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RELATION OF ORE MINERALIZATION TO GEOCHEMISTRY OF THE WEST CARPATHIAN ULTRAMAFIC MASSIFS

(Figs. 1—5, Plates I—II)

A b s t r a c t: The different geological position and genesis of the ultramafic bodies in the West Carpathians brought about the origin of various rock-forming and ore mineral associations. Ultramafic massifs of the gabbroperidotite formation with increased Fe and Ti contents are characterized by the association of the ore minerals ilmenite — pyrrhotite and is accompanied by magnetite, chalcopyrite and pentlandite. Massifs of the peridotite formation with higher Mg and Ni contents are characterized by chromite, chrome spinel and millerite, acompanied by magnetite and pentlandite.

Key words: *West Carpathians, ultramafic massifs, ore mineral associations*

Р е з ю м е: Различная гелогическая позиция и генезис тел ультрамафических пород Западных Карпат обусловили возникновение отличающихся ассоциаций породообразующих и рудных минералов. Ультрамафические массивы габброперидотитовой формации с повышенными содержаниями Fe и Ti характеризует ассоциация рудных минералов ильменит пирротин и ее сопровождают магнетит, халькопирит и пентландит. Массивы перидотитовой формации с высшим содержанием Mg и Ni характеризуют хромит, хромошпинель и миллерит и сопровождает их магнетит и пентландит

Introduction

Papers dealing with the problem of ore minerals in ultramafic massifs of the West Carpathians are sporadic. The paper of J. K a n t o r (1955) who described ore minerals from ultramafic bodies known at that time is fundamental. He identified microscopically also some rare minerals, like heazlewoodite and awaruite. S. Ď u r o v i č — J. K a m e n i c k ý (1955) described a dimineralic olivine-chromite aggregate from the serpentinite body in Dobšiná. I. R o j k o v i č et al. (1978) published results of the spinel group mineral investigations in ultramafic massifs. J. H u r n ý et al. (1978) described chrome spinel and pentlandite from the ultramafic body near Hodkovce.

During the last two years one of the authors (I. R.) has studied ore minerals from ultramafic massifs of different geological positions and various ages. Ore mineral identification was carried out microscopically, by means of the microprobe and X-ray analysis. The results of these studies are in stage of completion (I. R o j k o v i č, in prep.).

In the presented paper we try to evaluate the relation between the ore mineral associations and parent rock type on one, as well as the dependence of their formation on the type and intensity of different geological processes (serpentini-

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zation, regional metamorphism, weathering processes) on the other hand. As bonds between various ore minerals and different genetic types of ultramafic massifs has been proved during the last years, we shall discuss the studied mineral associations in dependence on petrogenesis of the massifs in which they appear.

Minerals of the spinel group mentioned in this paper belong to spinel, chromite and magnetite. For closer characteristics we refer in the denomination the representation of other trivalent elements as they are described in our work dealing with minerals of spinel group (I. Rojkovič et al., 1978), i. e. for spinel, chrome spinel and rarely ferrispinel in agreement with the classification of R. E. Stevens (1944).

Characteristics of main genetic group of ultramafic massifs

1. Small, prevalently lenticular ultramafic bodies situated in metamorphites of the almandine amphibolite facies, or in granodiorite massifs belonging in geologic view to core mountains and to northveporide zones of Slovenské rudohorie Mts. (with pronounced sharp contacts) belong in petrographical view to two rock types:

a) amphibole peridotite at Veľká Lúka and Filipovo is made up of olivine, pyroxene, amphibole, unsubstantial amount of serpentine minerals, steatite and ore minerals. The presence of green ferrispinel is characteristic for the body at Veľká Lúka (I. Rojkovič et al., 1978).

b) For antigorite serpentinites (Pohronská Polhora, Beňuš, Mýto pod Ďumbierom) also the presence of talc, chlorite or amphibole is characteristic (particularly at the body margins). According to D. Hovorka (1976) ultramafites of the a) type represent the product of deserpentinization (dehydration) of originally hydrated ultramafic rocks. Granodiorite massifs were likely the source of these processes. Increased Fe, Ti or Mn contents and other geochemical differences between the massifs of this group (compared with massifs of other geological units) suggests their assignment to the gabbro-periodotite formation (D. Hovorka, 1978 a, b).

