04	0.39	0.10	0.08
P_2O_5	0.05	0.04	0.08	0.21	0.03
H_2O^+	1.64	1.33	1.80	1.19	n.d.
H_2O^-	0.10	0.07	0.16	0.07	0.09
Corg	n.d.	n.d.	n.d.	n.d.	0.02
SO_3	0.01	0.10	0.08	0.01	n.d.
l. ign.	43.37	42.89	38.37	42.51	43.67
TOTAL	100.21	100.23	100.24	99.85	100.01
			ppm		
Ba	62	50	162	86	79
Sr	142	135	136	130	173
Zn	2056	1490	2125	3925	439
Pb	157	184	220	1210	205

1, 2, 3 - Hraničná North,
4 - Hraničná Fe-ore deposit,
5 - Petrovice

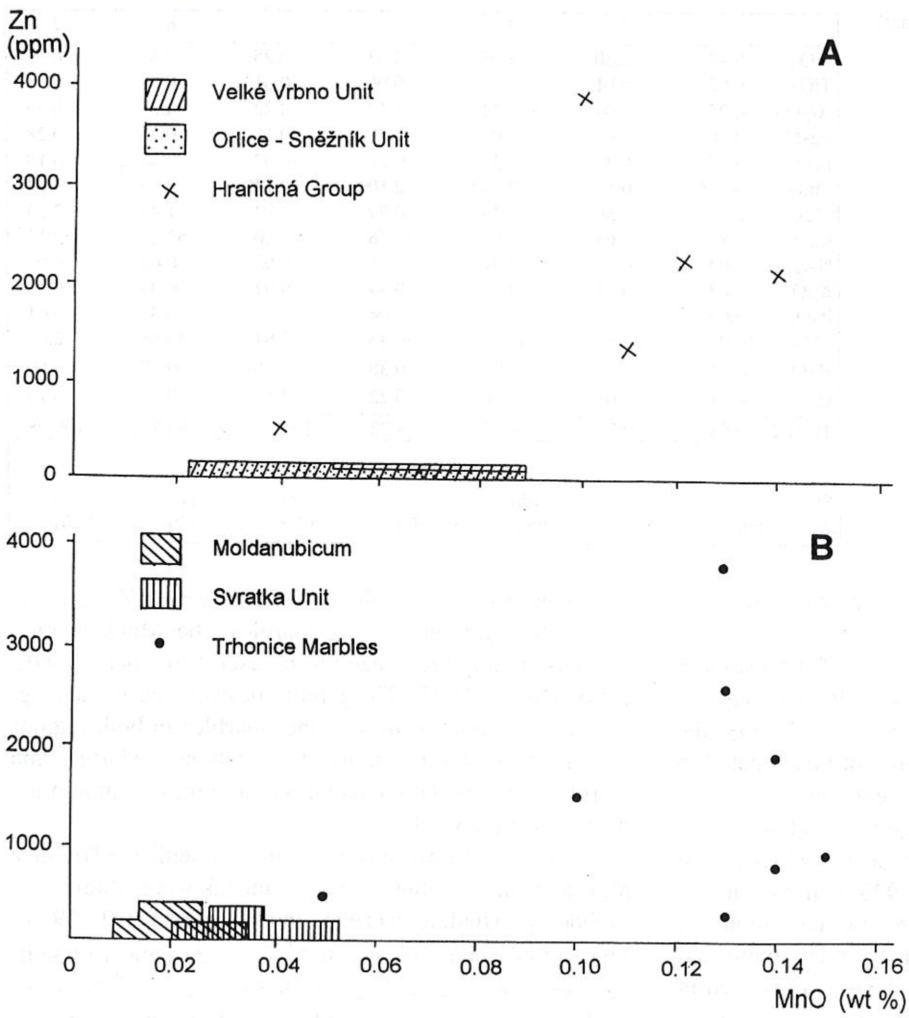

Fig. 3. MnO versus Zn in marbles of the eastern part of the Bohemian Massif
A - Hraničná Group, the Orlice-Sněžník Unit and the Velké Vrbno Unit;
B - Trhonice Marbles and Moldanubicum, the Svratka Unit

