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STUDY OF OPAQUE MINERALS FROM SOME SERPENTINITES OF LOWER SILESIA (POLAND)

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A b s t r a c t. Opaque minerals occurring in selected Lower Silesian serpentinite samples from Grochowa, Wiry, Bystrzyca Górna and Jordanów were found to be represented by spinels of the spinel-magnetite-chromite series (Mg, Fe) (Al, Cr, Fe)$_2$O$_4$. Two generations of these minerals – primary and secondary – were distinguished on the ground of microscope study. Some, most probably, primary grains display zoned structure. Their internal parts consist of primary dark chromian spinel of magmatic origin. Its composition can be expressed by the formula:

$$(Mg^{2+}_{0.77} Fe^{2+}_{0.22} Mn^{2+}_{0.01}) (Al^{3+}_{1.28} Cr^{3+}_{0.54} Fe^{3+}_{0.17}) O_4$$

These cores are surrounded by lighter coloured zones impoverished in Al and Mg and identified as ferritchromite, exemplifield by the formula:

$$(Fe^{2+}_{0.58} Mg^{2+}_{0.35} Mn^{2+}_{0.07} Zn^{2+}_{0.01}) (Fe^{3+}_{1.13} Cr^{3+}_{0.65} Al^{3+}_{0.20}) Ti^{4+}_{0.01} O_4$$

The rims of these grains consist of magnetite containing but minute amounts of Cr, Mg, Ti, Al and Mn. Its approximate formula is as follows:

$$(Fe^{2+}_{0.82} Mg^{2+}_{0.17} Mn^{2+}_{0.01}) (Fe^{3+}_{1.84} Cr^{3+}_{0.10} Al^{3+}_{0.06}) O_4$$

These variations of chemical composition spinel– magnetite–chromite are continuous and gradual. Spinel occurring in grains showing no zoned structures was found to be also ferritchromite. In the present authors opinion this mineral is the product of internal reaction between the core and magnetitic rims of grains, taking place during metamorphic processes, characteristic of this member of ophiolitic suite.

INTRODUCTION

Opaque minerals occurring in serpentinites are significant petrogenetic indicators due to complexity and heterogeneity of their composition. Usually they are represented by chromian spinels of general formula (Fe,Mg) (Cr, Fe, Al)$_2$O$_4$. Within individual spinel grains we often observe alteration phenomena, consisting in gradual impoverishment of the mineral in Mg, Al and also Cr, accompanied by an increase of iron content from the core to the margins. These margins often display higher

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reflective indices and are close to magnetite in composition. A special term of "ferritchromite" (Spangenberg 1943) has been proposed for alteration products of primary chromian spinel, impoverished in Mg and Al.

There are several opinions on its origin. Many authors consider it to be a product of serpentinization (Spangenberg 1943; Miller 1953; Golding and Bayliss 1968, Beeson and Jackson 1969; Snetsinger 1973). Other students of the problem are connecting its formation with pre-serpentinization stage (eg. Černý 1968) or with magmatic alteration processes (Panagos and Ottemann 1966). Fairly justified is the opinion that ferritchromite is formed subsequently to serpentinization, presumably during metamorphism of serpentinite body (Tex 1955; Engin and Aucott 1971; Bliss and MacLean 1975).

The available data on opaque minerals in Lower Silesian serpentinites are, generally, limited to microscope descriptions and classical chemical analyses. Niśkiewicz (1979) distinguished primary and secondary ore minerals in fresh, unweathered serpentinites from boreholes in the Szklary region. Chromite and primary magnetite would represent the former ones, whilst secondary magnetite and haematite (being the product of marthitization process) – the secondary minerals. Fine concentrations of opaque minerals in serpentinite rocks from other regions of Lower Silesia were described as secondary magnetite (Wierzchołowski 1960, Maciejewski 1963, Szumlas 1960). Horninger (1941) and Spangenberg (1943) stated that Al-chromite (picotite) is the essential ore mineral of Tąpadła (Radunia group). The occurrence of chromian spinel, being a mixture of chromite and picotite was established by K. Smulikowski in the Czarna Góra chromite deposit near Tąpadła (after Majerowicz 1981) and more recently by Sałaciński and Zawidzki (1983). During serpentinization considerable part of Al and Mg migrates outwards toward the environs of spinel grains to form opaque rims at the initial stages of alteration processes. Subsequently, the whole grains are getting opaque and their composition is intermediate between chromite and magnetite.

MATERIALS AND METHODS

The serpentinite samples studied were selected from specimens collected in the outcrops near Grochowa, Wiry, Bystrzyca Górna and Jordanów. Their mineral composition was determined using X-ray method. Preliminary identification of opaque minerals was carried out by means of microscope study both in reflected and transmittant light.

After disintegration of samples in agate mortar to the grain size below 80 μm, they were enriched in magnetic minerals using magnet separation in aqueous environment. The values of cell edge (a_0) for spinels contained in each magnetic concentrate were computed by extrapolation up to the value $\Theta = 90°$ using the least squares method. X-ray patterns were obtained using film technique at the TUR M-60 diffractometer by applying filtered CoK_α radiation in 114.6 mm camera, assymetric Straumanis-Ievins method. Corrections for contraction and absorption were taken into account.

