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SPINEL GROUP MINERALS IN THE WEST CARPATHIAN ULTRABASIC ROCKS

(Fig. 1—23, Tab. 2)

A b s t r a c t: In the paper are presented the results of study of chemical composition and genesis of spinel group minerals from ultrabasic bodies of the West Carpathians of various geological position.

Spinel from ultrabasic massivs of various types are characterized by considerable variability of chemical composition, morphology and different intensity of secondary alterations. The observed two generations of chromites and chromium spinel in some ultrabasic massifs probably correspond to formation of mineral associations of these rocks in the upper mantle and crust.

K. W: spinels, ultramafic rocks, West Carpathians

Р е з ю м е: В статье приводятся результаты исследований химического состава и генеза минералов группы шпинеля из ультраосновных тел Западных Карпат разного геологического положения.

Шпинели из ультраосновных массивов разных типов характеризованы значительной изменчивостью химического состава, морфологии и разной интенсивностью вторичных изменений. Наблюдаемые два поколения хромитов и хромшпинелей в некоторых ультраосновных массивах отвечают вероятно формации минаральных ассоциаций этих горных пород в верхней мантии и коре.

1. *Introduction*

In spite of their accessory occurrence chromium spinels are a potential indicator of physical-chemical conditions of origin of parent ultramafic rocks. They are characterized by high variability of the content of bi-and trivalent cations; they are sensitive indicators of chemical and thermal conditions of formation.

The spinel group, in dependence on repressentation of trivalent ions, is divided into three series (C. P a l a c h e et al., 1944): the series of spinel (Al), magnetite (Fe^{+3}) and chromite (Cr). The simplest formula of spinel minerals is $R^{++}R_2^{+++}O_4$. In the group usually 6 following terminal members are mentioned: $FeCr_2O_4$-chromite, $FeAl_2O_4$-hercynite, $Fe^{+2}Fe^{+3}_2O_4$ magnetite. $MgCr_2O_4$-picrochromite (T. N. I r v i n e, 1965) or magnesiochromite (W. A. D e e r et al., 1963), $MgAl_2O_4$-spinel and $MgFe_2O_4$-magnesioferrite.

The terminal members of the mentioned isomorphus series are only rarely found in the form of natural minerals. The individual mineral varieties differ in representation of R^{+2} and R^{+3}. For instance, spinels with higher content of Fe^{+2} and $Mg:Fe^{+2}$ from 3:1 are designated as pleonaste or ceylonit (W. A. D e e r et al., 1963). On the contrary, hercynite with higher Cr or with Al>Cr and with ratio Fe:Mg 3:1 is called picotite. In classification of A. N. and H. W i n c h e l l

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(1951) several mineral varieties are mentioned, however, trivalent iron is not taken into regard. M. Zhelyazkova-Panayotova (1971) suggested a classification of spinels in which the first part of the name is „magno" or „ferro" on the bassis of the ratio of bivalent and the second part on the basis of trivalent cations: spinel (Al), chromite (Cr) and ferrite (Fe^{+3}).

With chromium spinels and other ore minerals in Mesozoic serpentinites of the Spišsko-gemerské rudohorie mts. dealt J. Kantor (1955, 1956). He characterized microscopically chromite and chromium spinel from some bodies of ultrabasites. According to the mentioned author (l. c.) chromite occurs mainly in less serpentinized types whereas it has not been found in dynamo-metamorphosed serpentinites of antigorite type. From the locality Dobšiná (known from mining of chrysolite asbestos) chromite was described, on the basis of X-ray diffraction analysis its lattice constant $a_0 = 8{,}281$ has been established (S. Ďurovič – J. Kamenický, 1955). There are doubts (D. Hovorka, 1975) about credibility of the occurrence of „chromite ore" mentioned in the compendium of A. Papp (1916) near Tiba (in which are the presence of ultrabasic body has not been confirmed in the last years). The presence of chromium spinels in rocks with fuchsite at the deposit Rudňany was considered by M. Mandáková et al. (1971) as one of the facts for identification of listvenites. The chromium spinel established by the authors was documented by incomplete analysis.

A higher number of chromium spinels analyses is available from the body near Hodkovce (J. Hurný, 1975, in J. Zlocha et al., 1975; I. Rojkovič-E. Martiny, 1975). The authors mentioned stated besides magnetite essentially 2 spinel types.

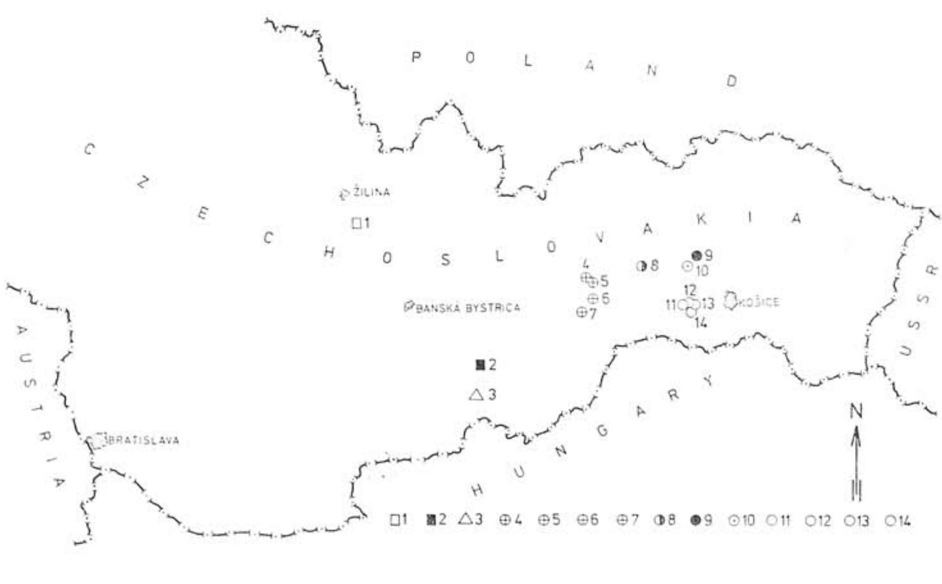


Fig. 1. Map of localities: 1 – Veľká Lúka, 2 – Cinobaňa, 3 – Mašková, 4 – Danková, 5 – Dobšiná, 6 – Kobeliarovo, 7 – Ochtiná, 8 – Rudňany, 9 – Sedlice, 10 – Jaklovce, 11 – Jasov, 12 – Rudník, 13 – Hodkovce, 14 – Paňovce.

Fig. 2. Allotriomorphic spinel-ceylonite in amphibolic peridotite. Veľká Lúka, reflected light, 160 x, 1 nicol. Photo I. Rojkovič.

The fundamental data on Cr distribution in various types of ultramafic rocks of different West Carpathian geological units are presented in the works by D. H o v o r k a (1975).

Patent rooks, their geological setting; characteristics of the spinel-group minerals.

1. Ultrabasic body in granites

Represented by a body of amphibolic peridotite on the Veľká Lúka in the Malá Fatra mts. (Fig. 1), "drowned" in hybrid biotitic granodiorites of the mentioned mountain range. It represents a member of the pre granite magmatosedimentary series of Early Proterozoic (?) or Early Paleozoic (?) age. The fundamental mineral phases of peridotite are: olivine, amphibole, spinel. The mentioned association is most probably a product of dehydratation (deserpentinization) processes, which took place in the original ultrabasic body (D. H o v o r k a, 1967).

Spinels are a relatively frequent accessory in rocks. The grains are mostly 0.1–0,5 mm in size. They are allotriomorphous and fill in lobe-shaped the interstices between amphibole and pyroxene grains (Fig. 2). Inner reflexes of yellowishgreen colour are. Sometimes small, up to 0,05 mm pyroxene inclusions are observed in spinels. From other opaque minerals were found ilmenite, pentlandite, pyrrhotite, chalcopyrite, which are dispersed in rocks and represent the younger phase of mineralization than spinels.

In their composition spinels are close to spinel with slightly increased content of bivalent iron-ceylonite (Tab. 1). Variability of composition in the individual samples is minimum.