2. Ultramafic massifs situated in metmorphites of higher-temperated subfacies of the greenschist facies (garnet micaschists of the Kohút crystalline complex) show the character of antigorite serpentinites (D. Hovorka et al., in prep.). They contain in the rule also chlorite, talc, amphibole, carbonates and ore minerals. The bodies are in the marginal parts of distinct schistose character. The presence of a concentric reaction-metasomatic zone (blackwall) is characteristic. In some bodies of this geologic position fibrous serpentines and amphiboles make up unexpressive accumulations (Uhorské). Ore mineral associations were studied in the bodies near Muránska Dlhá Lúka, Málinec, Uhorské and Strieborná near Cinobaňa.

3. During the last years small ultramafic massifs were found also in the Early Paleozoic of Spišsko-gemerské rudohorie Mts. (in the Gelnica and Rakovec Group of the Paleozoic at the localities Bukovec, Vyšný Klátov, and Vyšný Medzev). According to the author's reconnaisance studies they are of antigorite serpentinite nature, and locally beds are developed with essential amount of steatite. The country rocks of these massifs are various metasediments and metaeruptive types belonging to the greenschist facies. The association of ultra-

Table 1
Survey of position and constitution of ultramafic massifs

Petro-gen. type	Magm. formation	Geol. units	Country rocks	Typomorphie serpentine mineral
I.	gabbro-peridotite	1 core mountains northveporide zone	granitoids; metamorphites of almandine amphib. facies	antigorite
II.	peridotite	2 Veporide Kohút zone	metamorphites of higher temperated greenschist facies	antigorite
	peridotite	3 Gemerides; Early Paleozoic	metamorphites of lower temperated subfacies of greenschist facies	antigorite
	peridotite	4 Gemerides	metamorphites of lower temperated subfacies of greenschist facies	antigorite
	peridotite	5 Gemerides; Triassic	Triassic anchimetamorphic sediments	orthochrysotile, lizardite

mafic bodies with huge masses of basic volcanics of spilite to keratophyre character would indicate their assignment to the Paleozoic ophiolite complex. Scarce information, however, on these ultramafic bodies does not allow to eliminate the protrusive nature of these bodies, in which case they would correspond to bodies of the Mesozoic ophiolite formation which were "hidden" during protrusion in the Paleozoic besement complexes.

4. Small completely serpentinized bodies in Upper Carboniferous metasediments (Breznička, Ochtiná, Ploské, Slavoška, Slovenská skala near Jelšava) are of very similar character to those situated in Early Paleozoic (group 3). Based on conodont fauna (R. Mock - oral communication) the stratigraphic division of the complexes regarded as Carboniferous in the past was revaluted recently, where for a part of the strata Middle- to Upper Triassic age was established. Thus it is possible, that even one part of the bodies of this group will be assigned in future to the Mesozoic. We deal in this group also with ore minerals from Carboniferous rocks of listvenite character from the deposit Rudňany, the origin of which has not been solved definitely yet.

5. For Mesozoic sequences of the southernmost unit of the Inner Carpathians (Gemerides, Bükkides, Inner West Carpathians) beside basic extrusives and sporadic lava flows of basic volcanics also the presence of intensively serpentinized peridotites is characteristic. They show the character of chrysotile – lizardite serpentinites (D. Hovorka et al., in prep.). Relicts of ortho- and clinopyroxenes, in places even olivines appear in the serpentinites. The bodies of this position are a member of the "incomplete Mesozoic ophiolite formation" (D. Hovorka in print). The largest ultrabasic body in the West Carpathians, the Hodkovce – Komárovce body and number of the bodies (Bretka, Danková, Dobšiná, Jaklovce, Jasov, Rudník, Kobeliarovo) belong to it. We assigned to this grup also the slightly serpentinized dunite – harzburgite – lherzolite body in the Paleogene at Sedlice. Vein chryzotile serpentinization is the interest of present-day survey on several bodies.

6. For comparison also ore minerals of spinel peridotite xenolithis of Late Cenozoic alkali olivine basalts (D. Hovorka 1978 b) from Mašková at South Slovakia have been studied.

Geochemical characterists of the ultramafic massifs

From the above mentioned review of ultramafic massifs situated within different geological units it follows, that the massifs had originated and were later on metamorphosed under nonuniform pT conditions. We try to explain these differences on the example of the massifs of group 1 and 5.

Compared with the massifs being members of the incomplete ophiolite series of Mesozoic age (group 5 of this work) increased iron, titanium and manganese contents and low amounts of magnesium and nickel are characteristic for the ultramafic massifs of group 1 (D. Hovorka 1978a). In accordance with this statement the values of M/F coefficient are rising from the massifs of group 1 to those of group 5 (D. Hovorka 1978a, p. 90).

