GEOLOGICA CARPATHICA, 42, 4, BRATISLAVA, AUGUST 1991
223–229

MAGNETITE INDICATOR OF GENESIS AND POTENTIAL GRANITOID ORE-BEARING IN THE HODRUŠA-ŠTIAVNICA INTRUSIVE COMPLEX (LATE TERTIARY, WESTERN CARPATHIANS)

JÁN RAJNOHA[1], PETER ANDRÁŠ[1] and TOMÁŠ GREGOR[2]

[1] Geological Institute, Slovak Academy of Sciences, Dept. of Raw Materials, Horná 15, 974 01 Banská Bystrica, Czecho-Slovakia
[2] Geological Institute, Slovak Academy of Sciences, Dúbravská cesta 9, 842 26 Bratislava, Czecho-Slovakia

(Manuscript received May 23, 1990; accepted in revised form September 7, 1990)

Abstract: In the granitoid rocks of the Hodruša-Štiavnica Intrusive Complex there are two magnetite types observed: primary magmatic phenocrysts of idiomorphic or even hypidiomorphic habit of about 0.3 *mm* size and magnetite grain size over 0.3 *mm*. These must have been originated due to the reaction of rock-forming minerals with the melt. Chemical composition of Fe-Ti oxide minerals from granitoid rocks of the regions under study proved their being formed by magnetite which contains magnetite solid solution as well as thin lamellae ilmenite solution. With its chemical composition this magnetite is similar to those from granitoid rocks – products of differentiation of trachyte-andesitic and trachyte-basaltic magma. Ni/Co ratio in the examined magnetites suggests a deeper magma origination under increased oxygen fugacity and original magma alkalinity. Elevated Au and lowered Pb and Zn contents in magnetites support the theory that the Intrusive Complex may have been one of the sources of the metals of base- and precious-metal mineralization in the Hodruša-Štiavnica Intrusive Complex.

Key words: Western Carpathians, Hodruša-Štiavnica Intrusive Complex, granitoids, magnetite, metal mineralization, magnetic susceptibility.

Introduction

According to Konečný et al. (1983), the Hodruša-Štiavnica Intrusive Complex (hereafter HŠIC) represents a complex of intrusive rocks in the area of Banská Štiavnica–Hodruša-Hámre; the rocks show diorite and granodiorite composition. In its central part HŠIC is formed by a granodiorite intrusion, most probably of bell-jar shape (Miháliková et al. 1980), and in the peripheral part by several smaller bodies. HŠIC, situated within underlying pre-volcanic rocks, is ascending onto the surface in the area of Hodruša. In the area of Štiavnica it is present under volcanic complex and has been proved by test boring and groves.

Sampling and treatment methodology

The examined sample material can be divided into three groups. The first group is represented by samples taken from exposures (labelled GRŠ, DRŠ), the second one by material from the workings of the Rosalia Mine, New Shaft and New Drainage Adit (labelled RB, BŠ, NOŠ) and the third group is represented by sample BT-7 from upper hole BT-7, from 916 *m* depth. The weight of the samples was 10 *kg*. Sample locations are given in Fig. 1.

All the samples were tested for their petrophysical features. Magnetic susceptibility was measured with a MA-21 apparatus at Kiev State University and with a KT-5 and KLY-2 apparatuses at the Geological Institute of the Slovak Academy of Sciences in Bratislava.

In sample treatment there was applied a methodology to get monomineralic fraction which was suggested by Veselský and Žabka (1976). Sample material was pounded, concentrated and separated and evaluated by a methodology commonly used with preparation and examination of "artificial schliers". To get pure monomineralic fraction of magnetite there were three methodologies applied: 1) magnetite separation with a hand magnet, 2) magnetite separation with a hand magnet followed by purification under a binocular, 3) magnetite separation with a hand magnet and by dissolution of impurities and mineral compounds (especially those with quartz and amphibole) with hydrofluoric acid.
After the results of trace elements distribution in magnetite being compared, separation with a hand magnet followed by purification under a binocular was found the most convenient methodology.

Then, magnetites were divided into two fractions of grain size: 0.25–0.50 *mm* and below 0.25 *mm*. In this way two magnetite generations were separated with their crystal shape considered as well. Primary development of magnetite is shown by idiomorphic octahedral grain shape (Fig. 2) and size up to 0.25 *mm*. Postmagmatic magnetites are characteristic for idiomorphic and hypidiomorphic texture with marked striation (Fig. 3). Their size usually exceeds 0.3 *mm*.