2. Ultrabasic bodies in metamorphites of amphibolite facies (Kohút crystalline)

Ultrabasites represent members of the original lherzolite-harzburgite formation, which together with the surrounding sediments underwent Variscan and Alpine metamorphic processes to the amphibolite facies. Characteristic of the ultrabasic bodies is complete serpentinization and in most bodies also intense steatitization. As reaction border around the bodies of ultrabasites rocks designated as „blackwall"-talc, actinolite and chlorite rocks formed.

Table 1a

Nr.	Locality	Weight per cent					Sum	Association
		MgO	FeO	Fe_2O_3	Cr_2O_3	Al_2O_3		
1	Veľká Lúka	12,9	17,6	5,1	4,9	51,0	91,5	ilm, po, pn, ccp
2	Veľká Lúka	13,6	17,2	5,6	4,5	52,1	93,0	ilm, po, pn
3	Veľká Lúka	14,3	16,0	4,0	2,7	54,6	91,6	ilm, po, pn, ccp
4	Cinobaňa	1,6	29,1	0,3	60,0	4,8	95,8	mag
5	Hodkovce	9,2	22,1	0,2	35,6	30,5	97,6	mag, lim, karb
6	Hodkovce	10,0	19,7	1,9	31,1	31,0	93,7	mag, lim, carb
7	Hodkovce	7,5	21,6	22,4	42,1	7,6	101,2	mag, pn, py
8	Hodkovce	8,4	20.2	24,0	41,2	7,3	101,1	mag, pn, py
9	Hodkovce	7,2	22,2	21,1	43,2	6,2	99,9	mag, pn, mil
10	Hodkovce	11,4	13,8	27,2	41,4	3,3	97,1	mag, pn, mil
11	Hodkovce	7,8	21,8	22,7	44,1	6,5	102,9	ccp
12	Hodkovce	9,1	19,7	22,0	40,4	10,0	101,2	ccp
13	Hodkovce	6,9	21,9	21,7	43,3	5,5	93,3	mag
14	Hodkovce	7,4	20,7	21,6	41,8	6,2	97,7	mag
15	Hodkovce	6,4	21,9	20,3	41,2	6,6	96,4	mag
16	Hodkovce	7,4	20,7	1,4	59,0	7,7	96,2	mag
17	Hodkovce	7,6	21,9	19,2	42,7	9,4	100,8	mag, lim
18	Hodkovce	8,6	20,5	15,0	38,5	14,9	97,5	mag
19	Hodkovce	6,2	24,2	17,0	45,0	8,9	101,3	pn, mag, hem
20	Hodkovce	12,1	16,8	—	28,8	39,6	97,3	mag, carb, Q
21	Hodkovce	8,7	20,8	2,9	53,6	13,7	99,7	mag, Q, karb
22	Paňovce	9,0	18,5	—	57,2	10,5	95,2	mag
23	Rudník	17,8	11,0	1,2	13,6	50,6	94,2	mag, pn
24	Rudník	2,8	25,5	49,7	16,5	0,5	95,0	pn, mil
25	Jasov	1,3	28,4	56,4	8,2	2,2	96,6	mil, pn
26	Jasov	—	30,5	59,2	8,0	—	97,7	mil, pn
27	Jaklovce	15,5	14,0	—	30,2	38,9	98,6	mag, pn
28	Jaklovce	16,6	11,1	2,1	22,4	41,2	93,3	mag
29	Jaklovce	0,9	28,7	45,9	19,2	0,9	95,6	crs
30	Jaklovce	15,3	11,8	3,7	27,5	34,7	93,0	mag, mil, pn, hw, hem
31	Ochtiná	7,0	21,9	0,6	52,3	13,3	95,1	mag
32	Kobeliarovo	2,2	26,9	53,4	10,8	2,4	95,7	cr, pn
33	Dobšiná	10,2	17,4	0,8	52,4	14,7	95,5	
34	Danková	13,4	14,3	2,1	30,6	32,2	92,6	mag
35	Danková	13,2	12,6	2,6	50,5	15,6	94,5	pn
36	Rudňany	11,4	17,1	3,7	43,4	21,7	97,3	mag, ccp
37	Rudňany	—	32,3	11,2	46,5	7,4	97,6	mil, py, gf, co
38	Sedlice	11,4	12,1	—	26,2	45,4	95,5	mag
39	Sedlice	11,6	12,5	—	24,9	46,0	95,0	mag
40	Sedlice	11,8	13,4	—	27,9	45,7	98,8	pn, mil
41	Sedlice	11,7	13,0	—	27,5	45,7	97,9	pn, mil

Table la. Continuation

42	Sedlice	1,8	29,7	8,1	53,0	5,9	98,5	mag, pn, mil, aw
43	Sedlice	10,7	18,4	1,7	39,8	25,3	95,9	mag, pn, mil
44	Sedlice	—	30,8	63,1	5,1	—	99,0	cr, pn, mil
45	Sedlice	7,1	20,1	—	61,6	6,3	95,1	mag, pn, lim
46	Sedlice	6,0	22,8	—	62,9	5,9	97,6	mag, pn, hem
47	Sedlice	—	32,6	66,3	5,8	—	104,7	cr, pn, hem
48	Mašková	17,8	9,2	2,4	19,0	43,8	92,2	py
49	Mašková	17,4	10,6	2,2	21,6	43,1	94,9	py
50	Mašková	17,4	9,9	1,4	18,7	44,4	91,8	py

The spinels were analysed on X-ray microanalyzer Jeol JXA-5A by J. Krištín. Analysed were the elements Mg, Fe, Cr, Al. Other elements, which are present in spinels as e. g. Zn, Mn, Ti and other have not been analysed quantitatively ad the qualitative analysis did not prove more distinct contents of these elements. The spinels were analysed with voltage 20 KV, calculating time 20 sec. In recalculations corrections to the background, fluorescence, absorption and atomic number were taken into regard.

The FeO and Fe_2O_3 values were recalculated from total iron, supposing stoichiometry of $R^{++}R_2^{+++}O_4$.

Association:
aw — awaruite, carb — carbonates, ccp — chalcopyrite, co — cobaltite, cr — chromite, crs — chromium spinel, gf — gersdorffite, hm — haematite, hw — haezlewoodite, ilm — ilmenite, lim — limonite, mag — magnetite, mil — millerite, Q — opal, chalcedony, quartz, pn — pentlandite, po — pyrrhotite, py — pyrite.

In the body near Cinobaňa chromite has been found out as rarely occurring mineral only. Idiomorphic as well as corroded and rounded grains are 0,05— to 0,25 mm in size. Inner reflexes are not observed. Chromites are usually rimmed and in form of thin veinlets intersected by magnetite. Magnetite is also scattered in rocks. It is directed and intergrown with actinolite (Fig. 3). In its chemical composition the observed mineral unambiguously belongs to chromite as is evident from the low centent of Fe^{+3} and Al.

3. *Ultrabasic bodies in Triassic sediments of the Spišsko-gemerské rudohorie Mts.*

The bodies are members of incomplete ophiolite formation (series) of this geological unit of the West Carpathians (D. Hovorka, 1976). They are of lenticular, platy and other shapes and intensively serpentinized (70—90 %). The initial rocks were peridotites (lherzolites and harzburgites), dunitic and pyroxenic types have been found rarely only. In contrast to ultrabasic bodies, geological position of which is known, of particular position is a large body in the SW part of the Košická kotlina basin (area of the body around 100 km²), known as the body from Komárovce or Hodkovce. In the next we designate it as the Hodkovce—Komárovce body. In this body supergenic alternations were distinctly