Mg, Al, Ca, Ti, Cr, Mn, Fe and Zn contents were estimated in three selected samples using X-ray microprobe analyzer ARL SEMQ in the Institute of Technology and Mechanization of Founding, Academy of Mining and Metallurgy in Cracow. The acceleration voltage applied was 20 kV and the sample current 150 μA. Samples were covered with carbon dust. Spectral lines of the following standards were used: MgK_α, AlK_α, $CaCO_3$ (CaK_α), TiK_α, CrK_α, MnK_α, FeS_2(FeK_α), ZnK_α. The real concentrations of the above elements were computed by taking into account the proper corrections for absorption of radiation (Philibert 1965), fluorescence (Reed 1965) and difference of atomic numbers (Philibert and Tixier 1968). The contents of oxygen were calculated as the difference between 100 per cent and total percentage of the remaining elements.

When examining the sample SJN 5 a portion of magnetic fraction was additionally treated with hydrochloric and hydrofluoric acids (at room temperature) and the minerals thus separated were examined using X-ray diffractometry to determine their a_0 values.

RESULTS

Mineral composition of the examined samples is presented in Table 1. Apart from serpentine minerals they contain talc, tremolite, forsterite and quartz as major components. Chlorite, magnesite occur in subordinate amounts. Besides, there always occur opaque minerals that has been examined using microscope analysis. The results of this study of individual samples are detailed below.

Table 1

Mineral composition of investigated rocks

Sample No	Locality, type of the rocks	Mineral composition	
		Main component	Accessory components
SGR-6	Grochowa, Peridotite (borehole) Type II (Kubicz 1966)	Serpentine, talc, tremolite, forsterite	Chlorite, magnesite, magnetite
SGR-18	Grochowa, Serpentinite Type IV (Kubicz 1966)	Serpentine, quartz	Magnesite, talc, tremolite, chlorite, magnetite
SW-1	Wiry, Serpentinite	Serpentine, talc	Chlorite, tremolite, magnesite, olivine, magnetite
SBG-1	Bystrzyca Górna, Serpentinite	Serpentine	Magnetite, magnesite, talc
SJN-5	Jordanów, Serpentine	Serpentine	Magnetite

Sample SJN-5 contains two types of opaque minerals. The first is represented by larger grains of irregular shapes, up to 1 mm in size. In some larger grains 3 phases were found to occur (Phot. 1):

I – dark gray isotropic phase showing reflectivity ca. 13%, forming internal parts of the grains,

II – light gray, also isotropic phase, rimming the former one and displaying higher reflectivity (ca. 17%),

III – white, isotropic phase (reflectivity ca. 21%) occurring close to fissures and in outer parts of the grains.

The second type of opaques is represented by very small, drop-shaped, elongated, sometimes idiomorphic grains, 0.005–0.1 mm in size. Their reflectivity is ca. 21%. They occur in irregular aggregates, but some of them display parallel orientation, concordant with directed structure of accompanying silicate mineral.

Sample SGR-18 also contains two types of opaque minerals. The first is represented by evenly distributed, large, isometric, distinctly corroded and fissured grains, 0.1–1 mm in size (Phot. 2). The second type is represented by drop-shaped, locally isometric small grains, 0.005–0.1 mm in size. Their aggregates are usually observed along or within fissures in opaque minerals (Phot. 3). Locally they form string-shaped elongated aggregates (Phot. 4). Microscope studies have shown that these aggregates occur in chlorite-carbonate veins. All the grains in question show similar optical features. They are gray-white in colour, homogeneous and isotropic. Their reflectivity amounts to ca. 17%.

Samples SGR-6 and SW-1 distinguish by the presence of predominantly one type of opaques. Microscope observations in reflected and transmittant light have shown the occurrence of large, irregularly shaped, usually string-shaped grains. Sometimes they are surrounded by silicate minerals (Phot. 5) or occur in chlorite-carbonate veinlets. Besides, there also occur small drop-like grains, 0.005–0.1 mm in size. Optical properties of all these ore grains are similar. They are colourless, isotropic and their reflectivity varies from 17 to 20 per cent.

In the sample SBG-1 opaque minerals, 0.1–0.8 mm in size, are evenly distributed. They are corroded, fractured and isometric in shape. In reflected light they are gray, isotropic, showing reflectivity ca. 13%. In immersion we may distinguish two phases in these grains, slightly differing in reflectivity. Locally, at the margins of these grains, we observe alteration into isotropic gray-white phase, showing slightly higher reflectivity (ca. 20%). Apart from this type of grains, there occur segregations of opaque minerals along the boundaries of silicate mineral aggregates (serpentine – Phot. 6). In reflected light they are isotropic, gray-white in colour, showing reflectivity ca. 20%.