Mineral assemblages of the gahnite-bearing marbles

The mineral assemblage Dol+Cal+Tr+Phl+Di, typically found in silicate-poor gahnite-bearing marbles, exhibits Cal > Dol (Trhonice Marbles) and Dol > Cal (Hraničná Group), respectively. Quartz, amphibole and titanite are typical accessory minerals; forsterite, feldspars and tourmaline (dravite to uvite) were exceptionally found in the Trhonice Marbles (Novák 1988, unpublished data of the authors), epidote and apatite in the Hraničná Group (Litochleb 1974). Other non-silicate minor to accessory minerals include: oxides - magnetite, gahnite, franklinite (Hraničná), hematite, and sulphides - sphalerite, galenite, pyrite, chalcopyrite, pyrhotite (Hraničná). A retrograde stage of metamorphism is represented by replacement of phlogopite by chlorite found at both localities, replacement of gahnite by chlorite+sphalerite in Hraničná (Litochleb 1972, 1975), and forsterite by antigorite in the Trhonice Marbles (Novák 1988, Slobodník - Hladíková 1994).

The mineral assemblage Dol+Cal+Phl+Tr+Di, typical in gahnite-bearing marbles in both regions, as well as the presence of gahnite, do not allow a reliable estimate of the PTX-conditions of metamorphism, because the mineral assemblages and gahnite are stable in a broad range of PTX-conditions (Eggert - Kerrick 1981, Spry 1982). The presence of the rare assemblage forsterite+calcite in the Trhonice Marbles indicates, that the temperature could reach values higher than 700 °C for P_{fluid} = 600 MPa and X_{CO_2} from 0.2 to 0.8. These marbles probably underwent slightly higher degree of metamorphism relative to the Hraničná Group. However, the PTX-conditions; T = 550-700 °C for P_{fluid} = 600 MPa and X_{CO_2} = 0.2-0.8, derived from the mineral assemblages Cal+Dol+Tr+Phl±Di (Eggert - Kerrick 1981), are slightly lower than those given for the metamorphism of metabasites in the central part of the Staré Město Unit (Štípská et al. 1996).

Silicate-rich marbles from Hraničná exhibit mineral assemblages different from those of silicate-poor gahnite-bearing marbles. Gahnite forms subhedral zoned grains with Zn-enriched rims, concentrated particularly in magnetite-rich bands. Litochleb (1975) considered that gahnite and hematite originated during metamorphic event later than the main stage of metamorphism, which produced the main mineral assemblage including magnetite, franklinite and most silicates and sulphides.

Chemical composition of gahnite and other minerals

Chemical composition of Zn-bearing spinels in marbles was studied only exceptionally (Spry 1982); spinel with the gahnite and hercynite components up to 20 mol. % were found in the Moldanubicum (Ulrych 1971, Němec 1973). Detailed study of Zn-enriched spinels in the Strážek Moldanubicum (Fig. 4) yielded up to 50 mol. % of the gahnite and up to 20 mol. % of the hercynite components. Such composition is distinct from those in the Trhonice Marbles and in the Hraničná Group (Fig. 4).

Gahnite from both studied regions is close to the end-member, with up to 92 mol. % of the gahnite component (Fig. 4). However, distinct compositions were also found among the studied localities. Gahnite from Ubušínek, Borovnice and most samples from Trhonice exhibit Mg > Fe, gahnite from Sedliště and exceptionally from Trhonice (both localities are from the Trhonice Marbles) is characterized by Mg = Fe to Mg < Fe, and gahnite from Hraničná typically shows Mg < Fe to Mg << Fe (Fig. 4). Gahnite with Mg < Fe is mostly associated with magnetite (Hraničná) or Zn-rich magnetite (Sedliště). Manganese contents are mostly below the detection limit of the electron microprobe. The Al contents incorporated in the B-site of the spinel structure mostly correspond to the theoretical value 2 (Table 3), hence substitutions of divalent cations in the A-site seem to be dominant. Most of gahnite grains display zonality with Zn-enriched rims, typical for Zn-spinel from metamorphosed massive-sulphide deposits (Spry 1985). Representative compositions of gahnite, associated Zn-rich magnetite and franklinite are given in Table 3.