Despite the fact that recrystallization-metamorphic processes applying particularly on ultramafic massifs of the 1. group (on the other ultramafic bodies as well) might have partly placed the chemical composition of the original mineral associations, we regard the pronounced differences in chemical constitution of the discussed groups of ultramafic massifs as a consequence of their original nonuniform composition (D. Hovorka, 1978a). The massifs of the 1. group were described in the past as members of the "gabbroperidotite formation" (l. c. 1978a, b).

The Upper Mantle origin of the peridotite massifs in orogenic zones, namely of the peridotite massifs being members of ophiolite complexes of different ages was accepted by the majority of the authors. In accordance with present knowledge (D. H. Green – A. E. Ringwood, 1963; P. J. Wyllie, 1969 etc.) on partial melting of the basaltic melt from the upper mantle pyrolite (garnet plagioclase peridotite) the ultramafic bodies in core mountains and in the northern Veporide zones represent a relict upper mantle material from which a comparatively small portion of the basaltic melt has been partially melted. High iron and titanium or other geochemically similar elements content in these massifs is the consequence of this model of generation. Due to this property of these massifs, groups of "critical" cations represented by the "M" and "F" coefficients may be applied for the comparison of massifs with different geological position. On the other hand, Mesozoic ultramafic massifs, i. e. members of the incomplete ophiolite series represent the congealed upper mantle material, which crystallized after advanced partial melting of the basaltic magma. This postulation is based on the extremely low alkali element contents, low silicium content and high contents of magnesium and accompanying cations.

In accordance with the division of ultramafic massifs in massifs of gabbro-peridotite and peridotte formations (D. H o v o r k a, 1978 a, b), those massifs situated south of the Muráň fault system belong to the peridotite formation, regardless of the intensity of metamorphic-recrystallization processes, which affected the ultramafic bodies of this geological position.

Since the era of H. H. H e s s (1933) the value of the M/F coefficient ($M = MgO$, $F = FeO + Fe_2O_3 + MnO + NiO$) is used for the evaluation of the differentiation degree of the upper mantle material. In case of its undifferentiated or unsubstantially differentiated character the value of this coeficient is higher than 6 (H. H. H e s s, 1933, G. V. P i n u s, 1957, V. M a r m o, 1958, T. P. T h a y e r, 1960). Applying this coefficient in consistence with the present dominating ideas on the composition of the primary (undifferentiated) upper mantle material, the high values (in the rule over 6) of this coefficient may be used for undifferentiated, of few diferentiated upper mantle ultramafic masses. Thus it results the lower ratio of basaltic melt from the primitive upper mantle material, the lower will be also the value of this coefficient. The different M/F coefficient values are given in diagram 5.

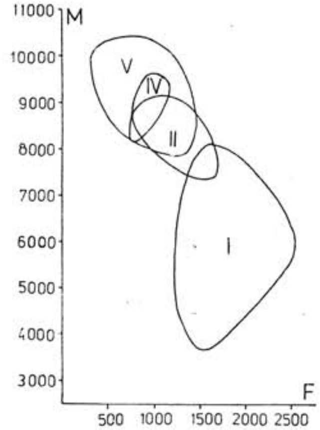

Fig. 1. Graphic representation of M (MgO) and F ($FeO + Fe_2O_3 + MnO + NiO$) coefficients (D. H o v o r k a, 1978a, p. 90).

I — ultramafite field in Tatride granitoid massifs and in metamorphites of almandine amphibolite facies (=northern zones of the Veporide crystalline complex of Slovenské rudohorie Mts.);

II — ultramafite field in metamorphites of higher temperated subfacies of the greenschist facies (=Kohút zone of the Veporide crystalline complex of Slovenské rudohorie Mts.);

IV — ultramafite field in metamorphites of low temperated subfacies of greenschist facies (Gemeride Carboniferous):

V — ultramafite field in anchimetamorphosed Triassic sediments of Spišsko-gemerské rudohorie Mts.

The relation of the values M:F are shown on Fig. 1 (D. Hovorka, 1978a, p. 90). The gradual shift of the ultramafic projection fields from group 1 to group 5 towards higher M values reflects the basic trend of chemical composition changes of these West Carpathian ultramafic groups.

In the modified MFA diagram M = MgO, F = FeO + O.9Fe_2O_3, A = CaO + Na_2O + K_2O the field of the first ultramafic group is shifted towards peak F (Fig. 2 A). The fields of the other ultramafic groups are overlapping. Thus also ultramafic groups are overlapping. Thus also ultramafite field projections underline the stated division of ultramafic massifs in two basic petrogenetic groups. In this coordinate system (Fig. 2 B) fields are marked for Ti – Ni and Cr – bearing massifs (A. I. Bogachev, 1969). It follows from the diagram that the projection field of 1. ultramafic group is identic with the field for nickelbearing massifs, and the fields of the other groups with that of chromitebearing massifs.