Table 2

Cell parameter (a_0) of magnetic mineral

Sample No	a_0 [Å]
SGR-6	8.382±0.004
SGR-18	8.390±0.001
SW-1	8.394±0.002
SBG-1	8.45 ±0.07
SJN-5	8.394±0.005

Table 3

X-ray reflections and interplanar spacings of the mineral separated by acid treatment from magnetically enriched concentrate (sample SJN-5)

I	d [Å]	hkl
2	4.76	111
1	2.91	220
10	2.48	311
1	1.68	422
1	1.58	333; 511
3	1.457	440
1	1.235	533

a_0 = (8,13±0,05) Å

Optical properties of opaque minerals occurring in serpentinite rocks in question indicate them to represent spinels of the spinel-magnetite-chromite series. Their chemical composition was till now – not exactly known. The shapes and forms of grains of these minerals suggest the presence of various genetic types. In general, they can be subdivided into primary and secondary generations. The first group is represented by opaques formed during the origin of primary host rocks – peridotites. They are isometric in shape, corroded, generally evenly distributed in the matrix (Phot. 2). Besides, irregular aggregates of small, drop-shaped or idiomorphic grains, forming inclusions within olivine crystals (Phot. 3) can also be assigned to primary generation. Opaque minerals generated during alteration processes of ultrabasites are considered to belong to secondary generation. They are represented by irregular aggregates of very small grains, grouping along cleavage planes of transparent mafic minerals formed during their alteration processes (eg. uralitization). Secondary minerals form small and larger grains of irregular, string-shaped habit (occurring within chlorite-carbonate veinlets – Phot. 4), as well as secretions along the borders of transparent minerals (Phot. 5, 6). The latters are probably connected with metasomatic alteration of peridotites. It should be emphasized that it is not always possible to distinguish the minerals of these two generations.

Because of intimate intergrowths of opaque and serpentine minerals, it was impossible to separate pure magnetic spinel grains. The obtained concentrates were containing but 30 to 70% of it. Cell parameters of these minerals are presented in Table 2. Three of them (samples SGR-18, SW-1 and SJN-5) are characteristic of magnetite, whereas that of sample SGR-6 (8.382±0.004 Å) is intermediate in value when compared with a_0 characteristic of magnetite and chromite. Because of high admixture of serpentine, the data for the sample SBG-1 are not precise. Cell edge value computed for magnetic concentrate of the sample SJN-5 was found to be: $a_0 = 8.394 \pm 0.005$ Å i.e. typical of magnetite. After etching this concentrate with hydrochloric and hydrofluoric acids (at room temperature), a typical cell edge parameter of Al spinel (8.13±0.05 Å) was obtained. The corresponding X-ray data are detailed in Table 3. Lack of characteristic reflections of Al spinel is, probably, due to low content of this mineral in the primary concentrate.

Electron microprobe analyses of large opaque mineral grains in the sample SJN-5 have shown the occurrence of three phases in them. These phases have been already described in the discussion on the results of microscope study. Moreover, similar analyses of microscopically homogeneous grains in samples SGR-6 and SGR-18 have been carried out. The selected data, representative of individual phases, are presented in Table 4.

Table 4

Electron microprobe analytical data (in weight %)

Sample No	SJN-5			SGR-6	SGR-18
	Phase I	Phase II	Phase III		
TiO_2	0.05	0.3	0.1	0.2	0.5
Al_2O_3	38.4	4.7	1.5	0.8	0.4
Cr_2O_3	24.6	23.4	3.4	25.9	20.9
Fe_2O_3	8.1	42.6	65.3	44.4	48.0
FeO	9.4	19.1	26.5	22.2	25.7
MnO	0.3	2.2	0.4	0.6	0.5
MgO	18.2	6.6	2.8	5.5	3.0
ZnO	0.2	0.2	0.00	0.2	0.1
CaO	0.00	0.00	0.00	0.00	0.00
Total	99.3	99.1	99.9	99.8	99.1

On the ground of these analyses we may distinguish three following phases within large grains of opaque minerals occurring in serpentinite of Jordanów:

1. Homogeneous phase I of the core parts of grains in question, consisting of chromian magnesiospinel of the composition:

$$(Mg^{2+}_{0.77}Fe^{2+}_{0.22}Mn^{2+}_{0.01})(Al^{3+}_{1.28}Cr^{3+}_{0.54}Fe^{3+}_{0.17})O_4$$

2. Intermediate zone consists of phase II, considerably differing in composition from that of the core. It is much lower in Al and Mg and this deficit is compensated by increased iron content, both as FeO and Fe_2O_3. We observe also some increase of Ti and Mn contents whilst that of Cr remains nearly constant. Crystallochemical for-

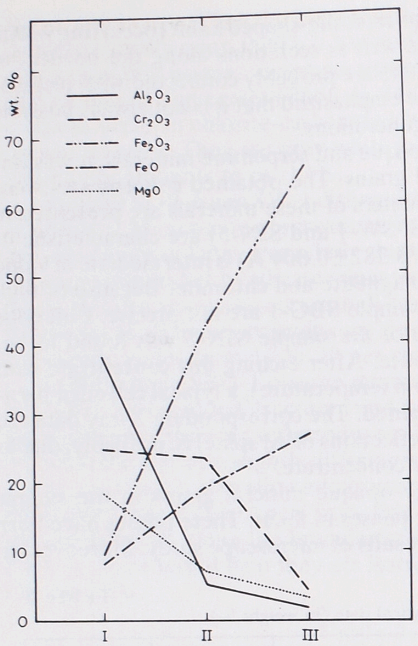

Fig. 1. Diagram showing variation of percentual (wt. %) contents of the five major oxides (FeO, Fe_2O_3, Al_2O_3, Cr_2O_3, MgO) from the core (phase I) through intermediate zone (phase II) to the margin (phase III) of an opaque mineral grain in serpentinite from Jordanów

mula of typical spinel of this zone can be expressed as follows:

$$(Fe^{2+}_{0.58}Mg^{2+}_{0.35}Mn^{2+}_{0.07}Zn^{2+}_{0.01})(Fe^{3+}_{1.13}Cr^{3+}_{0.65}Al^{3+}_{0.20})Ti^{4+}_{0.01}O_4$$