Total TiO_2 contents in magnetites from the whole bulk of the separated mineral phase were determined by a classic gravimetric analysis (analyst Ernest Walzel). The contents of trace elements were stated by atomic absorption spectrometric analysis (AAS) with an atomic absorption spectrophotometer of Pye–Unicam Ltd. (Philips, model PU-9000 with deuterium background corrector) and by optical emission spectroscopy (OES) with a PGS-2 spectrometer of Carl-Zeiss Jena in a unidirectional current arc.

With particular magnetite samples, distribution of some elements (Ti, Fe, Ca, etc.) was examined with an X-ray microanalyzer JXA-5 (analyst D. Jančula) and Jeol Superprobe 733 (analysts: F. Caňo, P. Siman).

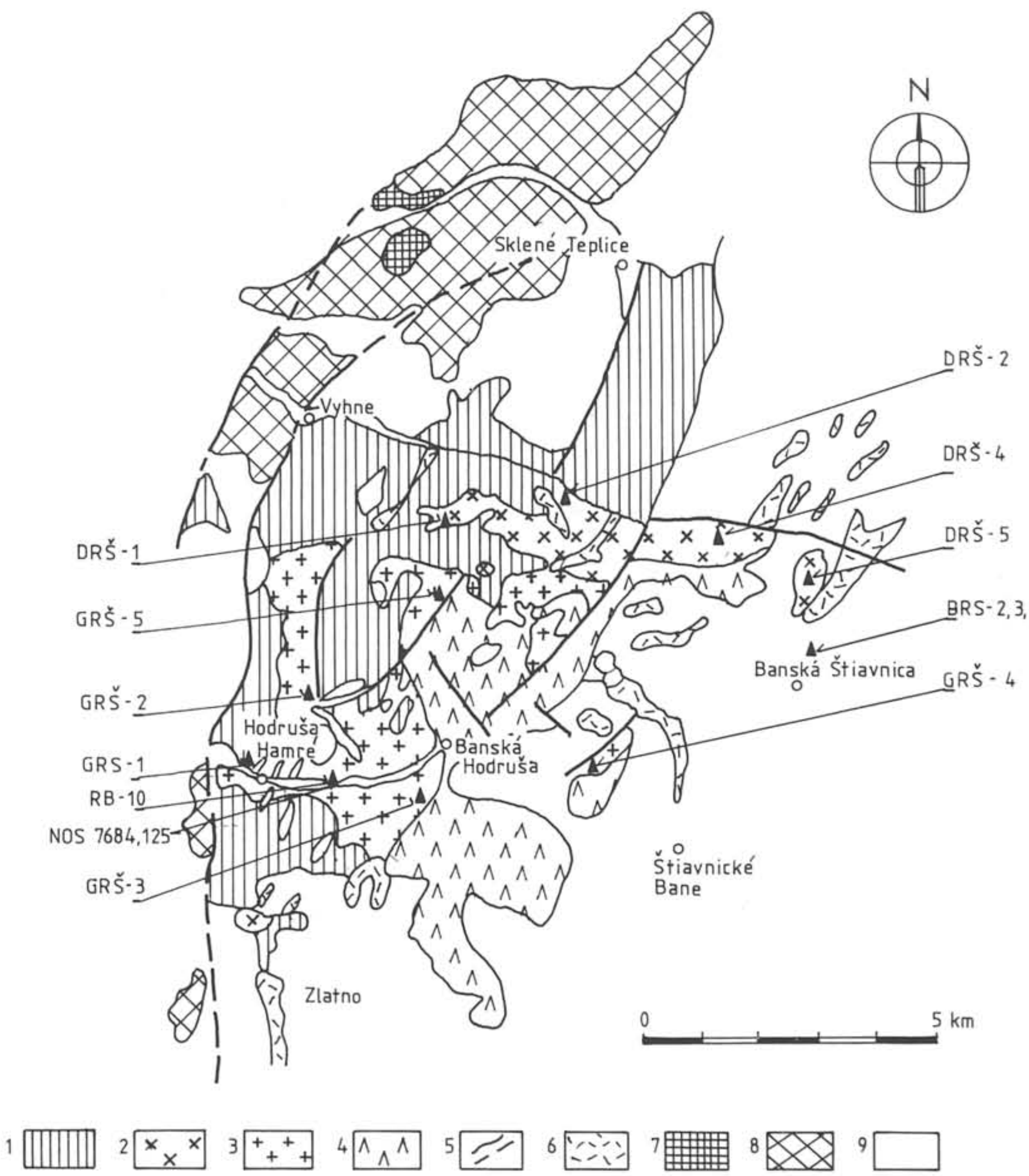

Fig. 1. Schematic geological map of the Banská Štiavnica and Hodruša surroundings.
1 – pre-Neogene fundament rocks; 2 – diorite-gabbrodiorite; 3 – granodiorite; 4 – quartz-dioritic porphyry (sills, localities); 5 – quartz-diorite porphyry (veins); 6 – quartz-diorite porphyry (thick veins); 7 – rhyolites of the Hliník type; 8 – rhyolites of the Kremnica type; 9 – andesites – non-classified (Badenian–Sarmatian).

