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NATIVE COPPER FROM RODINGITIZED GABBROIC DYKES IN SERPENTINITES OF THE BRASZOWICE—BRZEŹNICA MASSIF (LOWER SILESIA)

Abstract. The present paper deals with geological conditions of occurrence and results of mineralogical study of native copper found in serpentinite massif Braszowice-Brzeźnica. This mineral occurs here in strongly saussuritized and metasomatically altered gabbroic dykes within antigorite serpentinites on southern slopes of Kozie Chrzepty hill near Mikołajów. As follows from this study, native copper-bearing metasomatites belong to metarodingite group and this specific mineralization is due to serpentinization under strongly reducing conditions.

INTRODUCTION

Native copper occurrences in basites and ultrabasites are rather rare. Its presence was reported eg. in troctolites from layered gabbro intrusions in paragenesis with labradorite, ilmenite and titanomagnetite (Bowles 1978). In serpentinized ultrabasites of ophiolitic associations, native copper usually occurs together with magnetite, awaruite and heazlewoodite (Ramdohr 1967, 1975) whilst in metasomatic rodingites associated with serpentinites it is accompanied usually by diopside, grossular, vesuvianite and wollastonite (Leach, Rodgers 1978; Chamberlain 1980).

In Lower Silesia native copper was reported to occur in ultrabasic massif Gogołów—Jordanów (Ciemniewska *et al.* 1981), situated along N margin of the Góry Sowie Mts. block (Fig. 1). It occurs as irregular aggregates, 0.1—4 mm in size, in carbonate veins within antigorite serpentinite penetrated by borehole near Tąpadła.

GEOLOGICAL SETTING

Braszowice—Brzeźnica serpentinite-gabbro massif is situated within Fore-Sudetic block at S margin of Niemcza Dislocation zone. It is located along S border of the Góry Sowie Mts. block (Fig. 1, III), being ca. 40 km² in size. In K. Smulikowski's (1973) opinion, these serpentinites were formed from primary wehrlites. Locally they are mineralized by veiny magnesite or altered into talc rocks and covered by

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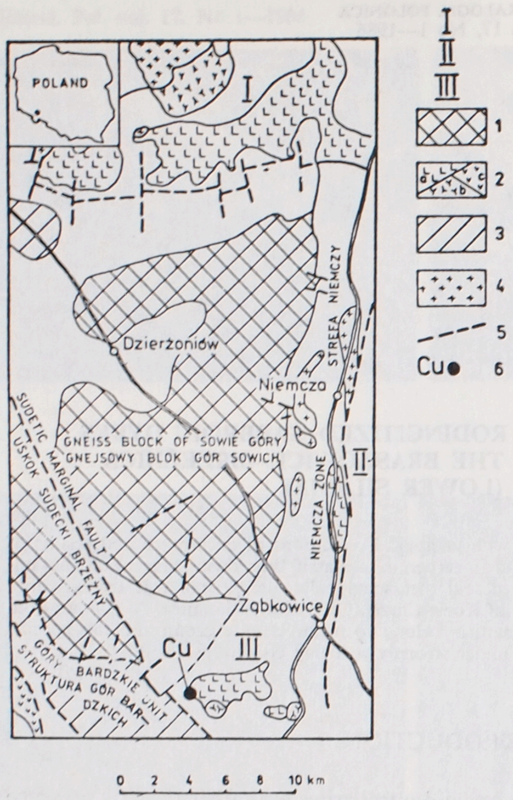

Fig. 1. Geologic sketch map (simplified) showing the distribution of gabbro-serpentinite massifs in the surroundings of gneissic Sowie Góry Mts. block (after Dziedzicowa, 1979 with author's supplements)
I — Gogołów—Jordanów serpentinite massif, *II* — Szklary serpentinite massif, *III* — Braszowice—Brzeźnica serpentinite massif. *1* — gneisses, *2* — basic and ultrabasic rocks: a — serpentinites, b — gabbroic rocks, c — diabases, *3* — greywackes and claystones of the Góry Bardzkie Mts., *4* — Variscan granitoids, *5* — dislocation lines, *6* — occurrence site of native copper

brown serpentinitic weathering crust of small thickness. Ultrabasic rocks of the Braszowice—Brzeźnica massif are considered to be pre-Upper Devonian in age (H. Teisseyre *et al.* 1957) and, most probably, represent a fragment of dismembered ophiolite complex (eg. Dziedzicowa 1979, 1981; Bakun-Czubarow *et al.* 1982).