Table 1b

Nr.	Locality	Coefficients					name	
		Mg/R^{+2}	Fe^{+2}/R^{+2}	Fe^{+3}/R^{+3}	Cr/R^{+3}	Al/R^{+3}	I. M. Irvine, 1965	M. Panayotova-Zhelyazkova, 1971
1	Veľká Lúka	0,567	0,433	0,057	0,058	0,885	spinel	magno-spinel
2	Veľká Lúka	0,585	0,415	0,061	0,051	0,887	spinel	magno-spinel
3	Veľká Lúka	0,613	0,387	0,043	0,030	0,927	spinel	magno-spinel
4	Cinobaňa	0,090	0,910	0,005	0,888	0,107	chromite	ferro-chromite
5	Hodkovce	0,424	0,576	0,003	0,438	0,559	hercynite	ferro-spinel
6	Hodkovce	0,475	0,525	0,024	0,393	0,584	hercynite	ferro-spinel
7	Hodkovce	0,388	0,612	0,286	0,561	0,153	chromite	ferro-chromite
8	Hodkovce	0,428	0,572	0,306	0,551	0,143	chromite	ferro-chromite
9	Hodkovce	0,357	0,643	0,276	0,597	0,127	chromite	ferro-chromite
10	Hodkovce	0,596	0,405	0,358	0,575	0,067	picrochromite	magno-chromite
11	Hodkovce	0,389	0,611	0,287	0,585	0,128	chromite	ferro-chromite
12	Hodkovce	0,452	0,548	0,275	0,530	0,195	chromite	ferro-chromite
13	Hodkovce	0,358	0,642	0,287	0,600	0,113	chromite	ferro-chromite
14	Hodkovce	0,388	0,612	0,288	0,584	0,129	chromite	ferro-chromite
15	Hodkovce	0,342	0,659	0,274	0,586	0,139	chromite	ferro-chromite
16	Hodkovce	0,390	0,610	0,036	0,822	0,160	chromite	ferro-chromite
17	Hodkovce	0,384	0,616	0,244	0,572	0,184	chromite	ferro-chromite
18	Hodkovce	0,426	0,575	0,189	0,517	0,294	chromite	ferro-chromite
19	Hodkovce	0,314	0,686	0,217	0,605	0,179	chromite	ferro-chromite
20	Hodkovce	0,562	0,438	—	0,328	0,672	spinel	magno-spinel
21	Hodkovce	0,427	0,573	0,036	0,699	0,266	chromite	ferro-chromite
22	Paňovce	0,463	0,537	—	0,785	0,215	chromite	ferro-chromite
23	Rudník	0,743	0,257	0,013	0,151	0,836	spinel	magno-spinel
24	Rudník	0,162	0,838	0,733	0,256	0,012	magnetite	ferro-ferrite
25	Jasov	0,077	0,923	0,825	0,125	0,050	magnetite	ferro-ferrite
26	Jasov	—	1,000	0,873	0,127	—	magnetite	ferro-ferrite
27	Jaklovce	0,664	0,336	—	0,343	0,657	spinel	magno-spinel
28	Jaklovce	0,728	0,272	0,023	0,261	0,716	spinel	magno-spinel
29	Jaklovce	0,055	0,945	0,679	0,299	0,021	magnetite	ferro-ferrite
30	Jaklovce	0,699	0,301	0,043	0,332	0,625	spinel	magno-spinel
31	Ochtiná	0,364	0,636	0,007	0,721	0,272	chromite	ferro-chromite
32	Kobeliarovo	0,126	0,874	0,780	0,166	0,055	magnetite	ferro-ferrite
33	Dobšiná	0,510	0,490	0,011	0,698	0,291	picro-chromite	magno-chromite
34	Danková	0,626	0,374	0,025	0,380	0,596	spinel	magno-spinel
35	Danková	0,651	0,349	0,032	0,664	0,305	picro-chromite	magno-chromite
36	Rudňany	0,543	0,458	0,045	0,548	0,407	picro-chromite	magno-chromite
37	Rudňany	—	1,000	0,156	0,684	0,161	chromite	ferro-chromite
38	Sedlice	0,627	0,373	—	0,282	0,718	spinel	magno-spinel
39	Sedlice	0,624	0,376	—	0,268	0,732	spinel	magno-spinel
40	Sedlice	0,611	0,389	—	0,291	0,709	spinel	magno-spinel
41	Sedlice	0,615	0,385	—	0,288	0,712	spinel	magno-spinel
42	Sedlice	0,097	0,903	0,111	0,763	0,126	chromite	ferro-chromite
43	Sedlice	0,509	0,491	0,020	0,503	0,477	picro-chromite	magno-chromite
44	Sedlice	—	1,000	0,922	0,078	—	magnetite	ferro-ferrite
45	Sedlice	0,386	0,614	—	0,867	0,133	chromite	ferro-ferrite
46	Sedlice	0,318	0,682	—	0,877	0,123	chromite	ferro-chromite

Table 1b. Continuation

47	Sedlice	—	1,000	0,916	0,084	—	magnetite	ferro-ferrite
48	Mašková	0,775	0,225	0,026	0,220	0,754	spinel	magno-spinel
49	Mašková	0,745	0,256	0,024	0,246	0,730	spinel	magno-spinel
50	Mašková	0,759	0,241	0,016	0,217	0,767	spinel	magno-spinel

manifested (J. Zlocha, 1973; D. Hovorka, I. Rojkovič, Z. Zlocha, 1975).

A. Hodkovce—Komárovce ultrabasic body (Hodkovce, Paňovce, Rudník, Jasov)

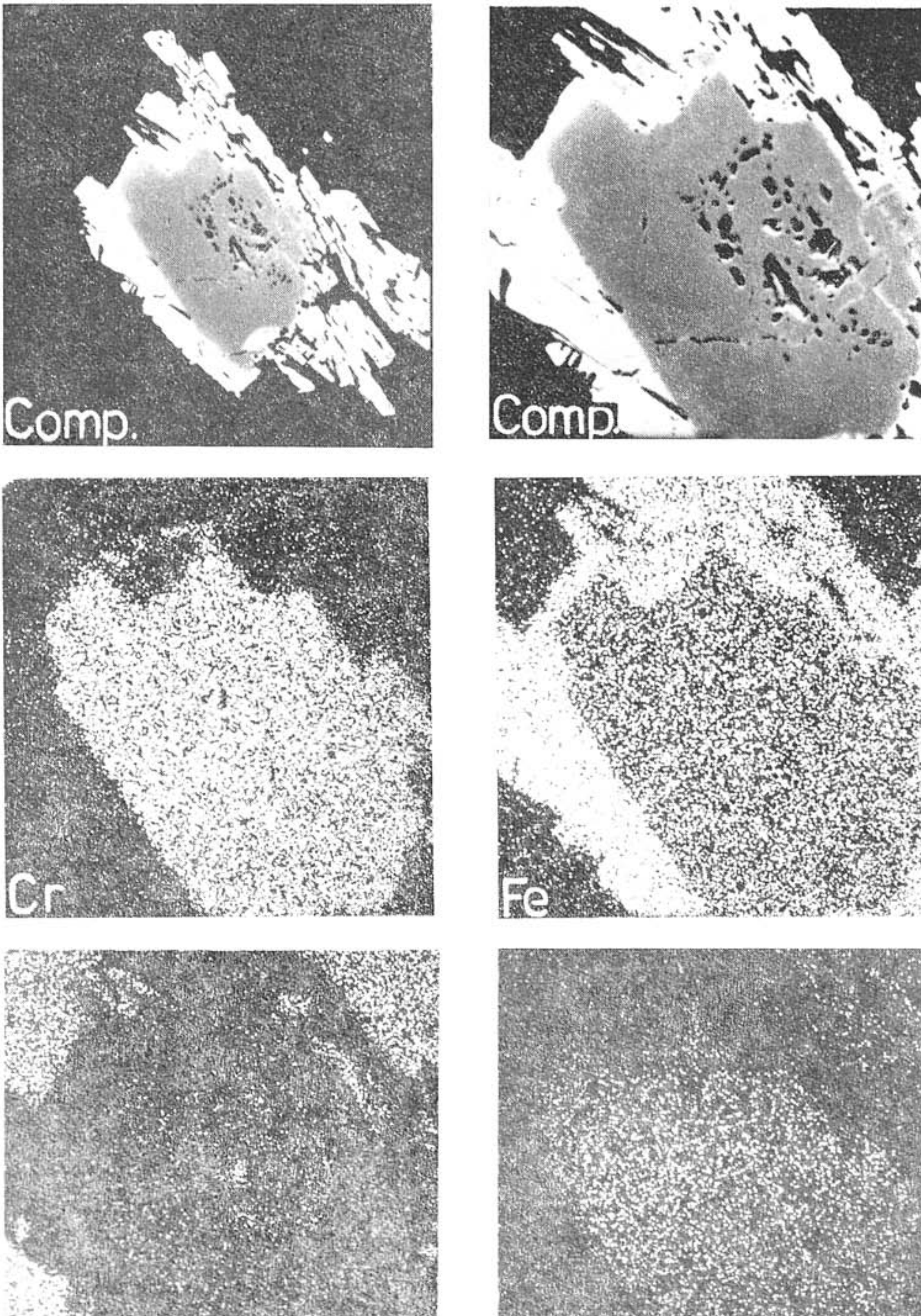
In the Komárovce body are observed under microscope chromite, chromium spinel and magnetite (Fig. 3). Also in spite of high serpentinization of ultrabasic rocks, we have observed chromite prevailingly in dunitic types (documented by prevailing loop textures with relicts of olivine) whereas chromium spinel is bound to serpentinites with relicts of pyroxenes (the original rocks were obviously of lherzolite-harzburgite character). From the studied localities, this one is richest spinels (up to 3 %).