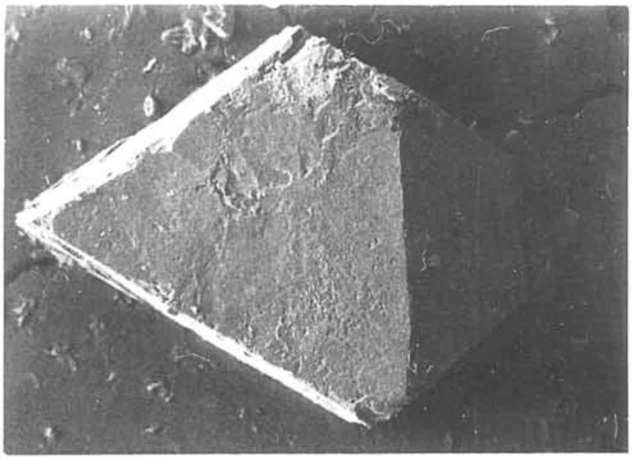

Fig. 2. Octahedral shape of primary magnetite (sample GRŠ-1), magnified 290 × (Photo: I. Holický).

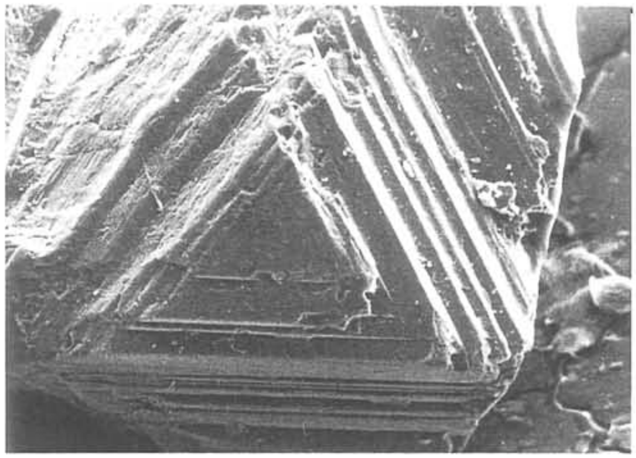

Fig. 3. Octahedral shape of secondary magnetite with striation (detail, sample GRŠ-2), magnified 770 × (Photo: I. Holický).

General characteristics of magnetite

Magnetite is the most widespread accessory mineral in all the examined samples of granitoid rocks. Its contents in granodiorites vary within the range of 9.364–19.129 *g/t*. Lower magnetite contents in diorites are rather strange, they range from 1.808 to 5.996 *g/t*. The lowest magnetite content was found in diorite from the locality of Vindišlajtňa (sample DRŠ-2) and the highest one in diorite from the area of Šobov (sample DRŠ-5).

In granitoid rocks of HŠIC, magnetite most frequently occurs in the shape of irregular granules, less frequently in the form of regular steel-grey or black crystals with octahedral habit. It is typical for its submetallic luster.

In HŠIC granodiorites there were found two genetic types of magmatic Fe-Ti oxides (Šulgan 1986). The first of them is represented by primary magmatic idiomorphic sometimes even hypidiomorphic phenocrysts of about 0.3 *mm* average size. They are enclosed mainly in biotite and amphibole. Less frequently they can be found in plagioclase and K-feldspar as well. The second genetic type of Fe-Ti oxides is formed by small granules occurring in the peripheral parts of amphibole and biotite phenocrysts. The granules must have originated as a result of the reaction of these minerals with the melt (Wones and Eugster 1965; Czamanske and Wones 1973).

In general, all Fe-Ti oxides granules in HŠIC granodiorites are formed by magnetite which besides magnetite solid solution Mt_{ss} contains also thin lamellae, and/or sandwich-shape formations made of ilmenite solid solution Ilm_{ss}. Separated Ilm_{ss} phenocrysts are very rare in granodiorites (less than 0.5 *g/t*) except one sample where Ilm_{ss} content is as high as 2 *g/t*. (Rajnoha 1987).