In the diagram FeO + Fe_2O_3 : SiO_2 + Al_2O_3 (Fig. 3) the projection points of the massifs of group 1 are shifted towards the higher values of both oxid groups used as diagram coordinates. In this case too we present for comparison the diagram of A. I. Bogachew (1969) – Fig. 3 B. Despite the position of the field of ultramafite group 1, it does not correspond to the absolute values in the diagram of mentioned author (l. c., Fig. 3 B). The fields of groups 2, 4 and 5 are overlaping in the prevailing part their planes. One part of the field of group 2 is distinctly elongated towards the high sum of the iron oxid values which is caused by higher iron contents in two bodies of this geological position (Čierna Lehota, Uhorské 1).

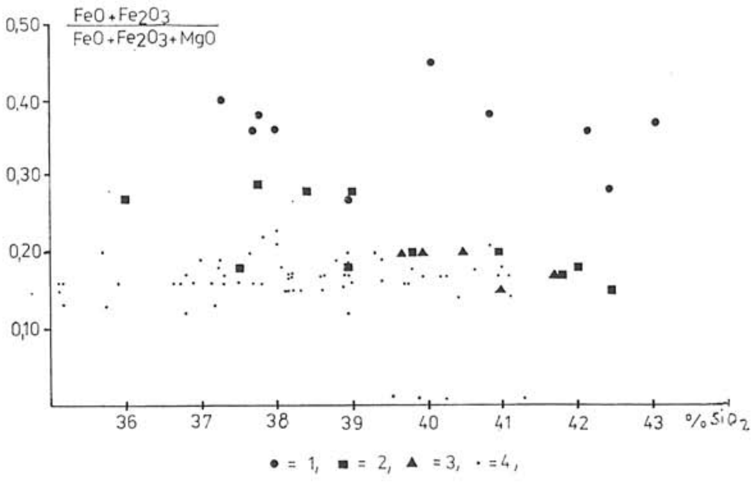

Fig. 2. 1 — projection points of ultramafites from Tatride granitoid massifs and from metamorphites of the almandine amphibolite facies (=northern zones of the Veporide crystalline mass of Slovenské rudohorie Mts.); 2 — projection points of ultramafites in metamorphites of higher-temperated subfacies of the greenschist facies (= Kohút zone of the Veporide crystalline coplex of Slovenské rudohorie Mts.); 3 – projection points of ultramafites from low — temperated subfacies of the greenschist facies (Carboniferous of Gemerides); 4 — projection points of ultramafites in anchimetamorphosed sediments of the Spišsko-gemerské rudohorie Mts. Triassic.

In the coordinate system $FeO + Fe_2O_3 : SiO_2$ (Fig. 4) used by E. F. Osborn (1959) for the description of the differentiation type of primitive magmatic masses, the West Carpathian ultramafites build vertically slightly articulated fields. This is documented by a small range of differentiation processes in the scope of these formations during their consolidation in the environment of the Earth's crust. The definitelly higher values of the coefficient $FeO + Fe_2O_3/FeO + Fe_2O_3 + MgO$ for analyses of the 1. group prove for their genesis as it has been mentioned above. The coherent few differentiated character of the