3. The outer zones of the grains under consideration consist of the phase III, distinctly enriched in FeO and Fe_2O_3. Simultaneously, the iron is more oxidized when compared with the core and the intermediate zone. Besides, we observe considerable decrease of Cr content and, less pronounced, of Al and Mg. Ti and Mn contents are close to those in the phase I. This phase can be defined as magnetite containing Cr, Mg, Ti, Al and Mn admixtures. Its typical formula can be presented as follows:

$$(Fe^{2+}_{0.82}Mg^{2+}_{0.17}Mn^{2+}_{0.01})(Fe^{3+}_{1.84}Cr^{3+}_{0.10}Al^{3+}_{0.06})O_4$$

The variations in percentual contents of five major oxides i.e. FeO, Fe_2O_3, Al_2O_3, Cr_2O_3, and MgO from the core (phase I) through intermediate zone (phase II) to the margins (phase III) in larger grains of spinel opaque minerals in serpentinites of Jordanów are presented in Fig. 1. On the other side, chemical composition of microscopically homogeneous spinel grains (Table 4) can be expressed by the following formulas:

a) sample SGR-6:

$$(Fe^{2+}_{0.68}Mg^{2+}_{0.30}Mn^{2+}_{0.02}Zn^{2+}_{0.01})(Fe^{3+}_{1.21}Cr^{3+}_{0.74}Al^{3+}_{0.03})O_4$$

b) sample SGR-18:

$$(Fe^{2+}_{0.82}Mg^{2+}_{0.17}Mn^{2+}_{0.02})(Fe^{3+}_{1.35}Cr^{3+}_{0.62}Al^{3+}_{0.02})Ti^{+}_{0.01}O_4$$

DISCUSSION

The phenomenon of variation of chemical composition of chromian spinel grains

from their cores to the margins was already reported for different serpentinite occurrences (Simpson 1920; Tex 1955, Miller 1953; Bliss and MacLean 1975), as well as for some non-serpentinized rocks that have been subjected to elevated temperature after chromite crystallized, such as xenoliths and xenocrysts in alkaline basalts (Frisch 1971; Evans and Moore 1968; White 1966; Muir and Tilley 1964).

As far as Lower Silesian serpentinites are concerned, this phenomenon was reported first by Spangenberg (1943) and Horninger (1941). The contents of Fe_2O_3, FeO, MgO and MnO in chemical analysis presented by Spangenberg for Al-chromite from Tąpadła (Radunia group) are similar to those in the phase I of Cr-spinel from Jordanów. The latter contains less Cr_2O_3 but more Al_2O_3. When compared with analyses of other chromian spinels (Simpson 1920; Pavlov 1949; Dede 1960; Shilova 1977; Caricin 1977; Bliss and MacLean 1975; Majerowicz 1981) our spinel phase I is lower in Cr and divalent iron but higher in Al and trivalent iron.

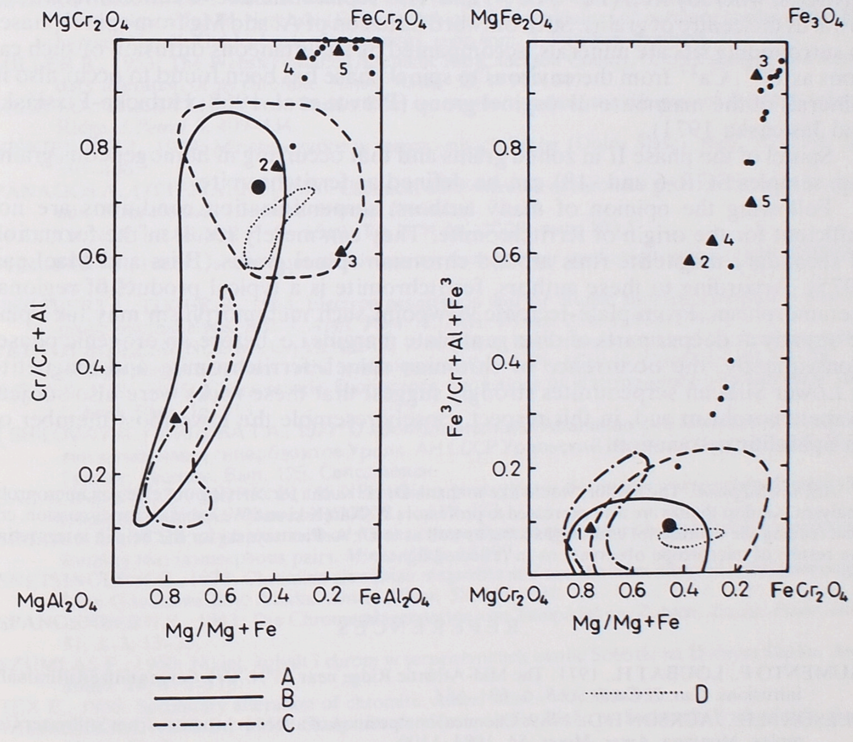

Fig. 2. Variation diagrams showing the trend of ferritchromite alteration in a zoned chromian spinel[1]. Large point corresponds to chromite core, the small to ferritchromitic margin. Triangles – analyses of chromian spinels from Lower Silesian serpentinites: *1, 2, 3* – phases I, II and III of the sample SJN-5; *4, 5* – samples SGR-6 and SGR-18 respectively. Other symbols – composition of chromian spinels from: *A* – layered intrusions; *B* – Alpine-type intrusions; *C* – ultramafic nodules; *D* – Mid-Atlantic Ridge serpentinites. *A,B,C* – after Irvine, (1967); *D* – after Aumento and Loubat (1971)