Tremolite, diopside and forsterite are close to their respective end-members (Table 4), however, their X_{Mg} ratios and the X_{Mg} ratios of phlogopite are mostly lower if compared to those in the Svratka Unit and Strážek Moldanubicum as well as marbles in Bystré (Novák 1988). Forsterite from Trhonice is Mn-, Fe-enriched, whereas other silicates are mostly Mn-poor.

Formation of gahnite

Gahnite is a typical minor to accessory mineral of zinc-sulphide ore deposits, and it is locally also reported from other metamorphosed rocks such as metapelite, orthogneiss, metapegmatite, quartzite and marble. Gahnite is stable over a broad range of PTX-conditions from lower amphibolite to granulite facies. It can form by the following processes: (i) desulphurisation of sphalerite, (ii) precipitation from a metamorphic-hydrothermal fluid, e.g., formation from Zn released during metamorphic reaction of Zn-bearing carbonates or Zn-bearing silicates such as dehydratation of Zn-staurolite; (iii) replacement of a primary ZnO phase (Plimer 1977, Dietvorst 1980, Hicks et al. 1985, Spry 1982, 1985).

Euhedral to subhedral grains of gahnite are embedded in calcite and/or dolomite; silicate minerals are mostly absent in the Trhonice Marbles or rare in silicate-poor marb-

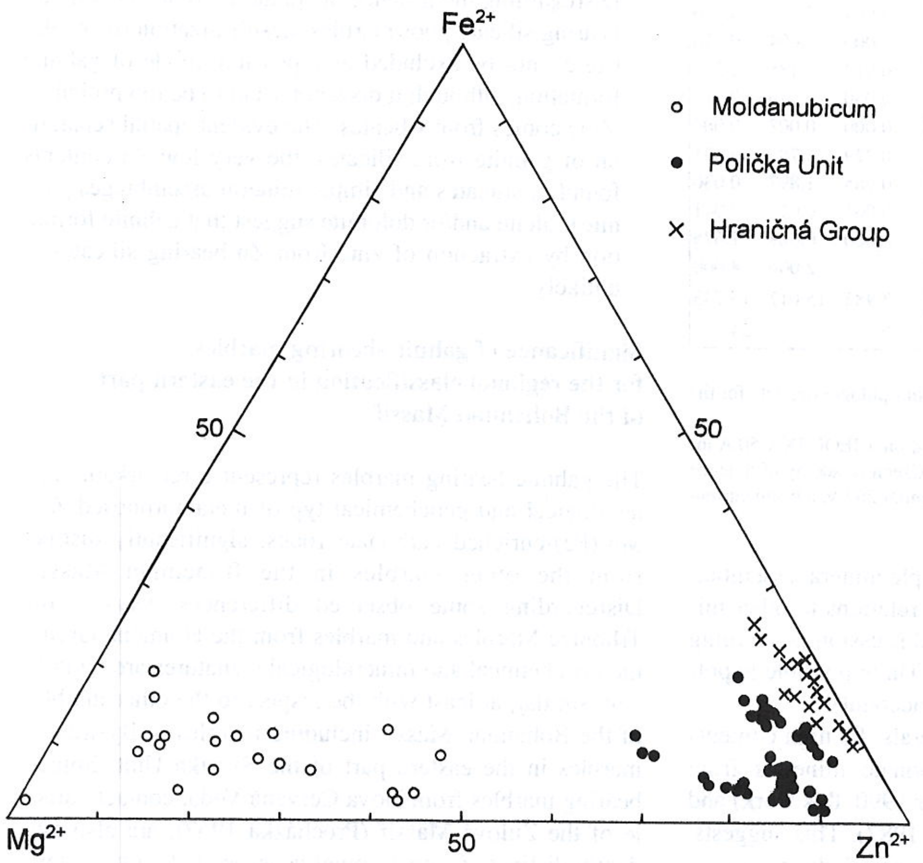

Fig. 4. Compositions of Fe-Zn-Mg spinels from marbles of the Bohemian Massif
Based on the following data: Moldanubicum - Ulrych (1971), Němec (1973), this work; Polička Unit and Hraničná Group - this work