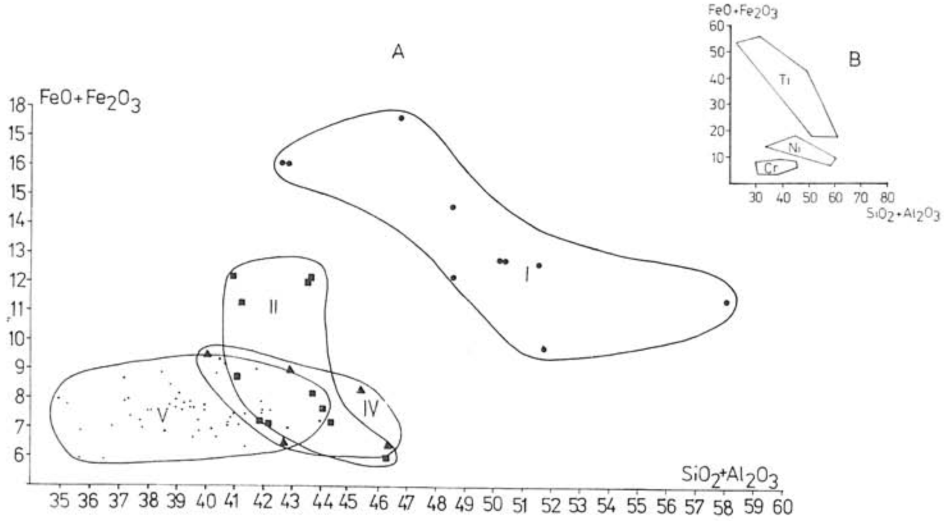

Fig. 3. Explanations as for Fig. 2. A — projection points of ultramafic massifs of the West Carpathians. B — fields of Ti-, Ni-, and Cr-bearing ultramafic massifs according to A. I. Bogachev, 1969.

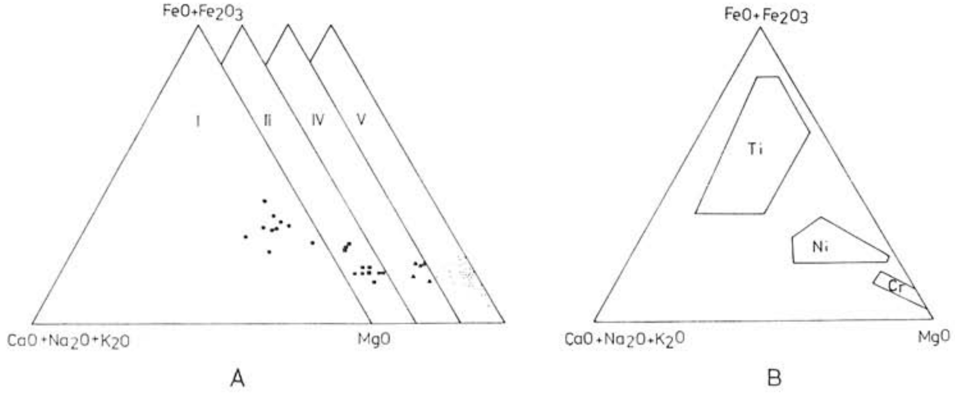

Fig. 4. Explanations as for Fig. 2. A —projection points of ultramafic massifs of the West Carpathians. B — fields of Ti-, Ni-, and Cr-bearing ultramafic massifs according to A. Bogachev, 1969.

ultramafic bodies in the Gemeride Mesozoic is documented on the discussed diagram by a narrow vertical diapazon of projections of this coefficient for bodies of this group.

In the M/F : Cr/Ti diagram (Fig. 5) analoguously like in the previous cases ultramafites of the 1. group have a pronounced separate position related to the other types. Eliminating some analyses with extremely low Cr/Ti ratios from group 2 and 4, this ratio is conspicuously higher (in order) in groups 2, 4 and 5 than for group 1.

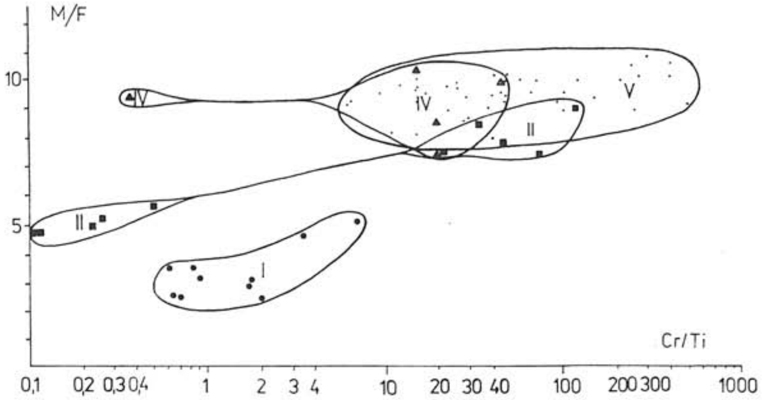

Fig. 5. Explanations as for Fig. 2.

Ore mineral associations

In ultramafic bodies on all localities ilmenite and pyrrhotite are present as essential minerals in metamorphites of the almandine amphibolite facies and in granitoids. They are usually accompanied by magnetite, pentlandite and chalcopyrite (Tab 2).

The ultramafic rocks occuring in metamorphites of the greenschist facies are of unhomogenous association. While at the localities Strieborná near Cinobaňa and Uhorské 1 unlike the last described association the typical mineral is beside magnetite, chrome spinel – chromite, on the locality Muránska Dlhá Lúka pyrrhotite and ilmenite is present. Pyrrhotite and ilmenite are typical for Málinec and pyrrhotite also for Uhorské 2.