In SE part of the massif, serpentinites are contacting with diallage-labradorite gabbros which penetrate into the former as dykes and veins. These dykes are strongly saussuritized or display rodingitization phenomena. These alterations have nearly completely obliterated primary structure of gabbroic rocks occurring within serpentinites in S slope of Kozie Chrzepty hill near Mikołajów.

Apo-gabbroic veins containing native copper are light greyish green in colour and are embedded in massive brownish black antigorite serpentinite. Their thickness varies from 0.2 to 0.5 m and the outcrops are from 1 to 3 m long. Usually they strike is 130—150° and dipping angles are fairly steep (70—80°C to SW and WSW). The veins are often bent and faulted (Phot. 2) and their contacts with serpentinites usually sharp (Phot. 1). However, within individual dykes, we may observe characteristic zonality expressed by decreasing grain size towards their inner parts. Some apophyses are separated from serpentinite by chloritic envelope of "blackwall" type.

PETROGRAPHIC AND CHEMICAL CHARACTERISTICS OF COPPER-BEARING ROCKS

Apogabbroic metasomatites show megascopically considerable variability of textures — from grano- and porphyro- to coarse-blastic (pegmatitic). The structure is usually massive and chaotic, rarely striped. In the matrix there occur large pale green pyroxene grains surrounded by dark green aphanitic mass. The rock is penetrated by single pink veinlets of variable thickness. Locally fluidal pink groundmass is embedding large (2—3 cm) pyroxene grains or is intergrown with dark green chloritic contact envelope.

In thin section the rock shows porphyroblastic texture and chaotic structure. Porphyroblasts are generally represented by xenomorphic clinopyroxenes, 4—10 mm in size, with characteristic dense (*100*) cleavage. The edges of pyroxene grains are usually rounded, locally strongly corroded and traces of cataclasis are often obser-

Table 1

Mineral composition of metasomatites from the environs of Mikołajów (after micrometric analysis, in vol. per cents)

Mineral	Sample symbol			
	G-2	G-3	2G	1G
Pyroxyne	13.70	61.83	45.42	43.27
Clinozoisite	20.68	—	17.50	14.25
Chlorite	10.64	3.95	10.29	5.24
Vesuvianite	45.37	20.00	12.42	26.49
Garnet	8.21	13.03	11.49	9.95
Opaques	1.40	1.13	2.88	0.88

Table 2

Chemical analyses of copper-bearing metasomatites (in wt. %)

	Sample symbol*		
	1G	2G	3G
SiO_2	39.23	36.15	39.14
TiO_2	0.15	0.15	0.12
Al_2O_3	14.59	12.72	14.72
Fe_2O_3	2.34	4.71	1.66
FeO	1.84	2.69	2.79
MnO	0.10	0.13	0.10
MgO	9.31	15.59	11.23
CaO	28.09	21.63	25.50
Na_2O	0.13	0.10	0.11
K_2O	0.15	0.13	0.13
H_2O^+	0.51	0.74	0.67
H_2O^-	4.14	6.16	4.43
	100.58	100.90	100.60

* Analyzed in chemical laboratory of the Department of Mineralogy and Petrography, Institute of Geological Sciences Wrocław University, 1984.

ved. Sporadically there occur deformed clinopyroxene grains showing kink bands. These porphyroblasts are usually surrounded by clinozoisite-chlorite aggregate composed of grey very fine scales penetrating into the spaces between pyroxene grains. In intersitia we may locally observe larger bluish-grey chlorite scales showing optical properties of clinochlore. It seems that the latest mineral generation in this rock is represented by garnet-vesuvianite veinlets cutting both clinopyroxenes and clinozoisite-chlorite aggregates. They usually consist of fine garnet idioblasts forming mosaic intergrowths with dark brown vesuvianite prisms. Opaque minerals (pyrite, native copper, ilmenite?, magnetite?) are sporadically met in chloritic groundmass as chaotically distributed irregular grains or concentrations. Their content in the rock does not exceed 2 vol. per cent. The results of micrometric and chemical analyses of metasomatic rocks containing native copper are presented in Tables 1 and 2.