	1	2	3	4	5	6	7	8	9	10	11	12
TiO_2	0.07	0.01	0.07	0.06	0.18	0.00	0.00	0.00	0.02	0.06	0.02	0.41
Al_2O_3	57.38	57.45	57.69	56.70	57.09	0.32	57.18	56.16	56.05	56.16	56.80	2.81
Fe_2O_3	-	-	-	-	-	69.01	-	-	-	-	-	63.24
FeO	2.91	1.74	6.59	0.72	2.82	26.12	6.70	4.38	8.92	8.28	7.69	-
MnO	0.02	0.03	0.00	0.07	0.08	0.23	0.00	0.00	0.07	0.11	0.08	0.30
MgO	2.53	2.01	2.30	1.95	2.61	0.59	1.07	0.01	0.73	0.45	0.15	0.24
ZnO	37.89	39.66	34.34	40.93	37.28	4.38	35.26	39.97	34.08	35.30	36.12	33.85
TOTAL	100.80	100.90	100.99	100.43	100.06	100.65	100.21	100.52	99.87	100.36	100.86	100.85
Ti^{4+}	0.002	0.000	0.002	0.001	0.004	0.000	0.000	0.000	0.000	0.001	0.000	0.012
Al^{3+}	1.993	2.001	1.994	1.993	1.993	0.014	2.007	1.999	1.988	1.989	2.001	0.129
Fe^{3+}	-	-	-	-	-	1.986	-	-	-	-	-	1.856
Fe^{2+}	0.072	0.043	0.162	0.018	0.070	0.835	0.167	0.111	0.225	0.208	0.192	-
Mn^{2+}	0.000	0.001	0.000	0.002	0.002	0.007	0.000	0.000	0.002	0.003	0.002	0.010
Mg^{2+}	0.111	0.089	0.101	0.087	0.115	0.034	0.048	0.000	0.033	0.020	0.007	0.014
Zn^{2+}	0.824	0.865	0.744	0.901	0.815	0.124	0.775	0.891	0.757	0.783	0.797	0.975
CATSUM	3.002	2.999	3.001	3.002	3.000	3.000	2.997	3.001	3.005	3.004	2.999	2.996

Table 3. Representative chemical compositions of spinel group minerals

Formula based on 4 O. Polička Unit: 1- Sedliště-core, 2 - Sedliště-rim, 3 - Trhonice, 4 - Ubušínek, 5 - Borovnice (1-5 gahnite), 6 - Sedliště (Zn rich magnetite); Hraničná Group: Hraničná, (7-11 - gahnite, 12 - franklinite)