The localities Bukovec and Vyšný Klátov in the Early Paleozoic of the Gemerides are characterized in addition to magnetite by chrome spinel – chromite. At the locality Vyšný Medzev however, beside the two previous also ilmenite accompanied by pyrrhotite, pentlandite and chalcopyrite was found.

On the localities Ochtiná and Rudňany in the Gemeride Carboniferous in addition to magnetite, chromite – chrome spinel and millerite are typical. In the massif near Breznička ilmenite is the typical mineral (accompanied by magnetite, leucoxene, pyrrhotite, chalcopyrite and pentlandite) and on the locality Ploské it is pyrrhotite (accompanied by magnetite, chrome spinel – chromite, pentlandite, chalcopyrite and others). At Slovenská skala near Jelšava and at Slavoška only pyrite was found in substantial amounts.

Table 2

Ore mineral distributio on the localities

Localities		Abun-dant	Com-mon	Subordinate	Rare	Sporadic
1.	Be			mag	po, ilm, crs, pn mar	ccp
	Fi		ilm, mag		po, pn, ccp, nem	
	Mý	po		mag	pn, ccp	ilm, crs, goe
	PP	po		ilm, mag ccp, pn	cov, mar, goe	viol, bra, crs
	VL			ilm, sp, mag	po, pn	ccp, crs
2.	Ma		ilm	mag	po	hem, gra, cob
	MDL		mag	ilm	crs, po	pn, goe
	St			mag	crs	hem
	U 1			mag	hem	crs
	U 2			mag	po, ccp, py	pn, mar
3.	Bu		mag	crs	hem	
	VK			crs, mag	hem	
	VM		ilm	mag, crs		pn, ccp, po, goe
4.	Br		ilm, mag	leu	ccp, mil, hem, goe, po, pn	py, cob
	Oc		mag		crs, mil, ccp, py, hem, goe	pn, sieg, hea, lep
	Pl		mag	po	crs, pn, py, ccp, goe	cob, bra
	Ry		crs	mag, hem leu	mil, ccp, py, td, viol, gn, sf	gers, cob, X_1
	Sl				py	
	SS	py		mag, goe		
5.	Bt			mag	mil, crs, goe	py
	Da			mag	crs, py	mil
	Do			crs, mag	mil, pn, ccp	goe
	Ho		crs	mag	pn, py, hem	mil, ccp, goe
	Ja		crs, py	mag	mil, po, pn, ccp, hem	hea, sieg, gn, sf, goe
	Jv			mag	mil, pn	
	Ko				crs, mag	pn, ccp
	Pn	crs		mag		
	Ru			mag	crs, pn, py, hem	mil, ccp, goe
	Se		crs	mag, pn	mil, viol, bra py, hem	aw, goe
6.	Mš				sp	py, mar

Explanations to Tab. 2

Bodies occuring in:
1. metamorphites of almandine amphibolite facies and in granitoids;
2. metamorphites of the greenschist facies;
3. the Early Paleozoic of the Gemerides;
4. the Carboniferous of the Gemerides;
5. the Mesozoic of the Gemerides;
6. xenoliths from Late Cenozoic alkali olivine basalts.

Localities: Be — Beňuš, Br — Breznička, Bt — Bretka, Bu — Bukovec, Da — Danková, Do — Dobšiná, Fi — Filipovo, Ho — Hodkovce, Ja — Jaklovce, Jv — Jasov, Ko — Kobeliarovo, Ma — Málinec, MDL — Muráňska Dlhá Lúka, Mš — Mašková, Mý — Mýto pod Ďumbierom (dolina Hudák), Oc — Ochtiná, (Banská dolina), Pl — Ploské, Pn — Paňovce, PP — Pohronská Polhora, Ru — Rudník, Ry — Rudňany, Se — Sedlice, Ss — Slovenská skala pri Jelšave, St — Strieborná pri Cinobani, U 1, U 2 — Uhorské, VK — Vyšný Klátov, VL — Veľká Lúka, VM Vyšný Medzev

Minerals: aw — awaruite, bra — bravoite, ccp — chalcopyrite, cob — cobaltite, cov – covelite, crs – chromite-chromspinel, gers – gersdorffite, gn – galena, goe – goethite, gra — grafite, hea — heazlewoodite, hem — hematite, ilm — ilmenite, lep – lepidokrokite, leu – leukoxéne ,mag – magnetite, mar – marcasite, mil – millerite, pn – pentlandite, po – pyrrhotite, py – pyrit,e sf – sfalerite, sieg – siegenite, sp – spinel, td – tetrahedrite, viol – violarite, X – NiSBS mineral.