Porphyric granodiorite variety contains almost homogeneous magnetite granules with a few Ilm_{ss} lamellae (less than 5 % of the total Fe-Ti oxides area). Unlike this, Ilm_{ss} lamella and sandwich contents in non-porphyric granodiorites are much higher (more than 10 %). Irrespective of rock texture, mean TiO_2 content in Fe-Ti oxides from HŠIC granodiorites is about 2 % (Rajnoha 1989). This is a magnetite which contains not only ilmenite solid solution phase but also highly stoichiometric magnetite solid solution Mt_{ss}. Stoichiometric degree with ideal magnetites is 3 while with Mt_{ss} from HŠIC granodiorites it does not exceed 2.9. Mt_{ss} and Ilm_{ss} textures also support the primary origin of accessory magnetites.

Magnetite chemical composition

The results of 24 X-ray analyses of various HŠIC rock types (Tab. 1) show a rather low variability in chemical composition. Magnetite is typical for high TiO_2 contents, as high as 10.75 *wt* % in sample DRŠ-2. The lowest TiO_2 content was found with sample GRŠ-1 (0.68 *wt* %).

All the samples show lowered NiO contents (0–0.006 *wt* %) compared to CoO, the contents of which are of a higher rank, which is proved by AAS and OES analyses (Tabs. 2, 3) and Ni/Co ratio is always lower than 1.

Elevated Cr_2O_3 contents in all the magnetites from HŠIC granodiorites (on average 0.09 *wt* %) support their belonging to the group of basic magma differentiation products.

Chemical composition of magnetites from HŠIC granodiorites is similar to those from granodiorites – differentiation products of trachyte-andesitic and trychyte-basaltic magma (Rub et al. 1988).

In the examined magnetites from granitoids (Tabs. 2, 3), Ti, Mn, Cr, Co, Ni, Cu and Sc contents are close to the mean contents of these elements in the magnetites of intrusive granitoid rocks which are supposed to have originated from magmas of gabbro-diorite-granodiorite rank. The composition of accessoric magnetite from HŠIC granitoids proves its correspondence to a derived granitoid formation that was originated by basic melt differentiation. This presumption is supported also by Ni/Co ratio in the magnetites from the granitoid rocks of the Complex. In the rocks derived from under-crustal and crustal magmas Ni/Co ratio is higher than 1 (Kogarko 1973). Ni/Co ratio in HŠIC magnetites varies within the range of 0.4–0.7 which shows that HŠIC granitoid rocks were formed by gabbroid magma differentiation under mantle conditions of oxygen fugacity and melt alkalinity.

Pb, Zn and Cu contents (10–43 *ppm*, 137–162 *ppm* and 17–45 *ppm* respectively) in magnetites (Tab. 2) are lower than those given for non-productive granitoid rocks