Bulk chemical analyses of rocks were carried out in the Chemical Laboratory of the Department of Mineralogy and Petrography of the Institute of Geological Sciences, Wrocław University using gravimetric, complexometric and photometric methods. Some trace elements (Cu, Ni, Co and Cr) were determined using AAS method. The contents of Cu and Co correspond approximately to their mean concentrations in basic rocks after Vinogradov (1962), whereas those of Cr and Ni are slightly higher (Tab. 3).

Table 3

Some trace elements content in metasomatites from the environs of Mikołajów (in ppm)

	Sample symbol		
	1*G*	2*G*	3*G*
Cu	70	20	120
Co	60	60	100
Ni	670	600	890
Cr	620	800	2250

Supplementary identification of major minerals of the examined rocks was carried out by means of X-ray powder method using Soviet DRON-2 apparatus and Ni-filtered CuK_α radiation. In the obtained X-ray diffractometer patterns we observe strong reflections of diopside (Di_{74-78}) (11—654 ASTM) and of anhydrous grossular with $a_0 = 11.8924$ Å (4) (3—826 ASTM). Besides, weaker reflections of vesuvianite (22—533 ASTM) and of magnesian chlorite—leuchtenbergite (12—242 ASTM) are present.

MINERALOGICAL CHARACTERISTICS OF NATIVE COPPER

Methods and results

Mineralogical investigations of selected samples have been carried out using various microscopic and X-ray powder methods. The former consisted in applying both transparent and reflected light optical and scanning techniques, whilst X-ray study was performed by means of HZG-1 apparatus (GDR) using Ni-filtered CuK_α radiation.

Chemical analysis was carried out by means of JXA-3A electron microprobe analyzer.

Native copper occurs nearly exclusively in clinozoisite-chlorite groundmass of the rock (Phot. 3) and, sporadically, in contact zone with grossular-vesuvianite veinlets (Phot. 4). Usually it forms individual rounded grains and irregular aggregates of dark red or, sometimes, brown colour. These aggregates are from 0.1 to 8 mm in size (most often 2—3 mm). Rather scarcely we observe native copper forming elongated filiform crystals up to 100 mm long and 0.5—2 mm wide. Locally, there occur dendritic forms, 10—20 mm in size.

In rocks showing fine porphyroblastic texture irregular copper aggregates are often arranged in narrow single stripes alongated concordantly with orientation of saussuritic groundmass. These stripes are usually oriented obliquely relative to the contact of apo-gabbroic veins with serpentinite. Small native copper grains in these stripes ore often covered with green-bluish or brown weathering products. Copper mineralization of metasomatites from Kozie Chrzepty hill is distinctly dispersed in character and quantitative content of Cu in parent rock does not exceed 1 volume per cent.

When observed in reflected light, native copper is usually reddish in colour, isotropic and shows high reflectivity. In some veins it is partly replaced by chlorite which penetrates into its grains or surrounds fluidally its sharp-edged grains (Phot. 6). Generally, native copper does not form intergrowths with other ore minerals but sometimes, when examining in immersion, we find single very small inclusions of grey cuprite (Phot. 7). The latter mineral is isotropic but displays much lower reflectivity and shows weak brownish internal reflections. The edges of native copper grains are usually covered by brownish incrustations of weathering products. Pyrite is rather abundant accompanying ore mineral, forming often idiomorphic grains, several mm in size, chaotically distributed in the rock.

More detailed observations of morphology of native copper grains were carried out using scanning microscopy. It was found that filiform crystals 0.8×0.2 mm in size, are characterized by the presence of parallel composition planes which are locally cut by transverse furrows of irregular edges (Phot. 8, 9). These fissures within single crystal are up to 0.1 mm wide (Phot. 9) and are, probably, due to later tectonic events.

Very interesting is scanning image of transverse section of filiform crystals of native copper. Under magnification ca. 1200 times, we observe a characteristic "cellular" structure consisting of single small tubes, polygonal in shape and mutually densely packed (Phot. 10). These tubes are from 4 to 12 microns in diameter and the thickness of their walls varies from 0.2 to 1 micron. The latters are sometimes lattered and battered (Phot. 11). Scanning microscopy has shown that filiform crystals of native copper represent parallel aggregates of these tubular forms.