a) Chromite occurs in rocks mostly in form of scattered isolated grains, often observed also megascopically (Fig. 4). More rarely chromite aggregates form parallel oriented streaks up to 1—2 cm thick (Fig. 5). The observed banded arrangement of chromite grains testifies to the action of gravitational processes during formation of mineral associations of ultrabasites of various units still in the upper mantle of the earth. The grain dimensions vary within the range 0,1—1 mm. They are mostly idiomorphic, less corroded and rounded. Besides corrosion also their cataclasis is observed (Fig. 6, 7). It is usually little distinct. Mostly it is shown by irregular cracking of grains. On the cracks replacement by magnetite or serpentine minerals occurs them. Inner reflexes are not observed. Chromite grains are rimmed by magnetite (Fig. 8), which is prevailingly scattered and accumulated often in veinlets, in close paragenesis with serpentine minerals.

b) Chromium spinel forms mostly isolated grains 0,1—0,5 mm, more rarely up to 2 mm in size, scattered in rock. Delimination of grains is mostly irregular. Inner reflexes are very rare, of brownishred colour. Cataclasis is relatively strong. Parallel cracking is observed in most cases, often combined with cross cracks. The chromium spinels are relatively often replaced by silicates from the margin in the shape of rims. The latter form irregular streaks in the centre of grains. They often originate mainly along cracks and form so a net in the spinels.

c) Magnetite or chromium magnetite forms the rim and veinlets replacing spinels; it is also abundantly scattered in rock. There it forms isolated, often idiomorphic grains and mainly clusters and veinlets in close paragenesis with serpentine minerals, also bordering them (D. Hovorka — I. Rojkovič, 1976).

The first two types of spinels have not been observed together. Their frequent accompanying mineral is magnetite. From other opaque minerals were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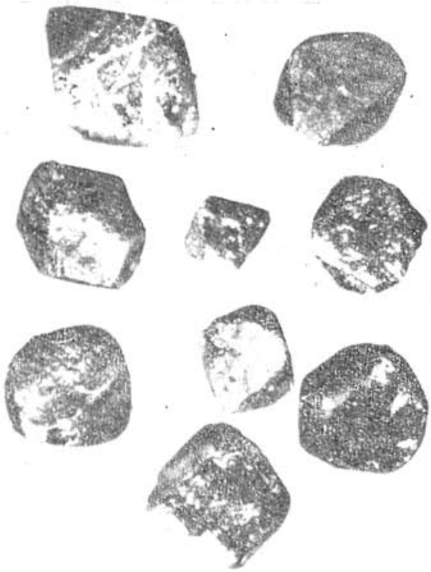


Fig. 4. Idiomorphic chromites from partly weathered serpentinite. Hodkovce, 30x, photo by L. Osvald.

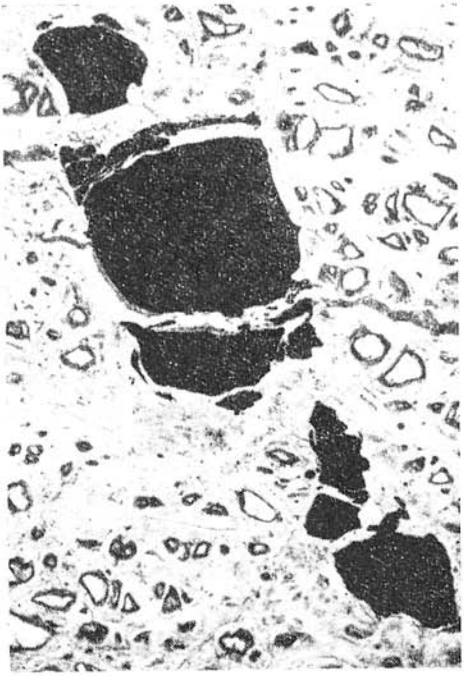
Fig. 5. Streaky parallel layers in serpentinite, enriched in chromite. Hodkovce. measure in cm. Photo by F. Martančík.

found: pentlandite, chalcopyrite, millerite, pyrite and haematite. In the weathered crust of this ultrabasic body are abundant quartz masses (opal, chalcedony, quartz, carbonates) magnesite, dolomite and calcite), oxides of iron and manganese (D. Hovorka – I. Rojkovič, 1976).

Chemical composition of spinels in the Komárovce body displays wide variability. It is shown best in the triangular diagram of trivalent elements (Fig. 9). The diagram with application of division by H. W. Haslam et al. (1976) shows that in their composition the idiomorphic grains are chromites, revailingly iron chromites, the allotriomorphic grains correspond to chromium spinel and magnetite rims and veins to chromium magnetite. According to the terminology of A. N. and H. Winchell (1951) most spinels correspond to berezovskite in their composition.

In this stage of study we separated out 6 samples of variable chemical composition from the localities Hodkovce, Sedlice, Danková and Rudňany (Tab. 2). The calculated X-ray data values display direct dependence on contents of Cr and indirect dependence on Al contents (Fig. 10), agreeing with the data of K. A. Rodgers (1973) and T. Peters, J. D. Kramers (1974). Correlation of X-ray data values with Fe^{++} and Fe^{+++} contents does not display direct dependence.

Fig. 3. Composition and areal distribution of Cr, Fe, Mg and Al chromite rimmed by magnetite in X-ray microanalyzer. Cinobaňa, composition 300x and 600x, other 600x. Photo by J. Krištín.



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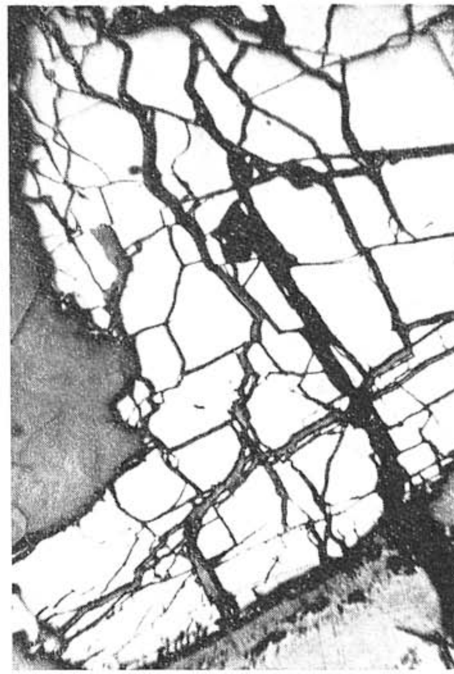

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Fig. 6. Xenomorphic cataclastized chromite grains. Cataclastized zones filled in with serpentine menerals. Hodkovce, transmitted light, 56x, X nicols. Photo by L. Osvald.

Fig. 7. Cataclastized chromite in serpentinite filled in with serpentine on cracks. Hodkovce, reflected light, 80x, 1 nicol. Photo by I. Rojkovič.

Fig. 8. Idiomorphic chromite rimmed by magnetite in serpentinite. Hodkovce, reflected light, 440x, 1 nicol. Photo by I. Rojkovič.