Table 4. Chemical composition of associated minerals

	Trhonice				Hraničná		
	Fo	Di	Tr	Phl	Di	Tr	Phl
SiO_2	39.62	54.69	57.88	42.38	55.71	58.84	42.15
TiO_2	0.04	0.00	0.05	0.92	0.00	0.04	0.74
Al_2O_3	0.00	0.07	0.37	13.04	0.29	1.17	13.41
FeO	8.68	1.02	1.46	2.22	1.67	1.51	2.69
MnO	0.46	0.11	0.13	0.01	0.00	0.07	0.03
MgO	51.21	19.28	25.51	24.97	17.29	23.86	26.01
CaO	0.00	24.83	13.30	0.00	25.50	13.13	0.20
Na_2O	0.00	0.02	0.10	0.51	0.01	0.11	0.15
K_2O	0.00	0.04	0.04	9.93	0.00	0.17	9.34
H_2O^*	-	-	2.22	4.23	-	2.23	4.27
TOTAL	100.01	100.05	101.06	98.21	100.47	101.13	98.99
Si^{4+}	0.971	1.978	7.821	6.011	2.008	7.915	5.926
Ti^{4+}	0.001	0.000	0.005	0.098	0.000	0.004	0.078
Al^{3+}	0.000	0.003	0.059	2.180	0.012	0.185	2.222
Fe^{2+}	0.178	0.031	0.165	0.263	0.050	0.170	0.316
Mn^{2+}	0.010	0.004	0.015	0.001	0.000	0.008	0.004
Mg^{2+}	1.870	1.040	5.138	5.280	0.929	4.785	5.451
Ca^{2+}	0.000	0.962	1.925	0.000	0.985	1.892	0.030
Na^{+}	0.000	0.001	0.026	0.140	0.001	0.029	0.041
K^{+}	0.000	0.002	0.007	1.797	0.000	0.029	1.675
H^{+}	-	-	2.000	4.000	-	2.000	4.000
CATSUM	3.030	4.021	15.161	15.770	3.985	15.017	15.743
O	4	6	24	24	6	24	24

* Determined by stoichiometry

Fo - forsterite, Di - diopside, Tr - tremolite, Phl - phlogopite; data for the Trhonice marble from Novák (1988).

Electron microprobe analyses were performed on a JEOL JXA-50 A instrument at the Geological Institution of the Czech Academy of Science under following conditions: accelerating potential 20 kV, a beam current 15 mA, counting time 20 s

les of the Hraničná Group. Such simple mineral assemblage as well as the absence of spatial relations to other minerals except carbonates make the discussion concerning formation of gahnite quite difficult. Three possible hypotheses may be discussed (taken into account):

1. Zinc comes from carbonate minerals. Its high contents were found particularly in carbonate minerals from Hraničná (Babčan 1962, Bauchner 1990, this work) and in the Trhonice Marbles (Novák 1987). This suggests, that gahnite formed from Zn, released during metamorphism particularly from carbonate minerals, under conditions of relatively high activities of Al and locally Fe (Hraničná) in metamorphic fluids. Chemical composition of gahnite close to the theoretical formula $ZnAl_2O_4$ at most localities, simple mineral assemblage gahnite+calcite and/or dolomite, and absence of Zn-enriched silicates significantly support such idea.
2. The gahnite originated due to desulphurisation of sphalerite. The absence of sphalerite relics in gahnite-bearing marbles but its presence in sulphide-rich and locally gahnite-free assemblage (Litochleb 1975, Slobodník - Hladíková 1994) may reflect only a strong variation in activity of S within a single marble body. Disregarding the absence of sphalerite relics in gahnite-bearing silicate poor marbles, desulfidization of sphalerite cannot be excluded as a possible mode of gahnite formation, although it does not seem to be too probable.
3. Zinc comes from silicates. The evident spatial separation of gahnite from silicates, the very low Zn-contents found in silicates and simple mineral assemblages gahnite+calcite and/or dolomite suggest that gahnite formation by extraction of zinc from Zn-bearing silicates is unlikely.

Significance of gahnite-bearing marbles for the regional classification in the eastern part of the Bohemian Massif

The gahnite-bearing marbles represent a remarkable mineralogical and geochemical typ of metamorphosed Zn-, Mn-(Fe)-enriched carbonate rocks, significantly distinct from the other marbles in the Bohemian Massif. Disregarding some observed differences between the Trhonice Marbles and marbles from the Hraničná Group, the geochemical and mineralogical signatures are remarkably similar, at least with the respect to the other marbles of the Bohemian Massif including marbles in Bystré and marbles in the eastern part of the Svratka Unit. Spinel-bearing marbles from Nová Červená Voda, contact aureole of the Žulová Massif (Procházka 1967), are also evidently distinct. Zn-poor spinel is associated with forsterite, phlogopite and pargasite, and formed in zoned metasomatic veins very likely related to the intrusion of the Žulová Massif (Novák, unpubl. data). According to the least authors knowledge, gahnite-bearing marbles examined are similar only to the Zn-, Fe-, Mn-ore deposits Franklin and Sterling Hill, N. Jersey, USA (compare Baker - Buddington 1970, Frondel - Baum 1974).