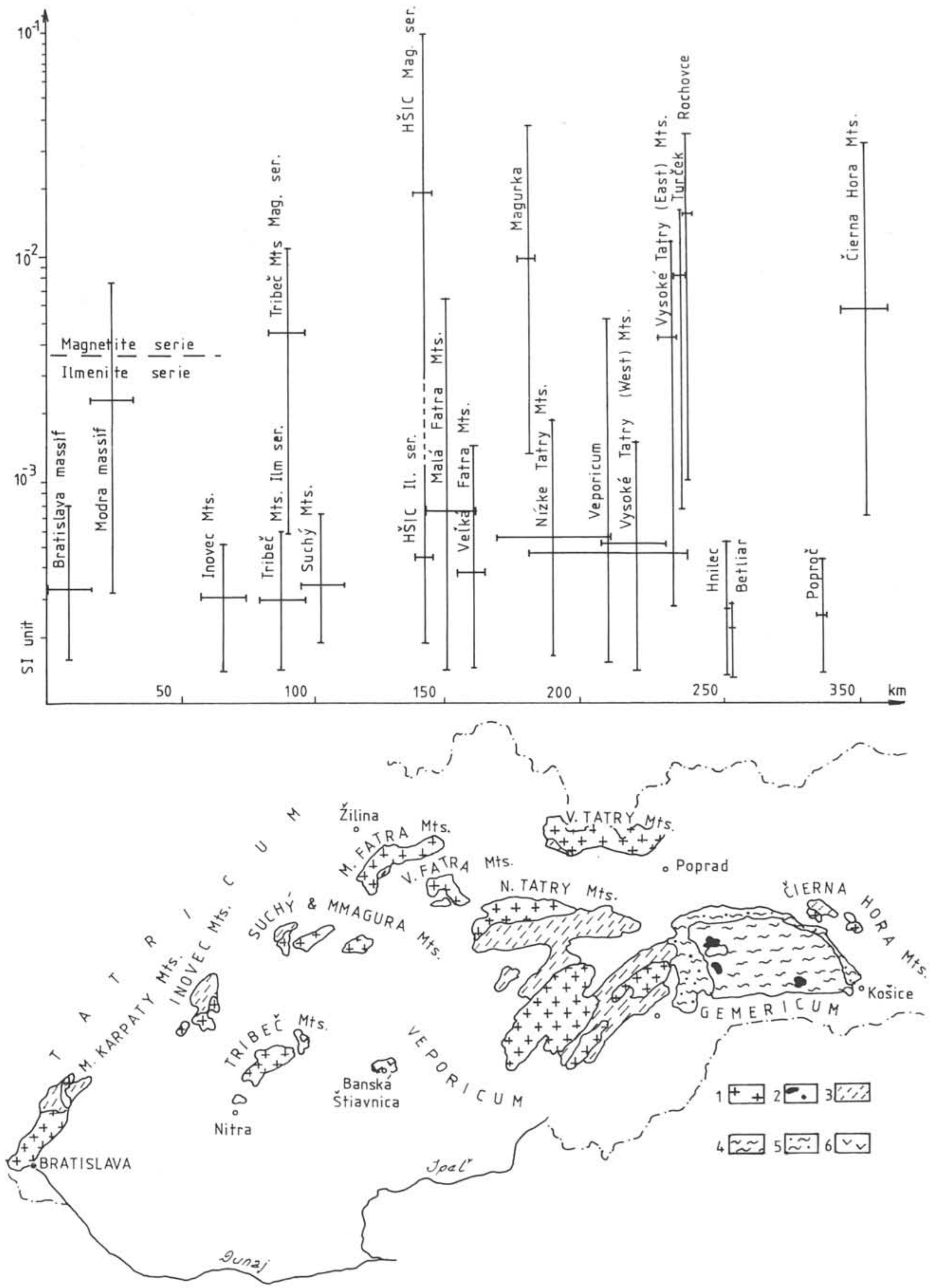

Fig. 4. Magnetic susceptibility of the Western Carpathian granitoids with their geographic dislocation (Gregor, 1990).
1 – Tatricum and Veporicum granitoids; 2 – Gemericum granitoids; 3 – metamorphic mantle of Tatricum and Veporicum granitoids; 4 and 5 – Gemericum metamorphic and sedimentary rocks; 6 – Hodruša-Štiavnica Intrusive Complex (HŠIC).

Table 1. X-ray microanalyses of magnetites from granodiorites and diorites of the Hodruša-Štiavnica Intrusive Complex.

Rock	Sample No.	Location of the analysed points	weight %										Total
			TiO_2	Cr_2O_3	MnO	Fe_3O_4	MgO	Al_2O_3	CaO	CoO	NiO	WO_3	
granodiorite	GRŠ-1	core	1.965	0.049	0.017	94.837	0.000	0.348	0.119	0.099	0.000	0.000	97.444
		rim	0.615	0.048	0.056	95.418	0.013	0.105	0.065	0.078	0.000	0.000	96.398
	GRŠ-2	core	1.664	0.042	0.038	94.834	0.000	0.246	0.017	0.081	0.011	0.091	87.024
		rim	1.254	0.054	0.020	95.924	0.000	0.273	0.156	0.103	0.010	0.023	97.816
	GRŠ-3	core	1.310	0.062	0.093	94.967	0.000	0.303	0.031	0.048	0.004	0.003	96.821
		rim	2.162	0.057	0.016	95.174	0.001	0.811	0.096	0.078	0.005	0.002	98.402
	GRŠ-4	core	1.254	0.071	0.093	93.523	0.026	1.030	0.011	0.051	0.003	0.113	98.847
		rim	2.698	0.055	0.081	94.444	0.000	0.815	0.000	0.083	0.004	0.045	98.225
	GRŠ-5	core	4.111	0.052	0.043	92.568	0.002	1.139	0.013	0.219	0.012	0.011	98.170
		rim	2.557	0.116	0.021	92.898	0.008	0.377	0.047	0.127	0.009	0.137	96.297
diorite	DRŠ-1	core	4.840	0.101	0.703	93.580	0.010	0.291	0.006	0.077	0.001	0.058	99.667
		rim	3.885	0.064	0.575	94.212	0.028	0.421	0.015	0.040	0.000	0.213	99.425
	DRŠ-2	core	10.757	0.079	0.066	87.242	0.000	0.071	0.016	0.078	0.001	0.021	98.331
		rim	7.823	0.098	0.053	89.323	0.001	0.109	0.021	0.062	0.001	0.009	97.500
	DRŠ-4	core	2.519	0.130	0.139	93.271	0.000	0.631	0.001	0.092	0.001	0.058	96.842
		rim	2.274	0.114	0.163	94.708	0.000	0.711	0.004	0.084	0.000	0.021	98.079
	DRŠ-5	core	1.983	0.173	0.432	94.952	0.001	0.901	0.008	0.049	0.000	0.000	98.499
		rim	2.173	0.129	0.566	95.325	0.002	0.989	0.009	0.031	0.000	0.000	99.224

Analysed by: E. Caňo, P. Siman.