B. *Other bodies in the Triassic (Jaklovce, Kobeliarovo, Dobšiná, Danková) and Carboniferous (Ochtiná) in Spišsko-gemerské rudohorie* mts.

In samples of other smaller ultrabasic bodies has not been observed such a variability of spinels as in the Hodkovce-Komárovce body.

At the locality Jaklovce, obviously due to alterations linked with younger hydrothermal mineralization, relatively strong alteration of chromium spinels and their replacement by silicate minerals took place (Fig. 11, 12). In some cases only magnetite rims have preserved, not replaced by Mg-silicates.

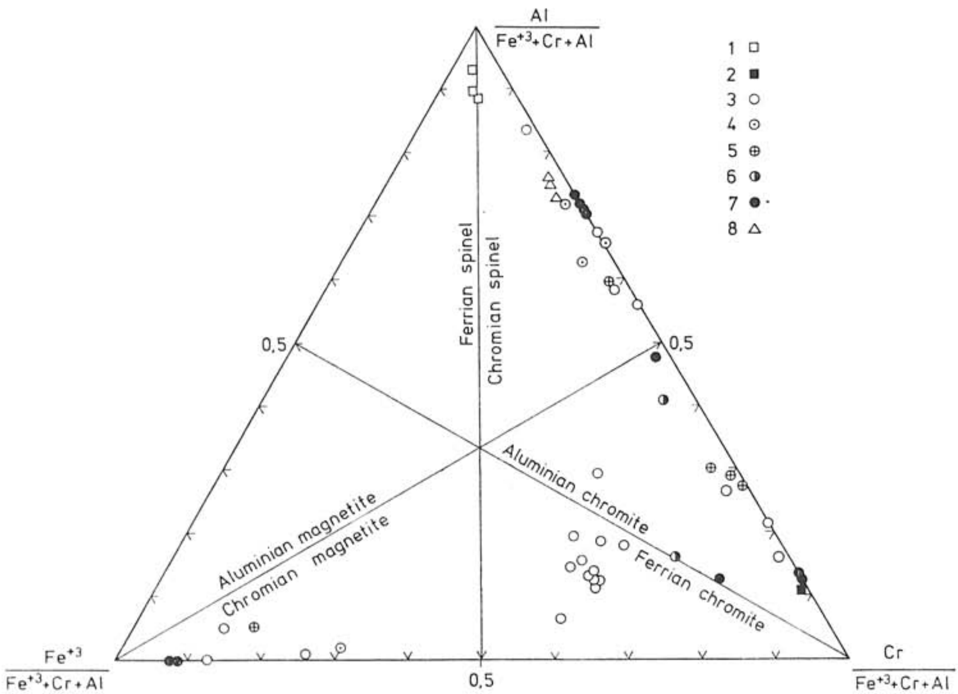


Fig. 9. Representation of trivalent elements in the studied spinels. 1 — Veľká Lúka, 2 — Cinobaňa, 3 — Hodkovce–Komárovce body, 4 — Jaklovce, 5 — other bodies in the Mesozoic and Carboniferous of the Spišsko-gemerské rudohorie mts., 6 — Rudňany, 7 — Sedlice, 8 — Mašková. Used is classification according to H. W. Haslam et al. (1976).

Table 2

No.	a_0
7	8,212 + 0,002
11	8,336 + 0,001
13	8,328 + 0,005
37	8,375 + 0,003
43	8,088 + 0,003
35	8,287 + 0,003

At the locality Ochtiná occurrence of chromite is similar as at the locality Cinobaňa in the Kohút crystalline. The chromites are rimmed by magnetite (Fig. 13), which is also abundantly scattered in rocks and forms the cement of actinolite crystals.

At the localities Dobšiná and Danková were found: chromite, chromium spinel and magnetite. Chromium spinels form scattered isolated and cataclastic grains of irregular shape. They are also rimmed and replaced cracks by magnetite. Magnetite also forms veins and clusters in rocks. Most distinct concentration (of weight up to several kg) from bimineral clusters with olivine were found with chromite. The chromites are highly cataclastized and filled in with serpentine minerals at cracks. Inner reflexes are not observed in them.

In other bodies of ultrabasic rocks in the Spišsko-gemerské rudohorie mts. spinels, similarly as in the Komárovce body, form three types. Again chromium spinel and chromium magnetite are present, however, in contrast to iron chro-

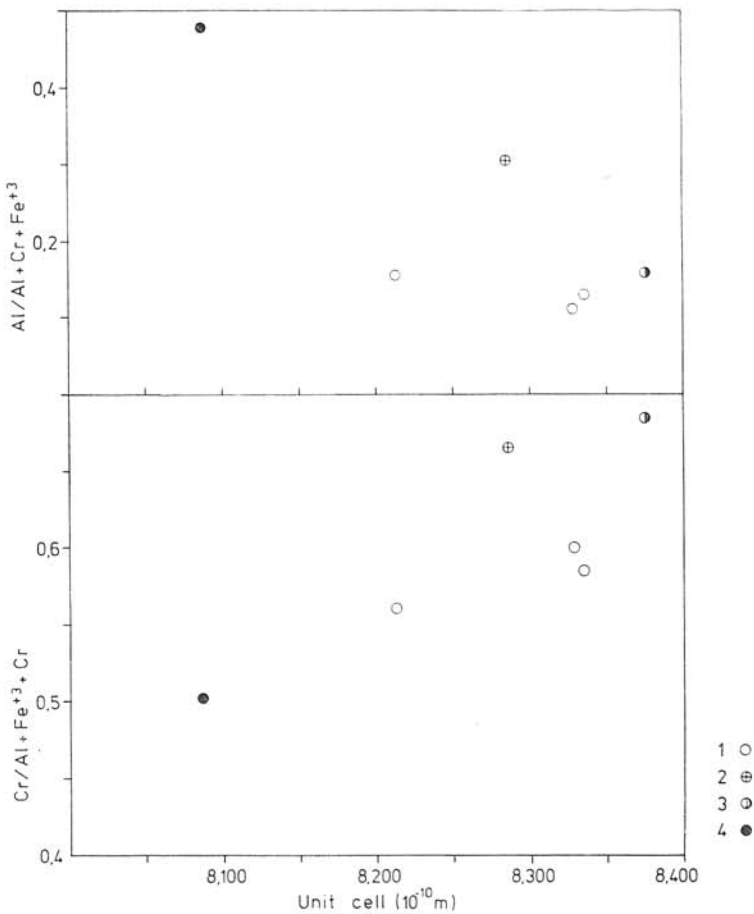


Fig. 10. Correlation of lattice constant with shares of Al and Cr in studied spinels. 1 – Hodkovce–Komárovce body, 2 – Danková, 3 – Rudňany, 4 – Sedlice.

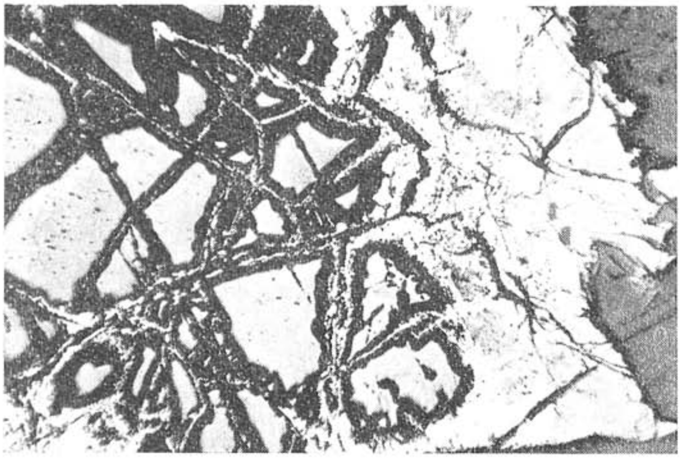


Fig. 11. Cataclastized chromium spinel (dark-grey), rimmed and filled in with magnetite (white) on cracks and with silicate minerals (light and medium grey). Jaklovce, reflected light, 80x, 1 nicol. Photo by I. Rojkovič.

mites of the Komárovce body alumochromites are present. Moreover, in the bodies of Dobšiná and Danková, as a consequence of higher $Mg/Mg + Fe^{++}$, greastes accumulations correspond to magno-chromites (M. Zhelyazkova – M. Panayotova, 1971) in their composition or to picrochromites (T. N. Irvine, 1965).