In ultramafic bodies in Mesozoic complexes of Gemerides and at the locality Sedlice in the ultramafic body within the Paleogene, chromite – chrome spinel and millerite are characteristic minerals, accompanied by magnetite and pentlandite. At the locality Jaklovce with more pronounced late hydrothermal activity pyrite occurs along with pyrrhotite.

In general it can be stated that the following minerals are typical for the individual ultramafic bodies (apart from magnetite present usually on all localities):

1. Ilmenite, pyrrhotite (pentlandite, chalcopyrite) for bodies in metamorphites of the almandine amphibolite facies and in granitoids of core mountains and north Veporide zones.

2. Chrome spinel – chromite at some localities even pyrrhotite and ilmenite for bodies in metamorphites of the greenschist facies from the Veporide Kohút zone.

3. Chrome spinel – chromite and at the site Nižný Medzev also ilmenite and pyrrhotite in the Early Gemeride Paleozoic.

4. An unhomogenous association in bodies of the Gemeride Carboniferous (due to late hydrothermal activity perhaps also by indistinct stratigraphic affilation).

a – chromite – chrome spinel and millerite on the localities Ochtiná and Rudňany (as in group 5);

b – chrome spinel with pyrrhotite on the locality Ploské;

c – ilmenite, pyrrhotite on the locality Breznička (association as in group 1).

5. Chromite – chrome spinel, millerite in bodies of the Gemeride and at locality Sedlice in Paleogene.

6. Spinel in xenoliths in Late Cenozoic alkali olivine basalts.

Discusion

Different geological setting and diverse genesis of the West Carpathian ultramafic bodies brought about also the generation of different rock-forming and ore mineral associations. The division of the West Carpathian ultramafic massifs, appearing in various geological units into two genetic groups was discussed in the precedent chapter.

The attribution of the ultramafite bodies belonging to the first group to the paleoophiolite series is most likely. The ultramafic bodies of both differentiated (classified) formations (I and II) represent Upper Mantle material. They differ essentially by the amount of basaltic melt, which had been partially melted out from the Upper Mantle pyrolite (peridotite) still prior to the generation of silicate and ore mineral associations of ultramafic massifs in the Earth's crust. While ultramafic bodies of the 1. type were generated by crystallization of the Upper Mantle mass after a comparatively small amount of melted basaltic magmas, the material of the 2 type (type II) represents actually a restite, which did crystallize after melting and transport of a substantial amount of the basaltic melt. Minerals of the spinel group present (no plagioclase or garnets) in both characterized ultramafic groups prove of the approximately equal level (the same pT conditions) of mass generation for both massifs types. Differences in essential and critical trace element contents in both basic genetic ultramafic types were proved by geochemical study (D. H o v o r k a, 1978 b).

In the past already we pointed to the presence of various ore mineral associations (D. H o v o r k a, 1978 b) in bodies of diverse genetic affiliation. For ultrabasic bodies of the gabbro-peridotite formation the presence of increased contents of iron and copper sulphides is characteristic (pyrite, chalcopyrite, pyrrhotite, pentlandite) in turn chrome spinel is the leading and typomorphic mineral in ultramafites of the peridotite formation.

The results given in this paper corroborate and complement the conclusions of D. Hovorka (l. c.) supported on the divisions of two basic genetic ultramafic rock types of the West Carpathians. The following differences appear in ore mineral representation:

1. Chromite was found only in ultramafics of the peridotite formation.

2. Chrome spinels appear more abundantly in ultramafites of the peridotite formation, less in rocks of the gabbroperidotite formation, though they were noticed almost at all localities.

3. Ilmenite is abundant in rocks of the gabbro-peridotite formation, particularly at the localities Filipovo, Pohronská Polhora, Veľká lúka and Mýto pod Ďumbierom.

4. Pyrrhotite occurs abundantly in rocks of the gabbroperidotite formation, as well as pentlandite and chalcopyrite.

5. The sulphide association in bodies of the Spišsko-gemerské rudohorie Triassic is represented mainly by pentlandite and millerite and is rarely accompanied by heazlewoodite and awaruite.

From the comparison of ore mineral associations with the geochemical conclusions of D. H o v o r k a (1978 b) it results:

1. Ultramafics of the gabbro-peridotite formation with higher iron and titanium content are characterized by: ilmenite and pyrrhotite, accompanied by magnetite, pentlandite and chalcopyrite.

2. Ultrabasites of the peridotite formation with higher magnesium and nickel content are characterized by chromite – chrome spinel and millerite and accompanied by magnetite and pentlandite.