[1] Points – analyses of Cr spinels from Manitoba (Bliss and MacLean, 1975).

Diagram showing variation trends of ferritchromite, including the data for a zoned chromite from Central Manitoba deposit (Bliss and MacLean 1975) is presented in Fig. 2. Moreover, variation fields of chromites from layered intrusions, alpine-type intrusions (metamorphic peridotites), ultramafic nodules and from serpentinites of Mid-Atlantic Ridge are marked in this diagram. Detailed inspection of this diagram leads to the following conclusions:

Chemical composition of chromian spinel (phase I) from serpentinite of Jordanów is the same as that from alpine-type instrusions (metamorphic peridotites). It is also very close to typical spinel from ultramafic nodules. A comparison of analyses of ferritchromite and magnetite, forming rims surrounding chromian spinel grains of Manitoba, and of those of the phases II and III in Cr-spinel of Jordanów, as well as for samples SGR-6 and 18 of Grochowa, clearly indicates that the character of these alterations is similar. It is, thus, concluded, that this change of chemical composition is due to diffusion migration of Al^{3+}, Cr^{3+} and Mg^{2+} cations from spinel phase to its environs, whereby iron (Fe^{2+}, Fe^{3+}) and Ti^{4+} replace the above cations, migrating towards the centre of grains. Such outward diffusion of Al and Mg from spinel phases to surrounding silicate minerals, accompanied by simultaneous diffusion of such cations as Ti^{4+}, Ca^{2+} from the environs to spinel phase has been found to occur also in minerals of the magnetite-ulvöspinel group (Prevot et al. 1968; Hubicka-Ptasińska and Jasieńska 1971).

Spinel of the phase II in zoned grains and that occurring in homogeneous grains (eg. samples SGR-6 and -18) can be defined as ferritchromite.

Following the opinion of many authors, serpentinization conditions are not sufficient for the origin of ferritchromite. They can merely result in the formation of secondary magnetite rims around chromian spinel grains (Bliss and MacLean 1975). According to these authors, ferritchromite is a typical product of regional metamorphism. From plate-tectonic viewpoint such metamorphism may take place already at deeper parts of divergent plate margins i.e. before an orogenic phase. Consequently, the occurrence of chromian spinel, ferritchromite and magnetite in Lower Silesian serpentinites strongly suggest that these rocks were also subject to metamorphism and, in this respect, closely resemble the lowermost member of an ophiolitic association.

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Z BADAŃ MINERAŁÓW NIEPRZEZROCZYSTYCH W SERPENTYNITACH DOLNEGO ŚLĄSKA

Streszczenie

W pracy przedstawiono wyniki badań minerałów nieprzezroczystych pochodzących z wybranych serpentynitów Dolnego Śląska (z odkrywek w Grochowej, Wirach, Bystrzycy Górnej i Jordanowie). Ogólnie biorąc, są to spinele szeregu spinel–magnetyt–chromit o ogólnym wzorze (Mg, Fe) (Al, Cr, Fe)$_2$O$_4$. Mikroskopowo stwierdzono występowanie dwóch odmian genetycznych tych minerałów – pierwotnej i wtórnej. Niektóre ziarna określone jako pierwotne wykazują strefowe zróżnicowanie. Wewnętrzne części ziarna stanowi pierwotny, ciemny spinel chromowy pochodzenia magmowego, którego przykładowy wzór chemiczny jest następujący:

$$(Mg^{2+}_{0.77}Fe^{2+}_{0.22}Mn^{2+}_{0.01})(Al^{3+}_{1.28}Cr^{3+}_{0.54}Fe^{3+}_{0.17})O_4$$

Jest on otoczony jaśniejszą strefą zubożoną w Al i Mg, określoną jako ferritchromit, o przykładowym wzorze chemicznym

$$(Fe^{2+}_{0.58}Mg^{2+}_{0.35}Mn^{2+}_{0.07}Zn^{2+}_{0.01})(Fe^{3+}_{1.13}Cr^{3+}_{0.65}Al^{3+}_{0.20})Ti^{4+}_{0.01}O_4$$

Obrzeża ziaren tworzy magnetyt zawierający nieznaczne domieszki Cr_2O_3, MgO, TiO_2, Al_2O_3 i MnO. Przykładowy skład chemiczny magnetytu – $(Fe^{2+}_{0.82}Mg^{2+}_{0.17}Mn^{2+}_{0.01})(Fe^{3+}_{1.84}Cr^{3+}_{0.10}Al^{3+}_{0.06})O_4$
Zmiana składu chemicznego spinel–chromit–magnetyt następuje w sposób ciągły i stopniowy. Spinel występujący w ziarnach nie wykazujących strefowego zróżnicowania można także uważać za ferritchromit. Ferritchromit powstaje w wyniku reakcji zachodzących pomiędzy jądrem ziarna i magnetytowym obrzeżem podczas metamorfizmu regionalnego.