Table 2. Contents of Mn, Zn, Cu, Cd, Bi, Ni and Pb in magnetites from granodiorites and diorites of the Hodruša-Štiavnica Intrusive Complex (atomic absorption spectrometry analysis).

Sample No.	Granularity *(mm)*	Rock	*g/t*						
			Mn	Zn	Cu	Cd	Bi	Ni	Pb
GRŠ-1	< 0.25	granodiorite	1 700	162	17	–	tr.	20	21
	0.25–0.50		2 030	160	38	< 10	tr.	70	10
GRŠ-2	< 0.25		1 625	140	38	tr.	tr.	50	23
	0.25–0.50		2 600	165	45	tr.	tr.	60	35
GRŠ-3	< 0.25		2 375	150	32	tr.	tr.	60	10
	0.25–0.50		3 180	156	38	< 10	tr.	16	60
GRŠ-4	< 0.25		675	137	25	< 10	< 100	25	15
	0.25–0.50		1 200	148	35	–	< 100	20	15
GRŠ-5	< 0.25		980	157	25	–	< 100	28	43
	0.25–0.50		800	155	28	< 10	< 100	20	24
NOŠ-125	< 0.16		2 450	100	39	< 10	tr.		25
	0.16–0.25		~ 5 000	92	16	tr.	tr.		45
	0.25–5.00		3 580	133	44	5.4	tr.		45
DRŠ-1	< 0.25	diorite	2 800	64	15	< 10	< 100	16	60
DRŠ-2	< 0.25		4 700	100	89	< 10	< 100	20	55
	0.25–0.50		2 310	125	30	< 10	tr.	10	20
DRŠ-4	< 0.25		9 150	154	24	< 10	< 100	30	55
	0.25–0.50		4 850	230	20	–	tr.	27	30
DRŠ-5	< 0.25		2 200	138	20	< 10	< 100	25	40
	0.25–0.50		2 150	178	28	< 10	< 100	20	30

Analysed by: P. Andráš.

Table 3. Spectrochemical trace elements analysis results of magnetites from the granodiorites and diorites (The Hodruša-Štiavnica Intrusive Complex).

Sample No.	Granu-larity (*mm*)		g/t																
			Cu	Pb	V	Ni	Co	Zr	Mn	Ti	Ag	Zn	Y	Cr	La	Sn	Mo	Sc	Ga
GRŠ-1	< 0.25	granodiorite	78	19.5	> 3000	23.4	32	620	1820	> 3000	< 3	191	51	24.5	245	< 30	< 3	< 3	132
	< 0.50		35	14.8	> 3000	18.8	29	690	≐ 3000	> 3000	< 3	112	76	11.5	355	< 30	< 3	< 3	129
GRŠ-2	< 0.25		60	17.0	> 3000	22.4	37	780	2240	> 3000	< 3	350	51	22.4	229	< 30	< 3	< 3	93
	< 0.50		35	7.6	> 3000	18.6	36	1000	2365	> 3000	< 3	229	68	28.5	282	< 30	< 3	< 3	76
GRŠ-3	< 0.25		148	20.4	> 3000	38.0	47	200	> 3000	> 3000	< 3	500	57	21.5	245	< 30	≐ 3	< 3	85
	< 0.50		132	12.6	> 3000	28.2	48	450	> 3000	> 3000	< 3	320	81	26.3	239	< 30	< 3	< 3	62
GRŠ-4	< 0.25		33	13.2	> 3000	11.5	36	470	870	> 3000	< 3	89	40	22.9	229	< 30	< 3	< 3	63
	< 0.50		44	60.0	> 3000	26.9	34	690	1150	> 3000	< 3	380	68	13.5	245	< 30	< 3	< 3	145
GRŠ-5	< 0.25		54	47.0	> 3000	25.5	35	1000	870	> 3000	< 3	540	64	21.4	380	< 30	< 3	< 3	87
	< 0.50		27	7.6	> 3000	18.4	27	890	575	> 3000	< 3	117	63	20.4	262	< 30	< 3	< 3	98
NOŠ-125	< 0.25		5	33.0	> 3000	29.5	47	470	> 3000	> 3000	= 3	525	63	91.0	470	45	8	13	257
	< 0.50		8	23.4	> 3000	28.2	44	1120	> 3000	> 3000	< 3	690	50	101.0	540	< 30	8	10	195
NOŠ-7884	< 0.25		14	22.1	> 3000	21.7	36	580	1910	> 3000	< 3	142	53	23.1	238	< 30	< 3	< 3	91
	< 0.50		26	9.3	> 3000	19.6	38	130	2150	> 3000	< 3	185	72	29.3	271	< 30	< 3	< 3	82
RB-10	< 0.25		9	19.2	> 3000	26.1	44	350	> 3000	> 3000	= 3	214	61	72.1	420	< 30	≐ 3	6	214
	< 0.50		12	31.8	> 3000	29.2	49	3000	> 1050	> 3000	< 3	470	58	97.0	420	< 30	< 3	< 3	129
DRŠ-1	< 0.25	diorite	10	10.0	455	21.4	22	< 30	1010	> 3000	< 3	330	72	23.4	100	< 3.0	< 3	< 3	< 3
	< 0.50		20	10.7	500	30.2	24	< 30	710	> 3000	< 3	288	65	25.1	100	< 30	< 3	6	< 3
DRŠ-2	< 0.25		110	10.2	2880	25.1	40	< 30	> 3000	> 3000	< 3	191	65	32.0	239	< 30	< 3	< 3	< 3
	< 0.50		46	7.1	1320	18.0	33	< 30	> 3000	< 3000	< 3	30	65	69.0	100	< 30	< 3	28	≐ 3
DRŠ-4	< 0.25		18.0	3.0	2450	71.0	81	< 30	> 3000	> 3000	< 3	370	24	45	≐100	< 30	< 3	21	< 3
	< 0.50		18.2	26.0	1620	43.0	46	< 30	> 3000	> 3000	< 3	30	38	17	>100	< 30	< 3	27.5	< 3
DRŠ-5	< 0.25		22.0	10.7	2750	29.5	31	< 30	2630	> 3000	< 3	450	49	48	191	< 30	< 3	< 3	7
	< 0.50		26.9	12.3	2750	22.9	31.6	< 30	2290	> 3000	< 3	35	45	81	>100	< 30	< 3	6	≐ 10