The first ore minerals which were formed during crystallization of the magma are chromite and ilmenite. Owing to change of thermodynamic conditions and by reaction of the restite magma melt chrome spinel and spinel were expelled.

The substantial part of sulphides and magnetite show close structural and textural relation to serpentinization processes as well as close mutual paragenetic interrelations. For the investigated rocks with poor mineralization it may be suggested the mineralization model elaborated by O. H. Eckstrand (1975) for the ultrabasic body Dumont at Quebeck in Canada to be valid, which means that the first reaction during serpentinization was the alternation of olivine to serpentine and magnetite. After consumption of oxygen from H_2O on the serpentinization front a reductive environment rich in hydrogen resulted. Nickel from magmatic silicate minerals enters during serpentinization into awaruite at absence of sulphur and into pentlandite and heazlewoodite in the presence of sulphur. Continued CO_2 import in the water solution from the country rock could have induced an oxidative medium and formation of the mineral with higher sulphur content – millerite. The formation of the pyrrhotite – pentlandite – chalcopyrite association, as formerly mentioned, was conditioned first at all by different mineralogical and chemical composition of the original rock of gabbro-peridotite formation. The linkage of these sulphides to serpentine and magnetite supports the possibility of their formation during serpentinization, although one part of the sulphides being older than magnetite. The occurence of graphite is known in many ultramafic bodies (J. S. R. Krishnarao, 1964, H. Papunan, 1970). The occurence of graphite on the locality Málinec may be explained by the reductive action of H_2 described by P. Ramdohr (1967). By creation of more intensive oxidative conditions at the termination phase of serpentinization pentlandite first becoms unstable (M. Sato, 1960, M. Sato – H. M. Mooney, 1960). It is replaced by millerite, violarite and bravoite. During continued oxidation pyrrhotite becomes unstable and goes over to marcasite.

The occurences of sulphides as galenite, sphalerite, pyrite, tetrahedrite, gersdorfite and cobaltite on some localities representing younger hydrothermal processes related with alternation processes and rock carbonatization is a specific case. Products of ore mineral weathering are goethite, heamatite and covellite.

Conclusion

The West Carpathian ultramafic massifs belong in petrogenetic aspect to two types:

I. Bodies generated from the Upper Mantle pyrolite (peridotite) after previous melting of a small portion only of the basaltic melt. These bodies are characterized by higher Fe, Ti, Mn content. In sense of the formation analysis principles these bodies may be classified to the gabbro-peridotite formation. They are likely a member of the paleoophiolite formation. Along with the encompassing sediments and eruptives these are metamorphosed under the conditions of the almandine amphibolite facies. This type of ultramafic bodies appears north of the Muráň fault (fault system) in core mountains and the northoveporide zones of Slovenské rudohorie Mts. For the ultramafic bodies of this group the association ilmenite – pyrrhotite accompanied by pentlandite and chalcopyrite is characteristic.

II. The second type is represented by serpentinized peridotites (mainly of the lherzolite – harzburgite type) with unsubstantial amount of dunitic and pyroxenic members. They were formed from Upper Mantle material after partial melting (compared with type I) of a greater deal of the basaltic magmas. The massifs are characteristic by high Mg, Ni, Cr content at the same time with low Si and alkali content. Rocks of this type occur south of the Muráň fault in the Kohút crystalline complex (group 2), in the Gemeride Early Paleozoic (group 3), in the Gemeride Upper Carboniferous (group 4), and in the Gemeride Mesozoic (group 5). The last mentioned group of ultramafic bodies is part of the incomplete ophiolite series in the Mesozoic of this geological unit of the Inner West Carpathians. For the ultramafic massifs of the second genetic group chromite (chrome spinel) and millerite accompanied by magnetite and pentlandite are characteristic.

Greater variability, and inhomogeneity of mineral representation in associations on some localities of groups 2–3–4 are caused by younger hydrothermal activity and possibly also by the effect of metamorphism and unclear stratigraphic classification.

Minerals which originated by crystalization from the melt are minerals of the spinel group (chromite, chrome spinel, spinel, and ilmenite). The substantial part of the sulphides represents a products of serpentinization processes of the ultramafic bodies. Also magnetite is the product of these alterations. Pyrite, galenite, sphalerite, gersdorfite, cobaltite and partly also pyrrhotite are the products of superimposed hydrothermal alternations of the mineral associations of ultramafic bodies. Poducts of ore mineral weathering of these genetic types are goethite, heamatite and covellite.

Translated by L. Mináriková.

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