X-ray identification analysis was carried out in Debye-Scherrer camera using Ni-filtered CuK_α radiation. For comparison purposes native copper crystal from the collection of Mineralogical Museum of the Wrocław University was analyzed using the same procedure. The obtained data and theoretical values of reflections are presented in Table 4. The calculated value of $a_0 = 3.615$ Å.

Chemical electron microprobe analysis has shown that within the examined native copper grain three mineral phases coexist: elemental, oxide and sulphide. Metallic copper distinctly predominates in this grain and contains admixture of Ni (1.12—2.0 wt.%) and Fe (up to 0.5 wt.%) whilst the Cu content in this phase amounts to 97—99%. However, a narrow zone of contact between metallic and oxide phases (30—100 μm thick) is completely free from Ni.

Oxide phase displays variable quantitative composition and concentrates mainly in outer zones of metallic one, sometimes penetrating into the latter one (Phot. 12). This phenomenon is particularly distinct in marginal parts of metallic phase where

Table 4

X-ray data for native copper from Mikołajów and standard specimens*

			ASTM $_{2-361}$	Moldavia	Mikołajów
h k l	N	$2\theta_{CuK\alpha}$ calc.	$2\theta_{CuK\alpha}$	$2\theta_{CuK\alpha}$	$2\theta_{CuK\alpha}$
1 1 1	3	43.354	43.35	43.35	43.35
2 0 0	4	50.501	50.5	50.50	50.5
2 2 0	8	74.198	74.20	74.20	74.20
3 1 1	11	90.028	90.03	90.029	90.029
2 2 2	12	95.258	95.26	—	—
4 0 0	16	117.08	117.08	—	—
3 3 1	19	136.72	136.72	136.72	136.72
4 2 0	20	144.98	144.98	144.98	144.98
		$a_0 = 3 \cdot 615$	$a_0 = 3 \cdot 650$	$a_0 = 3 \cdot 615$	$a_0 = 3 \cdot 615$

* Analyses carried out and compiled by J. Skowroński.

Cu content decreases whereas concentrations of other metals increase (Phot. 14). Quantitative analysis of oxide phase has shown that it contains 74—76 wt.% Cu, 0.02—0.05% Ni and less than 0.5% Mn+Ca. This phase represents, most probably, oxidation product of metallic copper (cuprite?, thenorite?) what results from the form of its occurrence at the margins of Cu grains.

Sulphide phase occurs generally as small irregular inclusions within metallic copper what is particularly evident in the SK_α distribution pattern (Phot. 13) and in electron pattern of copper grain (Phot. 12) on the right side of the photograph. The behaviour of this phase when contacting with electron beam suggests that it consists of sulphides of Cu_xS type, where $x \leqslant 2$. The presence of sulphide phase associated with native copper is of essential genetical importance. It can evidence of a pre-reduction stage of mineralization of gabbroids, though coexistence of syngenetic native copper and sulphides formed under conditions of local increased fugacity of sulphur should not be excluded. More detailed studies are needed to solve this problem.

DISCUSSION AND CONCLUSIONS

The problem of genesis of native copper associated with serpentinite metasomatites is not clear. The occurrence of native metals and intermetallic compounds in basites and ultrabasites is generally explained by their crystallization in strongly reducing (nearly oxygen-free) environment under conditions of extremely low sulphur fugacity (Thayer 1966; Ramdohr 1967; Bowles 1978). Differences in opinions are concerning only the mode of their origin. In Bowles (1978) opinion, native copper in stratiform Freetown intrusions (Sierra Leone), associated with ilmenite and titanomagnetite, is the product of crystallization during a magmatic stage characterized by low sulphur (below 10^{-11} bars) and extremely low (below 10^{-16} bars) oxygen fugacities at temperature ca. 700°C. On the other hand, Ramdohr (1967) postulated the formation of native copper accompanied by awaruite and heazelwoodite simply during processes of serpentinization under strongly reducing conditions and at temperature 250—300°C. Similar hypothesis was presented by Chamberlain *et al.* (1965). These authors, however, have assumed that serpentinization created favouring conditions for reduction of primary magmatic sulphides into metals.

Native copper in rodingites was reported eg. to occur in Quebec, Canada (Jeffreys Mine — Chamberlain 1980) and in Wairere, New Zealand (Leach, Rodgers 1978). The latter authors postulate the formation of metallic copper in rodingites at 250—360°C and sulphur fugacity 10^{-19}—10^{-22} bars.