C. *Rudňany*

At the hydrothermal polymetallic siderite-barite-sulphidic deposit Rudňany chromites and chromium spinels have been found in altered rocks occuring in the Carboniferous sequence. The chromites and chromium spinels are intensively cataclastized, moreover, the chromite is porous. Besides magnetite, millerite and violarite are found other minerals with chromite and chromium spinelite, typical of hydrothermal mineralization of this area: pyrite, gersdorffite, cobaltite, chalcopyrite, quartz and others.

Whereas compact, fresh spinel is equivalent to magnochromite or picrochromite in its composition, porous spinel, as a consequence of absolute absence of Mg, probably caused by secondary carying away of Mg and Al, corresponds to chromite or ferro-chromite.

4. *Ultrabasic body near Sedlice*

Geological position of the ultrabasic body near Sedlice has not been solved. It occurs amidst the Paleogene of the Spišská kotlina basin, north of the envelope Mesozoic strip of the Čierna hora zone. On the contrary to the bodies in the Mesozoic the grade of serpentinization is lower, varying within the range 30–70 %.

Distribution of spinel group minerals and their linking to rocks types in the body near Sedlice is similar as in the Hodkovce–Komárovce body. Chromites

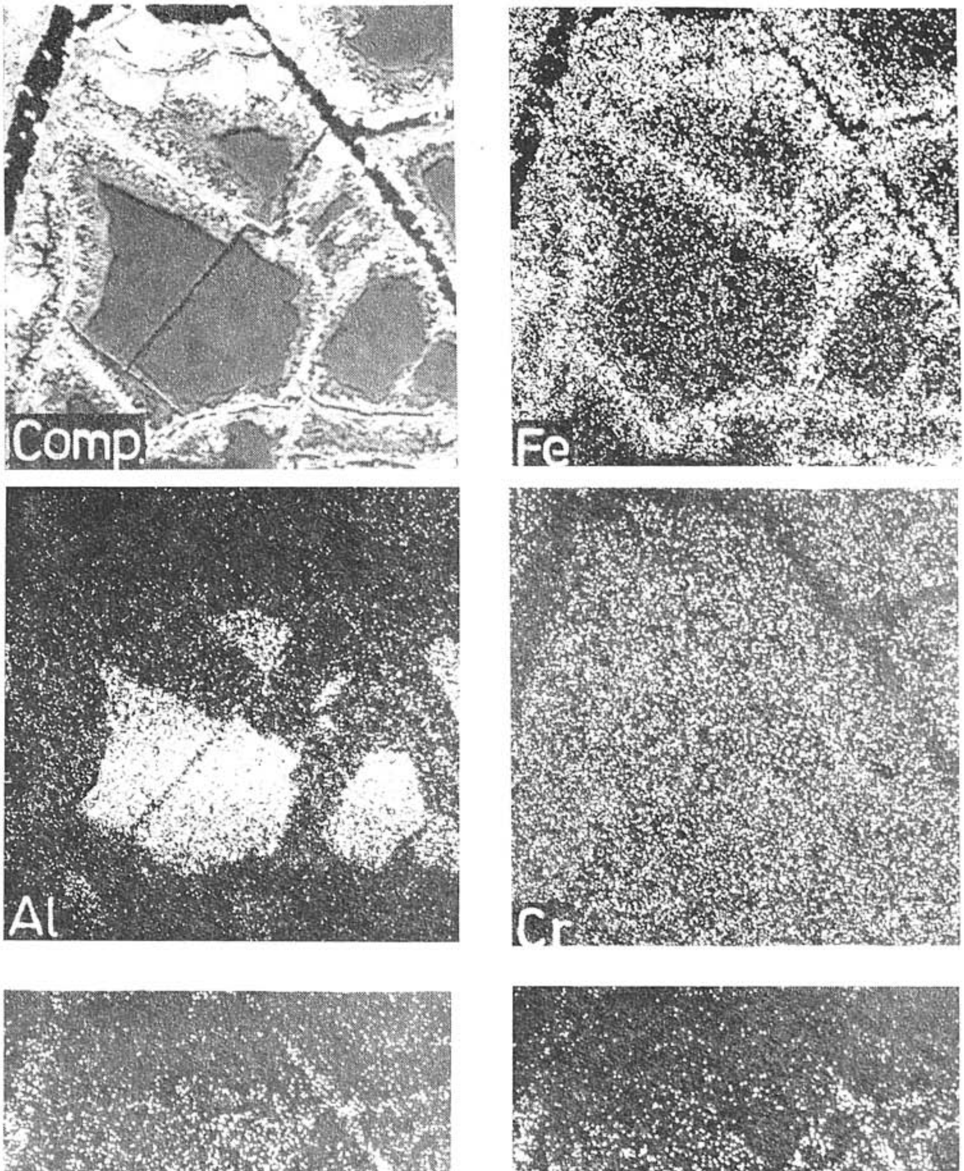

Comp
Fe
Al
Cr
Mg
Si

Fig. 13. Chromite (light-grey) is rimmed by magnetite (white), which intergrows with actinolite (dark-grey). Ochtiná, reflected light, 160x, 1 nicol. Photo by I. Rojkovič.

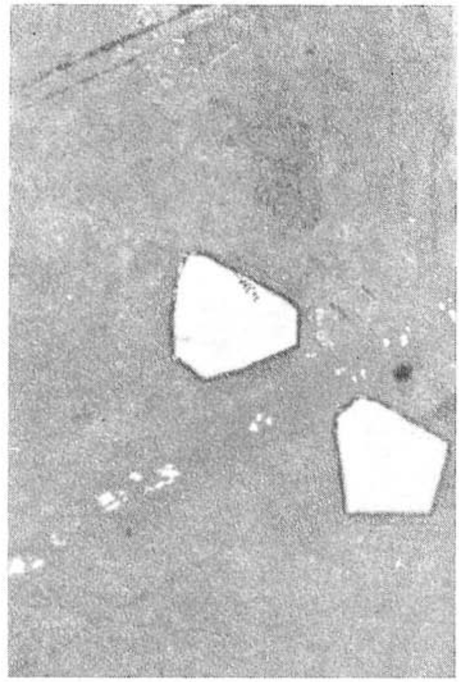


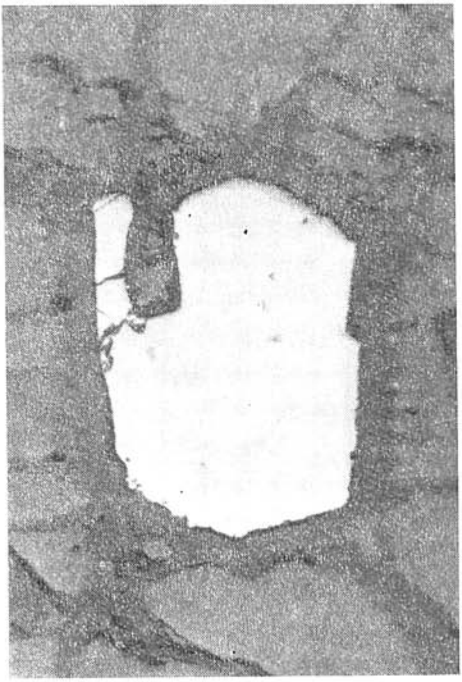
Fig. 14. Idiomorphic chromite in rock intersected by serpentine veinlet with magnetite. Sedlice, reflected light, 160x, 1 nicol. Photo by I. Rojkovič.

form idiomorphic (Fig. 14) or rounded, corroded (Fig. 15) and slightly cataclastized (Fig. 16) grains. Chromium spinels form irregularly delimited (Fig. 17) and elongated grains, in places parallely ordered (Fig. 18). Magnetite is scattered in rocks, forming thin veinlets in rocks and the foregoing spinels (Fig. 19), rimming them.