OBJAŚNIENIA FIGUR

Fig. 1. Zmiana udziału procentowego (% wagowy) pięciu podstawowych tlenków (FeO, Fe_2O_3, Al_2O_3, Cr_2O_3, MgO) przy przejściu od jądra
(faza I) przez strefę przejściową (faza II) do obrzeży (faza III) ziarna minerału nieprzezroczystego w serpentynicie z Jordanowa

Fig. 2. Diagramy zmienności pokazujące kierunki zmian składu chemicznego ferritchromitu w spinelu chromowym wykazującym strefowe zróżnicowanie. Punkty oznaczają analizy wykonane dla spineli chromowych z Manitoba (Bliss i MacLean, 1975)
Duży punkt oznacza jądro chromitowe, mniejsze punkty oznaczają ferritchromit. Trójkąty – analizy spineli chromowych z serpentynitów Dolnego Śląska: *1, 2, 3* – fazy I, II i III próbki SJN-5; *4, 5* – próbki SGR-6 i SGR-18. Pozostałe symbole – skład spineli chromowych pochodzących z: *A* – intruzji warstwowych; *B* – intruzji typu alpejskiego; *C* – soczew ultrazasadowych; D – serpentynitów Grzbietu Śródatlantyckiego. *A, B, C* – według Irvine (1967); *D* – według Aumento i Loubat (1971)

OBJAŚNIENIA FOTOGRAFII

Fot. 1. Próbka SJN-5. Fragment ziarna minerału nieprzezroczystego zawierającego trzy fazy. Światło odbite, 450×

Fot. 2. Próbka SGR-18. Kształty i formy skupień pierwotnych minerałów nieprzezroczystych. Światło przechodzące. 1 nikol, 50×

Fot. 3. Próbka SGR-18. Skupienia małych ziarn minerałów nieprzezroczystych w minerale krzemianowym. Światło przechodzące. 1 nikol, 50×

Fot. 4. Próbka SGR-18. „Sznurkowate" wydzielenia minerałów nieprzezroczystych w żyle chlorytowo-węglanowej. Światło przechodzące. 1 nikol, 110×

Fot. 5. Próbka SGR-6. Minerały nieprzezroczyste otaczające minerały krzemianowe. Światło przechodzące. 1 nikol, 50×

Fot. 6. Próbka SBG-1. Wydzielenia minerałów nieprzezroczystych wzdłuż granicy agregatów serpentynu. Światło przechodzące. 1 nikol, 50×

Войцех ПШИБЫЛОВИЧ, Мария ХУБИЦКА-ПТАСИНЬСКА

ИССЛЕДОВАНИЕ НЕПРОЗРАЧНЫХ МИНЕРАЛОВ В СЕРПЕНТИНИТАХ НИЖНЕЙ СИЛЕЗИИ

Резюме

В работе изложены результаты исследований непрозрачных минералов из выбранных серпентинитов Нижней Силезии (из обнажений в Гроховой, Вирах, Быстшицы Гурной и Йорданове). В основном, это шпинель из ряда шпинель–магнетит–хромит с общей формулой (Mg, Fe) (Al, Cr, Fe)$_2$O$_4$. Под микроскопом отмечено наличие двух генетических разновидностей этих минералов – первичной и вторичной. В некоторых зернах, определенных как первичные, наблюдается зональное строение. Внутренняя часть зерна состоит из первичной темноцветной хромшпинели магмового генезиса, с примерной химической формулой:

$$(Mg^{2+}_{0.77}Fe^{2+}_{0.22}Mn^{2+}_{0.01})(Al^{3+}_{1.28}Cr^{3+}_{0.54}Fe^{3+}_{0.17})O_4$$

Она обрамлена более светлой зоной убогой в Al и Mg, определенной как ферритхромит с примерной химической формулой:

$$(Fe^{2+}_{0.58}Mg^{2+}_{0.35}Mn^{2+}_{0.07}Zn^{2+}_{0.01})(Fe^{3+}_{1.13}Cr^{3+}_{0.65}Al^{3+}_{0.20})Ti^{4+}_{0.01}O_4$$

Каемку зерна образует магнетит, содержащий незначительные примеси Cr_2O_3, MgO, TiO_2, Al_2O_3 и MnO. Примерный химический состав магнетита:

$$(Fe^{2+}_{0.82}Mg^{2+}_{0.17}Mn^{2+}_{0.01})(Fe^{3+}_{1.84}Cr^{3+}_{0.10}Al^{3+}_{0.06})O_4$$

Изменение химического состава шпинель–хромит–магнетита происходит непрерывно и постепенно. Шпинель, образующая зерна без зонального строения, может быть принята за ферритхромит. Ферритхромит возникает в результате реакции, происходящей между ядром зерна и магнетитовой каемкой в процессе регионального метаморфизма.