The occurrence of native copper in metasomatites near Mikołajów is usually limited to tectonically strongly deformed dykes showing advanced alteration phenomena (saussuritization, rodingitization). Numerous grossular-vesuvianite veins and aggregates, filling free spaces between clinopyroxene grains and cutting clinozoisite-chlorite groundmass, indicate that infiltration metasomatism played considerable role in the formation of these rocks. Concentrations of native copper in veinlets and clinozoisite-chlorite aggregates may suggest that its origin should be connected with premetasomatic (metamorphic) stage of evolution of parent rocks. It could be formed both from primary magmatic melt without later alterations (Bowles 1978) or in the course of saussuritization processes when primary magmatic copper sulphides would be reduced. It should be mentioned that primary plagioclases may be also the source of copper. The occurrence of native copper in altered plagioclase grains was reported from Copper Canyon, Nevada (USA) and its origin is supposed to be connected with hypergenous processes (Clement 1968).

When comparing the occurrence of native copper in the environs of Mikołajów with those in other places (eg. Wairere, New Zealand; Quebec, Canada) we may state some differences. Paragenesis of anhydrous grossular-vesuvianite-chlorite indicates that metasomatites in question should be classified as metarodingites (after Frost 1975). Contrary to New Zealand and Canadian rodingites, the rocks of Mikołajów do not contain xenolite and hydrogrossular what was confirmed by X-ray study.

Summing up the above considerations on the origin of native copper in rodingitized gabbroic dykes within serpentinites of the environs of Mikołajów we may conclude that essential role in this process was due, most probably, to serpentinization under strongly reducing conditions which caused the reduction of primary magmatic sulphides (chalcopyrite?, pyrrhotine?, Cu-bearing pyrite?) to native copper. It is, however, not excluded that the source of copper would also be plagioclases, being, together with diallage, the major primary component of gabbroids from the environs of Mikołajów.

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REFERENCES

BAKUN-CZUBAROW N., NARĘBSKI W., WAJSPRYCH B., 1982: On the nature, origin and geotectonic significance of ophiolites and related rock suites in the Polish part of the Sudetes. *Ofioliti* 7, 2/3, 407—428.

BOWLES J. F., 1978: The geochemical role of primary copper-sulphur mineralization of the Freetown (Sierra Leone) layered gabbro. *Miner. Mag.* 42, 111—116.

BUCKNER D. A., ROY D. M., ROY R., 1960: Studies in the system $CaO—Al_2O_3—SiO_2—H_2O$. The system $CaSiO_3—H_2O$. *Am. J. Sci.* 258, 132—147.

CHAMBERLAIN J. A., Mc LEOD C. R., TRAIL R. J., LEACHANCE G. R., 1965: Native metals in the Muscox Intrusion. *Can. J. Earth. Sci.* 2, 188—215.

CHĄMBERLAIN S., 1980: Wollastonite, vesuvianite, native copper and diopside from the Jeffrey mine in Asbestos, Quebec. *Rocks Miner.* 55, (5), 188—191.

CIEMNIEWSKA M., CZEMIER-KOWALSKA M., LINDNER M., SAŁACIŃSKI R., 1981: Ultramafity masywu Gogołów—Jordanów i ich prognozy surowcowe. *Biul. Inst. Geol.* 330, t. V, 89—135.