Analysed by: M. Hrnčárová; — below the limit of determinability.

Table 4. Gold contents in magnetites and in rocks of the Hodruša-Štiavnica Intrusive Complex (atomic absorption spectrometry analysis).

Sample No.	Au g/t	
	Rock	Magnetite
GRŠ-1	0.312	0.091
GRŠ-2	0.120	0.072
GRŠ-3	0.071	0.061
GRŠ-4	0.110	0.080
GRŠ-5	0.120	0.077
BŠ-2	0.149	0.084
BŠ-3	0.040	0.061
BŠ-5	0.092	0.072
RB-10	0.161	0.088
NOŠ-125	0.079	0.063
NOŠ-7684	0.110	0.089
BT-7	0.091	0.071

Analysed by: P. Andráš, M. Hrnčárová

(Lyakhovitch and Lyakhovitch 1983). The mentioned authors suggest that polymetallic Pb-Zn ore mineralizations are bound to later phases of gabbro-granodiorite-granite intrusions in which mean Pb and Zn contents in magnetites are 30 *ppm* and 185 *ppm* respectively, while in primary magnetites from non-productive intrusions of granitoid rocks, mean Pb and Zn contents are 488 and 268 respectively.

Au contents (Tab. 4) in magnetites from HŠIC granodiorites show an inverse trend of Pb, Zn and Cu. They vary within the range of 0.06–0.09 *ppm* which considerably exceeds the mean value of Au content (0.028 *ppm*, Grabezhev et al. 1979) for magnetites of non-productive granitoid rocks. Mean Au content in magnetites from HŠIC granitoids (0.084 *ppm*) and lowered Pb and Zn contents suggest (Lyakhovitch and Lyakhovitch 1983) that one of possible sources of the metals of base- and precious-metal ore mineralization is HŠIC as well.

Discussion

With regard to variable magnetic susceptibility value Ishihara (1979, 1981) divided granitoid rocks into two granitoid series: magnetite and ilmenite series. Both they are connected with various types of ore mineralization (Ishihara, 1981). Magnetite series granitoids are mainly related to the deposits of Cu, Pb, Zn, Mo, Au, Ag and scheelite. Ilmenite series is typical for the deposits of cassiterite, wolframite, beryl and fluorite.

As Gregor (1987, 1990) presents, when studying magnetic susceptibility of the granitoid rocks of the Western Carpathians, several authors found low values of magnetic susceptibility of most granitoids which ranks them with ilmenite series. According to high values of magnetic susceptibility, HŠIC granitoid rocks can be included in magnetite series (Fig. 4). This conclusion is supported also by data on amphibole ferrosity (Šulgan 1986) and chemical composition of accessoric magnetites (Rajnoha 1987, 1989).