In paragenesis with the mentioned minerals are found: pentlandite, millerite, awaruite and in weathered samples haematite and limonite. The oxidation process has not caused any microscopically visible changes on spinels.

In composition of spinels wide isomorphism is shown, mainly between Al and Cr. Besides chromium magnetites occurring in the rims of older spinels and in rock, on the basis of their composition spinels belong to chromites or alumochromites in the case of idiomorphic grains and allotriomorphic grains to chromium spinels.

Fig. 12. Composition and areal distribution of Fe, Al, Cr, Mg and Si in chromium spinel and rims of silicate minerals and magnetite in X-ray microanalyzer. Jaklovce, 300x. Photo by J. Krištín.



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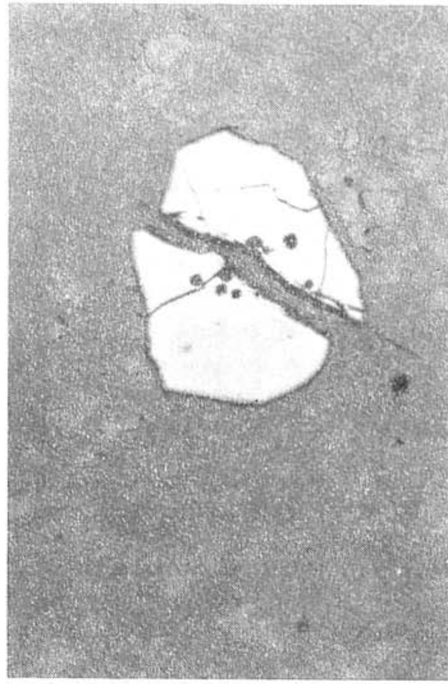

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Fig. 15. Corroded chromite in serpentinite. Sedlice, reflected light, 440x, 1 nicol. Photo by I. Rojkovič.

Fig. 16. Cataclastized chromite on joint, filled in with serpentine. Sedlice, reflected light 160x, 1 nicol, photo by I. Rojkovič.

Fig. 17. Allotriomorphic chromium spinel (white), intergrowing with silicate minerals. Sedlice, reflected light, 160x, 1 nicol. Photo by I. Rojkovič.

Fig. 18. Xenomorphic elongated grains of chromium spinel in serpentinite. Sedlice, transmitted light, 56x, 1 nicol. Photo by L. Osvald.

Fig. 19. Veinlets magnetite (white) in chromite (light-grey). Sedlice, reflected light, 440x, 1 nicol, Photo by I. Rojkovič.

5. *Spinels from peridotite xenoliths in Late Cenozoic alkalic basalts*

In the Late Cenozoic province of alkalic olivine basalts of the southern side of the Carpathian arc xenoliths of spinel peridotites have been established in the last time (D. H o v o r k a, 1977). They display a distinct upper mantle mineral association: magnesium olivine, ortho- and clinopyroxene and spinel. The grade of secondary alteration of xenoliths is low (attaining up to 26 cm on an average).

The spinels forms predominantly allotriomorphic grains (0,X–1 mm), filling in lobe-shaped the interstices between olivine and pyroxene grains (Fig. 20). Scarcely also idiomorphic grains (0,X–0,0X mm) were found, enclosed in the olivine of Ist generation (Fig. 21). The surface of spinel grains is very smooth and compared with olivine insignificantly raised only. Rarely inner reflexes of yellowishbrown colour are observed. In spinels are present finely rounded (up to 0,2 mm in size) enclosures of silicate minerals. From opaque minerals rarely pyrite has been found in xenoliths.

Allotriomorphic spinels from xenoliths in basalts display highest share of Mg Mg Fe ^{2} from all the observed spinels and are therefore nearest to spinel or magno-spinel. Variability of contents in the individual samples is minimum, however, their low number should be taken into consideration.

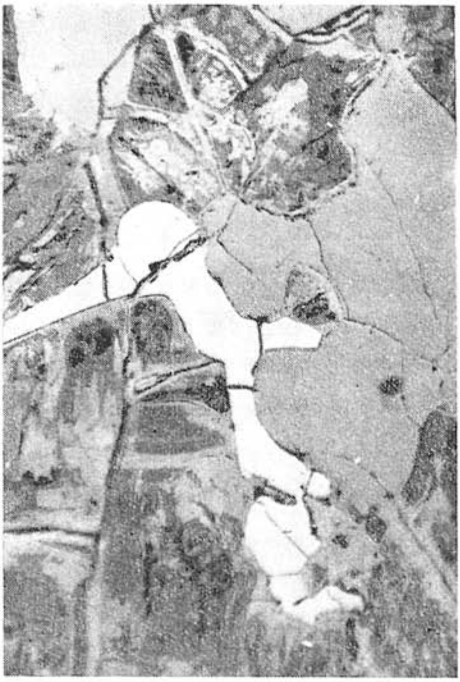

Fig. 20. Spinel (white) filling in the interstices of silicate grains in periodite xenolith. Mašková, reflected light, 160x, 1 nicol. Photo by I. Rojkovič.

Fig. 21. Idiomorphic spinel (rectangular cross section) in olivine (Ist generation) and irregular spinels of IInd generation. Xenolith of peridotite in alkalic basalt. Mašková, transmitted light, 56x, 1 nicol. Photo by L. Osvald.

Discussion

In the studied ultrabasic rocks spinels were forming in a long time interval of cooling. A relatively wide variation of chemical composition occured there, which may be observed in some larger bodies of ultrabasic rocks. Spinels rich in chromium, occurring in dunite types as idiomorphic grains, crystallized before and synchronously with silicate minerals. According to T. P. Thayer (1969), chromite with a high content of chromium crystallized earlier (before or at the same time with olivine); the younger one is progressively richter in Al. At the localities mentioned above, at which chromites and chromium spinels were observed, one may speak about a chronological succession from idiomorphic grains, richer in Cr, to allotriomorphic Al- richer grains, which are also directed. The wide variation of Cr and Al contents as well as the presence of two kinds of spinels is explained either magmatically at both the kinds (S. Capedri, 1976; P. Henderson, 1975) or by recrystallization of different primary association (A. T. W. Rothstein, 1971) in the individual bodies. A higher variability we have found in spinels of the body near Sedlice and in the Hodkovce–Komárovce body. Our results rather testify to a more gradual transition between the varieties. The „older" chromites are more corroded and so, on the basis of the above mentioned, formation of Al-richer varieties by the reaction of residual melt of magma, impoverished in Cr. may be supposed. The ratio of Cr/Al as well as of Mg/Fe^{+2} in indiomorphic chromites indicates a similar ratio in the magma, from which they crystallized. Indirect correlation of $Mg/Mg + Fe^{+2}$ to $Cr/Fe^{+3} + Cr + Al$ and direct to $Al/Al + Fe^{+3} + Cr$ in spinels from the Hodkovce—Komárovce and Sedlice bodies confirms increasing Al and Mg with cooling, rather corresponding to the succession of spinels in harzburgites from Euboea, Greece (S. Capedri, 1976) and also agreeing with positive correlation between Cr/Al and Fe^{+2}/Mg in Alpine type peridotites, established by T. N. Irvine (1967). Empirical application of spinel composition for distinguishing of Alpine type complexes from stratiform ones, however, cannot be used unambiguously (Fig. 22), what agrees with the opinion of P. Henderson (1975). $Fe^{+3}/Cr + Al + Fe^{+3}$ ratio is relatively stable and low in spinels of Alpine type peridotites, testifying to low fugacity of oxygene in the melt, from which the spinels formed (T. N. Irvine, 1967). In the spinels observed by us, however, besides predominantly low contents, a distinctly increasing share of Fe^{+3} in spinels or ferrian chromites of the Hodkovce—Komárovce body (Fig. 23) may be noticed. As this increase is shown not only in supergenic-altered but also in fresh rocks, higher volatility of oxygen may be possibly supposed in this body. With an increasing grade of metamorphism spinel approaches green $MgAl_2O_4$ (B. W. Evans, R. B. Frost, 1975), reflecting formation at high pressure and with equal composition of rock (K. Aoki, M. Prinz, 1974). Close to spinels of this type are ceylonites from the amphibolic peridotite occuring in granodiorites of the Malá Fatra.