CLEMENT S. C., 1968: Supergene copper concentration in altered plagioclase feldspar, Copper Canyon, Nevada. *Econ. Geol.* 63 (4), 401—409.
COLEMAN R. G., 1966: New Zealand serpentinites and associated metasomatic rocks. *New Zealand. Geol. Surv. Bull.* 76, 1—102,
DZIEDZICOWA H., 1979: Problem genezy magm bazaltowych i ich związek z ultrabazytami strefy Niemczy. Proponowany model reżimu geotektonicznego. in: Mat. Konf. Ter. Nowa Ruda 8—9 września 1979 r. Wyd. Uniw. Wrocław., 107—117.
DZIEDZICOWA H., 1981: Origin of primary basaltic magmas and their connection with ultrabasites of the Niemcza Zone — tentative model of geotectonic regime. in: Ophiolites and Initialites of Northern Border of the Bohemian Massif. Guide-book of Excursions vol II. Multilateral Cooperation of Academies of Sciences of the Socialist Countries. Problem Commision IX Subcommision 2. Potsdam—Freiberg, 153—161.
FROST B. R., 1975: Contact metamorphism of serpentinite, chloritic Blackwall and rodingite at Paddy-Go-Easy Pass, Central Cascades. Washington. *Journ. Petrology* 16, 272—313.
LEACH T. M., RODGERS K. A., 1978: Metasomatism in the Wairere Serpentinite King Country, New Zealand. *Miner. Mag.* 42, 45—62.
RAMDOHR P., 1967: Widespread mineral association connected with serpentinization. *N. Jb. Min. Abh.* 107, H.3, 241—265.
RAMDOHR P., 1975: Die Erzmineralien und ihre Verwachsungen. Akademie—Verlag Berlin, 1280.
SMULIKOWSKI K., 1973: Ultramafites de la Basse Silesie. in: *Mat. XV sesji AZOPRO* 6—16 września 1973. Wyd. Geol. Warszawa.
THAYER T. P., 1966: Serpentinization considered as a constant volume metasomatic process. *Am. Miner.* 51, 685—710.
TEISSEYRE H., SMULIKOWSKI K., OBERC J., 1957: Regionalna geologia Polski. T.3. Sudety, z. 1. Utwory przedtrzeciorzędowe. Kraków.
[VINOGRADOV A. P.] ВИНОГРАДОВ А. П., 1962: Среднее содержание химических элементов в главных типах изверженных горных пород земной коры. *Геохимия* 7, 555—571.

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MIEDŹ RODZIMA ZE ZRODINGITYZOWANYCH DAJEK GABROWYCH W SERPENTYNITACH MASYWU BRASZOWICE—BRZEŹNICA (DOLNY ŚLĄSK)

Streszczenie

W niniejszej pracy przedstawiono wyniki badań mineralogicznych miedzi rodzimej stwierdzonej po raz pierwszy w masywie serpentynitowym Braszowice—Brzeźnica (Dolny Śląsk). Mineralizacja miedzią rodzimą występuje zwykle w zaangażowanych tektonicznie dajkach gabrowych o niewielkiej miąższości (0,2—0,5 m) tkwiących w serpentynitach antygorytowych na południowym zboczu wzgórza Kozie Chrzepty w pobliżu Mikołajowa.

Okruszcowane miedzią rodzimą dajki wykazują oznaki silnej saussurytyzacji oraz zmian metasomatycznych (rodingityzacja). Metasomatyty z okolic Mikołajowa mają zwykle strukturę porfiroblastyczną i składają się z reliktowych klinopiroksenów o składzie Di 74,3—78,0, "opływających" je drobnołuseczkowych agregatów klinozoizytowo-chlorytowych oraz żyłkowych skupień mozaikowo przerastających się słupków wezuwianu i idioblastów grossularu.

Miedź rodzima koncentruje się zwykle w tle klinozoizytowo-chlorytowym skały i tworzy najczęściej nieregularne skupienia, druty, owalne pojedyncze ziarna bądź dendryty o rozmiarach od 0,2 do 10 mm.

Wyizolowane ze skały druty i ziarna miedzi rodzimej poddano badaniom mineralogicznym przy zastosowaniu mikroskopu scanningowego i rentgenowskiej analizy fazowej. Chemizm ziarn miedzi określono za pomocą mikroanalizatora rentgenowskiego.

W wyniku przeprowadzonych badań stwierdzono, że występujące w skale pojedyncze druty miedzi rodzimej są zespołami rureczkowych kryształów o przekroju wielokątnym i średnicy do kilkunastu mikronów. Mikroanaliza chemiczna owalnego ziarna miedzi rodzimej z Mikołajowa wykazała obecność w nim trzech faz mineralnych: fazy metalicznej składającej się z 97—99% Cu z domieszkami Ni (0,02—2%) oraz Fe (0,5%), fazy tlenkowej będącej produktem utleniania fazy metalicznej oraz fazy siarczkowej typu Cu_xS ($x \leqslant 2$). Faza tlenkowa występuje najczęściej na obrzeżeniu fazy metalicznej badanego ziarna miedzi, a faza siarczkowa tworzy drobne wpryśnięcia w obrębie fazy metalicznej.