Conclusions

Ni/Co ratio in magnetite series varies within the range of 0.4–0.6 which points to a deeper origin of magma under elevated oxygen fugacity and alkalinity of the original melt.

Elevated Au and lowered Pb and Zn contents in magnetites from HŠIC granodiorites suggest that granodiorite may have been a source of base- and precious-metal ore mineralization in the area of Banská Štiavnica–Banská Hodruša.

According to Ishihara's classification (1981), HŠIC granitoids with high values of magnetic susceptibility were ascending due to tension of the environment from big depths and under high oxygen fugacity. The presented data suggest that magmas may have been ascending up the faults caused by a tension in the crust due to diapir ascent in the area of the Pannonian Basin. The type of ore mineralization, in Ishihara's classification ascribed to this magnetite series, corresponds with that one in the district of the Hodruša-Štiavnica ore field which appears to be one the richest base- and precious-metal ore districts in Slovakia.

Translated by M. Spišiaková

References

Czamanske G. K. & Wones D. R., 1973: Oxidation during magmatic differentiation, Finnmarka Complex, Oslo area, Norway: part 2, the mafic silicates. *J. Petrology* (Oxford), 14, 348–380.

Grabezhev A. I., Levitan G. M., Vigorova V. G., Berzon R. O., Yershova N. A. & Tchashtchukhina A. V., 1979: Zoloto v biotitakh i magnetitakh granitoidov kak kriteriy metallogeneticheskoy spetsializatsiyi. *Izd. AN SSSR, Ser. Geol.* (Moscow), 9, 107–113.

Gregor T., 1987: Petrofizicheskie osobennosti granitoidov Zapadnikh Karpat s celyu ikh ispolzovaniya pri geofizicheskikh issledovaniyakh. Thesis, Kiev, 246.

Gregor T., 1990: Magnetite and ilmenite series of the Western Carpathian granitoids. *Geol. Zbor. Geol. carpath.* (Bratislava), 41, 4, 443–451.

Ishihara S. 1979: Lateral variation of magnetic susceptibility of the Japanese granitoids. *Geol. Japan.* (Tokyo), 85, 8, 443–451.

Ishihara S., 1981: The granitoid series and mineralization. *Econ. Geol.* (New Haven), 75th Aniversary Vol., 458–484.

Kogarko L. N., 1973: Otnosheniye Ni/Co – indikator mantiynogo proiskhozhdeniya magm. *Geokhimiya* (Moscow), 10, 187–192.

Konečný V., Lexa J. & Planderová E., 1983: Stratigrafické členenie neovulkanitov stredného Slovenska. *Západ. Karpaty Sér. Geol.* (Bratislava), 9, 285.

Lyakhovith T. T. & Lyakhovith V. V., 1983: Noviye danniye o sostave aktsessornikh mineralov. *Geokhimiya* (Moskva), 11, 1616–1633.

Mihálíková A., Konečný V. & Lexa J., 1980: Metodika identifikácie zakrytých intruzívnych telies ako potencionálneho nositeľa mineralizácie. Manuscript, D. Štúr Geol. Inst., Bratislava, 103.

Rajnoha J., 1987: Assotsiatscyia aktsessornikh mineralov v nekotorikh porodakh godrushsko-shtiyavnickogo komplexa. *Geol. Zbor. Geol. carpath.* (Bratislava), 33, 4, 488–506.

Rajnoha J., 1989: Výsledky výskumu akcesorických minerálov pre objasnenie genézy a potencionálnej rudonosnosti granitoidov hodrušsko-štiavnického intruzívneho komplexu a vyhnianskej drvenej žuly. Manuscript, Geol. Inst. Slov. Acad. Sci., Bratislava, 1–55.

Rub M. G., Ashikhmina N. A., Gladkov N. G., Pavlov V. A. & Troneva N. N., 1988: Tipomorfniye osobennosti aktsessornikh mineralov i ikh znacheniye dlya viyasneniya genezisa i rudonosnosti granitoidov. *Izd. Nauka AN SSSR* (Moskva), 197–235.

Šulgan M., 1986: Petrológia granodioritu hodrušsko-štiavnického intruzívneho komplexu z hľadiska možnej rudonosnosti. Manuscript, Geol. Inst. Slov. Acad. Sci., Bratislava, 132.

Veselský J. & Žabka M., 1976: Poznatky pri použití metódy ťažkých frakcií z drvenej horniny pri štúdiu akcesorických minerálov Malých Karpát. *Acta geol. geogr. Univ. Comen., Geol.* (Bratislava), 28, 155–170.

Wones D. R. & Eugster H. P., 1965: Stability of biotite: Experiment, theory, and aplication. *Amer. Mineral.* (Washington), 50, 1228–1272.