In spinels found in peridotites xenoliths in alkalic basalts highet $Cr/Cr + Al$ ratio and lowest $Mg/Mg + Fe^{+3}$ ratio is known in idiomorphic types formed under higher pressures whereas the lowest mentioned ratio display spinels filling in the interstices between grains (A. R. Basu, I. D. MacGregor, 1975). Spinels from xenoliths in alkalic basalts and basanites are usually richer in Al (B. W. Evans, R. B. Frost, 1975; C. S. Ross et al., 1954). Allotriomorphic spinels from xenoliths of Late Cenozoic alkalic basalts near

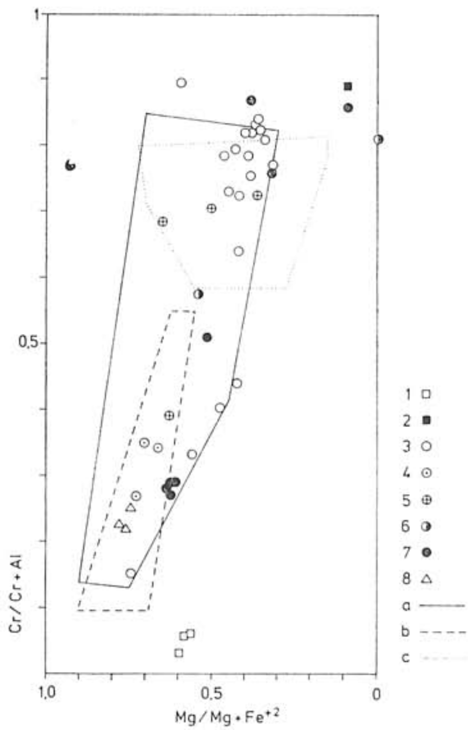

Fig. 22. Correlation diagram of $Cr/Cr + Al$ to $Mg/Mg + Fe^{+2}$ of spinels from the West Carpathians. 1 — Veľká Lúka, 2 — Cinobaňa, 3 — Hodkovce—Komárovce body, 4 — Jaklovce, 5 — other bodies in the Mesozoic and Carboniferous of the Spišsko-gemerské rudohorie mts., 6 — Rudňany, 7 — Sedlice, 8 — Mašková. a) field of Alpine type, b) xenolitic, c) stratiform spinels according to T. N. Irvine — T. C. Findlay (1972).

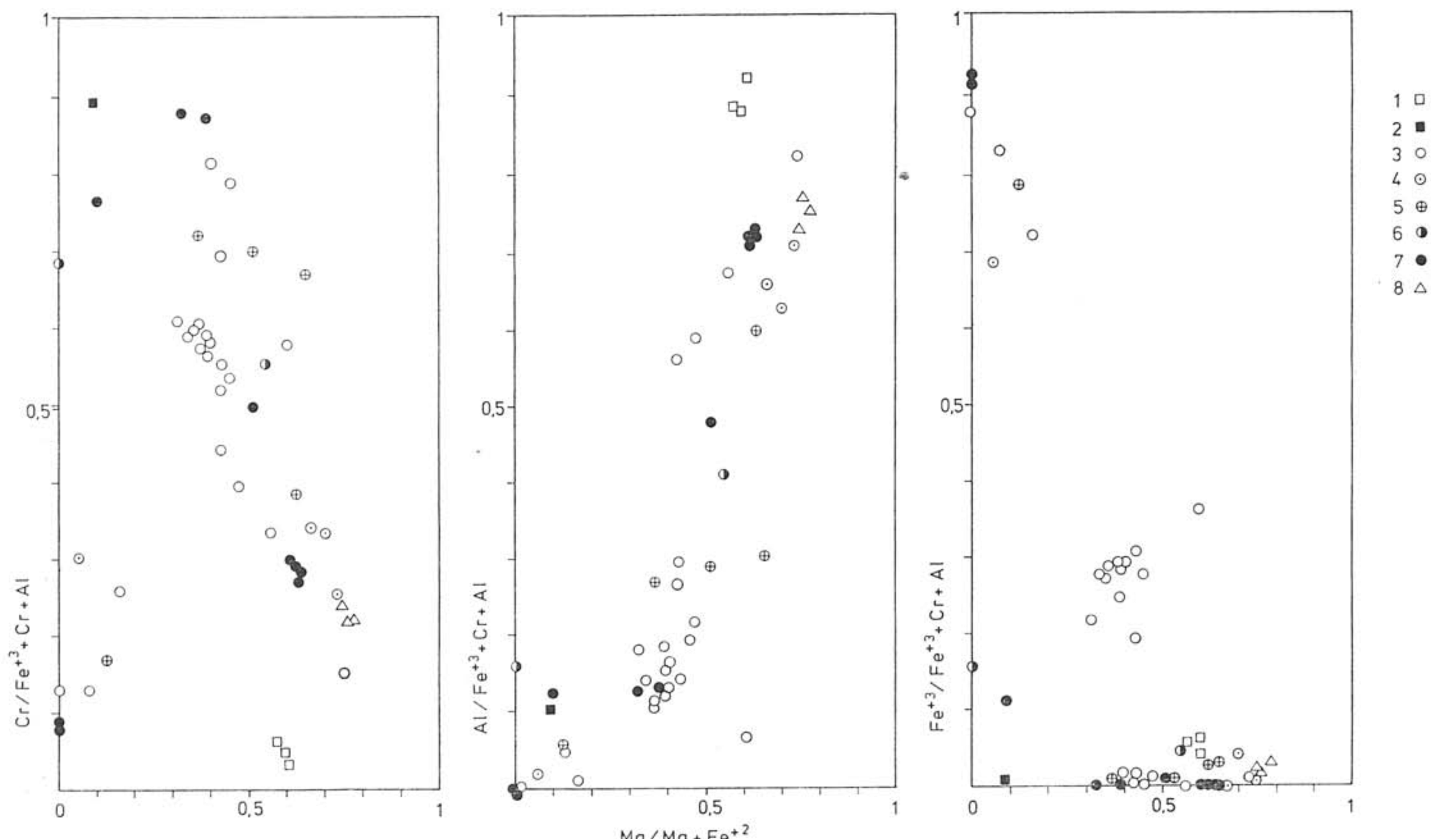

Fig. 23. Correlation diagrams of chemical composition of spinels from the West Carpathians (Plots of analyses of spinels). 1 – Veľká lúka, 2 – Cinobaňa, 3 – Hodkovce–Komárovce body, 4 – Jaklovce, 5 – other bodies in the Mesozoic and Carboniferous of the Spišsko-gemerské rudohorie mts., 6 – Rudňa-ny, 7 – Sedlice, 8 – Mašková.

Mašková display little variability and are close to spinel.

During serpentinization, under the influence of hydrothermal solutions, replacement of Cr^{+3} and Fe^{+3} and contingent carrying away of Mg and Al takes place. At some deposits of chromite in ultrabasites of the ophiolite series the origin of magnetite rims of chromite is cleared up by postmagmatic oxidation (R. Snethlage, D. D. Klemm, 1975). In the spinels studied by us replacement of chromites and chromium spinels by magnetite takes place from the margins and along cracks of cataclastized grains.

With the intensity of dynamothermal alteration of the individual ultrabasic massifs intensity of alteration of chromium spinels into magnetites increases on the whole. In places the original spinels are completely replaced by magnetite and in later recrystallization stages even spatial regrouping with formation of fine-grained magnetite pigment occurs. An exception forms the body near Cinobaňa. Ferrite-chromite has not been found, what may be explained by the circumstance that alteration of chromite into magnetite or ferrite-chromite with serpentinization is not as much a function of temperature as of the amount and mobility of Cr in the place of alteration (B. W. Evans, B. R. Frost, 1975).

Also in spite of secondary alterations of original chromium spinels, the phone content of Cr in metamorphosed ultrabasic massifs corresponds essentially to Cr content in dynamothermally unaffected bodies (D. Hovorka, 1975). Cr released by decomposition of chromium spinelides took part in composition of originating Cr-magnetite or of originating silicate minerals.

Translated by J. Pevný.

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