W omówieniu wyników badań mineralogicznych miedzi rodzimej z Mikołajowa przedyskutowano jej genezę w porównaniu z innymi podobnymi wystąpieniami na świecie (Wairere—Nowa Zelandia, Quebec—Kanada). Uznano, że zasadniczą rolę w powstaniu okruszcowania miedzią rodzimą odegrał proces serpentynizacji, który w warunkach niskiej lotności siarki i tlenu umożliwił redukcję pierwotnych magmowych siarczków miedzi.

OBJAŚNIENIE FIGURY

Fig. 1. Szkicowa mapa geologiczna (zakryta uproszczona) rozmieszczenia masywów serpentynitowo-gabrowych w obrzeżeniu gnejsowego bloku Gór Sowich według Dziedzicowej (1979) z uzupełnieniami autora.
I — masyw serpentynitowy Gogołów—Jordanów, *II* — masyw serpentynitowy Szklar, *III* — masyw serpentynitowy Braszowice—Brzeźnica, *1* — gnejsowy blok Gór Sowich, *2* — skały zasadowe i ultrazasadowe: *a* — serpentynity, *b* — skały gabrowe, *c* — diabazy, *3* — skały serii szarogłazowo-ilastej struktury Gór Bardzkich *4* — granitoidy waryscyjskie, *5* — linie dyslokacyjne, *6* — miejsce występowania miedzi rodzimej

OBJAŚNIENIA FOTOGRAFII

Plansza I

Fot. 1. Zachodnia ściana nieczynnego kamieniołomu serpentynitu na południowym zboczu wzniesienia Kozie Chrzepty. Okruszcowana miedzią rodzimą żyła apogabrowa (*G*) tkwiąca w serpentynicie antygorytowym (*S*). Fot. J. Stachowiak

Plansza II

Fot. 2. Zachodnia ściana nieczynnego kamieniołomu serpentynitu na południowym zboczu wzniesienia Kozie Chrzepty. Fragment zuskokowania okruszcowanej miedzią żyły apogabrowej (*g*) w serpentynicie. Fot. J. Stachowiak

Fot. 3. Ziarna miedzi rodzimej (czarne) tkwiące w chlorytowym tle (*chl*) metarodingitu. Światło przechodzące, z analizatorem, pow. 60×. Fot. autor

Plansza III

Fot. 4. Ziarno miedzi rodzimej w skale wezuwianowo (*we*)-chlorytowej (*chl*). Światło przechodzące, bez analizatora, pow. 60×. Fot. autor

Fot. 5. Nieregularne skupienia miedzi rodzimej (Cu) w metarodingicie. Światło odbite, bez analizatora, pow. 80×. Fot. autor

Fot. 6. Ostrokrawędziste skupienia miedzi rodzimej (Cu) wypieranej przez chloryt (*chl*). Światło odbite, bez analizatora, pow. 80×. Fot. autor

Fot. 7. Fragment żyłki miedzi rodzimej (Cu) w metarodingicie. W górnej części zdjęcia w obrębie żyłki miedzi widoczne owalne inkluzje kuprytu. Światło odbite, bez analizatora, pow. 80×. Fot. autor

Plansza IV

Fot. 8. Wyizolowany ze skały drutowy kryształ miedzi rodzimej. Mikroskop scanningowy, pow. 144×. Fot. J. Kassner

Fot. 9. Spękanie w obrębie drutu miedzi rodzimej. Mikroskop scanningowy, pow. 384×. Fot. J. Kassner

Plansza V

Fot. 10. Struktura „komórkowa" widoczna w poprzecznym przekroju drutu miedzi rodzimej. Mikroskop scanningowy, pow. 1200×. Fot. J. Kassner

Fot. 11. Fragment wiązki rureczkowych kryształów miedzi rodzimej. Mikroskop scanningowy, pow. 2700×. Fot. J. Kassner

Plansza VI

Fot. 12. Obraz elektronowy kontaktu ziarna miedzi rodzimej (faza metaliczna z fazą tlenkową CuO) ze skałą. Po prawej stronie zdjęcia widoczne owalne inkluzje fazy siarczkowej typu Cu_xS. Mikroanalizator rentgenowski, pow. 750×. Fot. J. Kubica