ОБЪЯСНЕНИЯ К ФИГУРАМ

Фиг. 1. Изменение процентного содержания (% весовой) пяти основных окислов (FeO, Fe_2O_3, Al_2O_3, Cr_2O_3, MgO) при переходе от ядра
(фаза I) через переходную зону (фаза II) к каемке (фаза III) зерна непрозрачного минерала в серпентините из Йорданова

Фиг. 2. Диаграммы заменяемости, показывающие направления изменения химического состава ферритхромита в хромшпинели характеризующейся зональным строением. Точки обозначают анализы хромшпинели из Манитобы (по Блиссу и Маклину 1975).
Крупной точкой обозначено хромитовое ядро, меньшими – ферритхромит. Треугольниками обозначены анализы хромшпинели из серпентинитов Нижней Силезии: *1, 2, 3* – фазы I, II, III пробы SJN-5, *4, 5* – пробы SGR-6 и SGR-18. Остальные символы – состав хромшпинели отобранной из: *A* – послойных интрузий, *B* – интрузий альпийского типа, *C* – ультраосновных линз, *D* – серпентинитов Срединно – Атлантического Хребта.
A, B, C – по Ирвину (1967); *D*– по Аументо и Лоубату (1971)

ОБЪЯСНЕНИЯ К ФОТОГРАФИЯМ

Фото 1. Проба SJN-5. Фрагмент зерна непрозрачного минерала содержащего три фазы. Отраженный свет, 450×

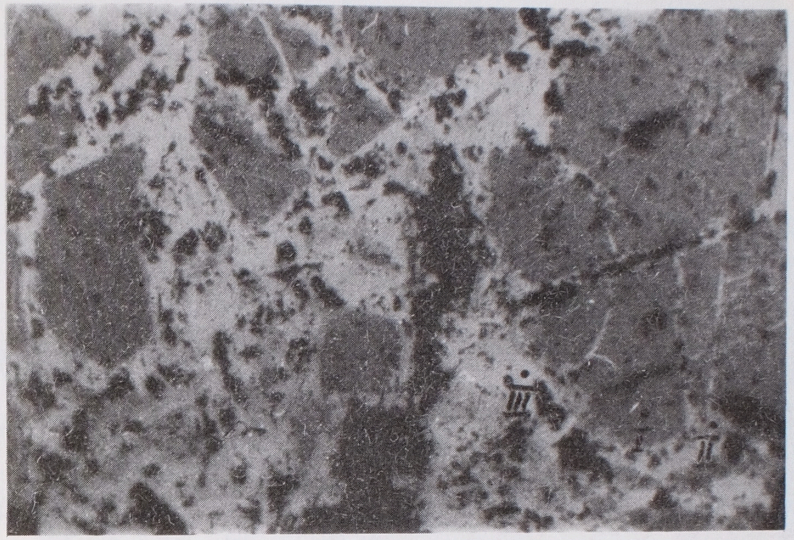
Фото 2. Проба SGR-18. Формы скоплений первичных непрозрачных минералов. Проходящий свет. 1 николь, 50×

Фото 3. Проба SGR-18. Скопления малых зерен непрозрачных минералов в силикатном минерале. Проходящий свет, 1 николь, 50×

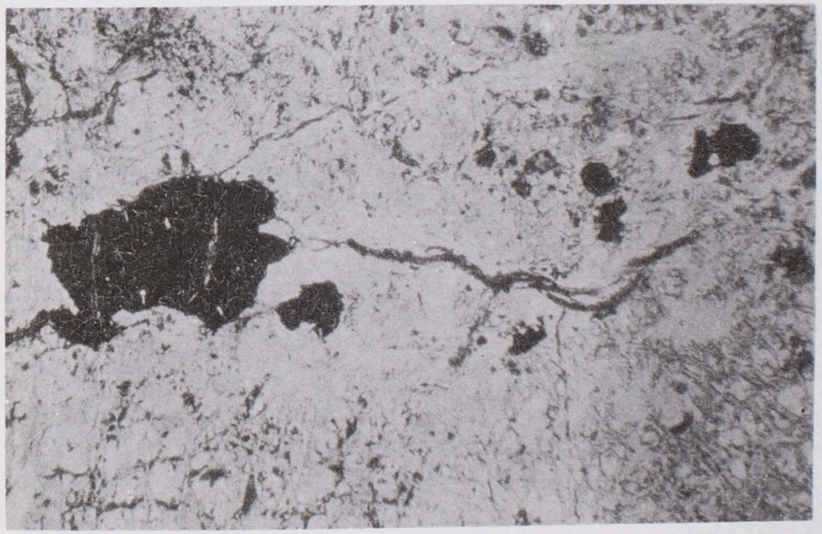
Фото 4. Проба SGR-18. Веревочные выделения непрозрачных минералов в хлорит-карбонатной жиле. Проходящий свет. 1 николь, 110×

Фото 5. Проба SBR-6. Выделения непрозрачных минералов, окаймляющие силикатные минералы. Проходящий свет. 1 николь, 50×

Фото 6. Проба SBG-1. Выделения непрозрачных минералов вдоль границы агрегатов серпентина. Проходящий свет. 1 николь, 50×