The classification of the Polička Unit, as a regional unit within the Bohemian Massif, is contraversial for a long time. It was considered a part of: the Svratka Unit (e.g., Svoboda et al. 1964), Bohemicum (e.g., Mísař et al. 1983, Mísař - Dudek 1993, Chlupáč - Vrána 1994), and Lugicum (e.g., Kodym - Svoboda 1950, Svoboda - Zoubek 1950, Suk 1987). Based on chemical composition, mineral assemblages and lithology of marbles, the Trhonice Marbles were recognized to be significantly distinct from the marbles in the adjacent Svratka Unit (Novák 1987). This distinction and remarkable similarities with the marbles of the Hraničná Group indicate the Polička Unit to be a part of the Lugicum. Similarities in the overall geological setting of the Polička Unit and the Staré Město Unit (e.g. abundant tonalitic rocks, two distinct marble groups, similar rock sequence and degree of metamorphism), lithological and metamorphic differences between the Svratka Unit and adjacent Polička Unit (Němec 1968), and significant tectonic border between both units (Herčík et al. 1963, Šouba - Duda 1975, Mísař - Dudek 1993) support such idea. Nevertheless, additional geological studies are required, in order to provide further evidences for the classification, proposed in the present paper.

Conclusions

1. Gahnite marbles in the Polička Unit and Hraničná Group were recognized as a distinct mineralogical and geochemical type of the marbles within the Bohemian Massif.
2. Chemical compositions of gahnite at both studied regions are distinct from those in other marbles of the Bohemian Massif. The authors also did not record any similar occurrences of Zn-spinels with such considerably high Zn-contens in marbles except the Zn-, Mn-, Fe-ore deposits Franklin and Sterling Mine, New Jersey, USA.
3. Formation of gahnite was not explained sufficiently due to very simple mineral assemblages and large stability fields of gahnite and its mineral assemblage. Crystallization of gahnite from Zn released during metamorphism particularly from carbonate minerals combined with of high activity of Al in metamorphic fluids seems to be probable.
4. Remarkably similar features such as lithology, chemical composition and mineral assemblages of the studied gahnite-bearing marbles, the presence of very similar sulphide and oxide ores, and typical gahnite compositions were found in both investigated regions. Consequently, the Polička Unit is suggested to be a part of the Lugicum, corresponding lithologically to the Hraničná Group (Staré Město Unit).

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Mramory s gahnitem a jejich význam pro regionální členění východní části Českého masivu

Mramory s gahnitem poličského krystalinika (trhonické mramory) a staroměstského krystalinika (skupina Hraničné) představují mineralogicky a geochemicky specifický typ mramorů v Českém masivu, vyznačující se relativně vysokým obsahem Zn a Mn (Fe). Jejich typickým znakem je přítomnost Zn-spinelidu, složením blízkého čistému gahnitu, který se vyskytuje v relativně čistých kalcitických i dolomitických mramorech. Zinek byl pravděpodobně vázán v karbonátech a při metamorfóze reagoval v prostředí bohatém Al za vzniku gahnitu. Jednoduchá minerální asociace mramorů Cal+Dol+Tr+Phl+Di odpovídá amfibolitové facii. Široké pole stability gahnitu i uvedené asociace minerálů neumožňují podrobnější diskusi PTX podmínek metamorfózy. Výskyt specifického typu hornin, gahnitových mramorů, v obou litologicky i metamorfně podobných jednotkách naznačuje možnost, že poličské krystalinikum a část staroměstského krystalinika představují části jednoho celku náležejícího k lugiku.