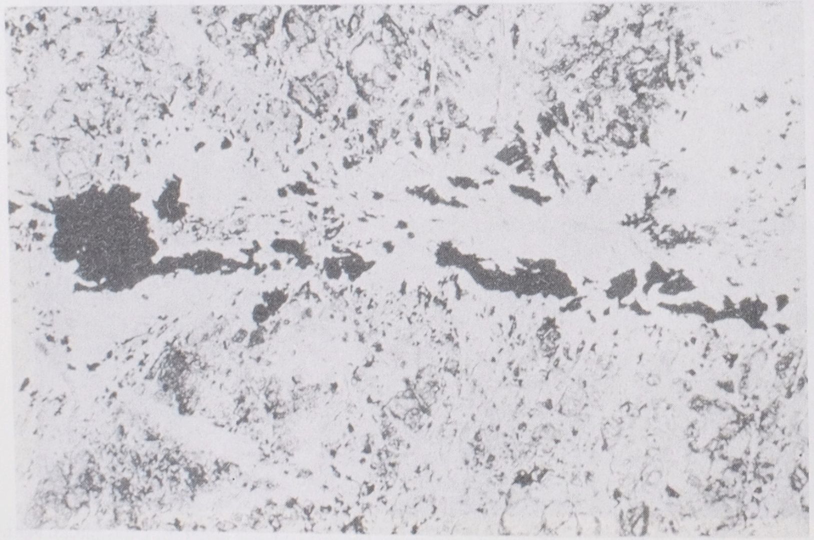
Phot. 1. Sample SJN-5. A fragment of opaque mineral grain consisting of three phases. Reflected light. 450×



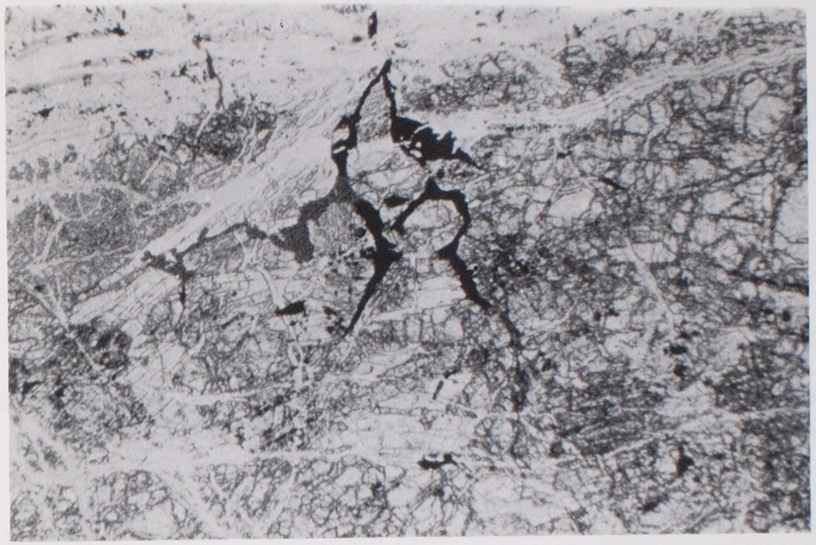
Phot. 2. Sample SGR-18. Shapes and forms of aggregates of primary opaque minerals. Transmittant light. One nicol, 50×

Wojciech PRZYBYŁOWICZ, Maria HUBICKA-PTASIŃSKA – Study opaque minerals from some serpentinites of Lower Silesia (Poland)

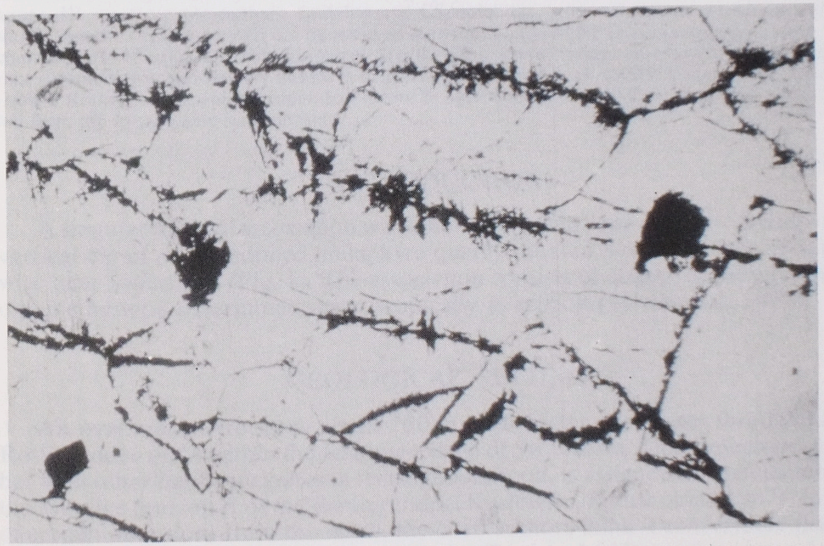
Phot. 3. Sample SGR-18. Aggregates of small grains of opaque minerals included in silicate. Transmittant light. One nicol. 50×



Phot. 4. Sample SGR-18. String-shaped secretions of opaque minerals in chlorite-carbonate veinlet. Transmittant light. One nicol. 110×



Phot. 5. Sample SGR-6. Opaque minerals surrounding silicate mineral grains. Transmittant light. One nicol. 50×



Phot. 6. Sample SBG-1. Secretions of opaque minerals along the boundaries of serpentine aggregates Transmittant light. One nicol. 50×