Fot. 13. Rozmieszczenie SK_α w ziarnach widocznych na fotografii 12

Fot. 14. Rozmieszczenie CuK_α w ziarnach widocznych na fotografii 12

Fot. 15. Rozmieszczenie FeK_α w ziarnach widocznych na fotografii 12

Петр ГУНЯ

САМОРОДНАЯ МЕДЬ ИЗ РОДИНГИТИЗИРОВАННЫХ ГАББРОВЫХ ДАЕК В СЕРПЕНТИНИТАХ МАССИВА БРАШОВИЦЕ—БЖЕЗЬНИЦА (НИЖНЯЯ СИЛЕЗИЯ)

Резюме

В настоящей работе изложены результаты минералогических исследований самородной меди, обнаруженной впервые в серпентинитовом массиве Брашовице—Бжезьница (Нижняя Силезия). Минерализация самородной медью проявляется обычно в вовлеченных тектонически небольшой мощности (0,2—0,5 м) габбровых дайках, секущих антигоритовые серпентиниты на южном склоне холма Козье Хшепты вблизи Миколаёва.

Дайки с оруденением самородной медью обнаруживают признаки сильной соссюритизации, а также метасоматических изменений (родингитизация). Метасоматиты окрестностей Миколаёва обычно порфиробластовой структуры и сложены реликтовыми пироксенами состава Ди 74,3—78,0, окаймляющими их мелкочешуйчатыми клиноцоизит-хлоритовыми агрегатами, а также прожилковыми скоплениями срастающихся столбиков везувиана и идиобластов гроссуляра.

Самородная медь концентрируется обычно в клиноцоизит-хлоритовой основной массе породы и чаще всего образует неправильные скопления, проволоки, овальные единичные зерна, или дендриты размерами от 0,2 до 10 мм.

Выделенные из породы проволоки и зерна самородной меди были подвержены минералогическим исследованиям с применением сканирующего микроскопа и рентгеновского фазового анализа. Химизм медных зерен определен с помощью микрозонда.

В результате проведенных исследований обнаружено, что присутствующие в породе единичные проволоки самородной меди представляют собой группировки трубкообразных кристаллов полигонального сечения диаметром до более десяти микрометров. Химический микроанализ овального зерна самородной меди из Миколаёва обнаружил в нем присутствие трех минеральных фаз: металлической фазы, состоящей из 97—99% Cu с примесью Ni (0,02—2%), а также Fe (0,5%), окисной фазы, являющейся продуктом окисления металлической фазы, а также сульфидной фазы типа Cu_xS ($x \leqslant 2$). Окисная фаза чаще всего развивается на периферии металлической фазы изучаемого зерна меди, а сульфиды образуют тонкие включения в металлической фазе.

В обсуждении результатов минералогических исследований самородной меди из Миколаёва рассматривался ее генезис в сопоставлении с другими подобными ее проявлениями в мире (Уэйрере — Новая Зеландия, Квебек — Канада). Считается, что основную роль в образовании оруденения самородной медью сыграл процесс серпентинизации, которая в условиях низкой фугитивности серы и кислорода создала возможность восстанавливания первичных магматических сульфидов меди.

УСЛОВНЫЕ ОБОЗНАЧЕНИЯ К ФИГУРЕ 1

Фиг. 1. Эскизная геологическая карта размещения серпентинит-габбровых массивов в обрамлении Совьегурской глыбы (по Дзедзиц, 1979, с дополнениями автора, упрощенное)

I — серпентинитовый массив Гоголув-Иорданув, *II* — серпентинитовый массив Шкляров, *III* — серпентинитовый массив Брашовице—Бжезьница, *1* — гнейсовая глыба Совьих гор, *2* — основные и ультраосновные породы: *a* — серпентиниты, *b* — габбровые породы, *c* — диабазы, *3* — породы граувакково-глинистой серии структуры Бардских гор, *4* — варисские гранитоиды, *5* — дислокационные линии, *6* — проявления самородной меди

ОБЪЯСНЕНИЯ К ФОТОГРАФИЯМ

Таблица I

Фото 1. Западная стена заброшенного карьера серпентинита на южном склоне холма Козье Хшепты. Апогаббровая жила (*G*) с оруденением самородной медью, заключенная в антигоритовом серпентините (S). Фото Ю. Стаховяка

Таблица II

Фото 2. Западная стена заброшенного серпентинитового карьера на южном склоне холма Козье Хшепты. Фрагмент нарушенной сбросами апогаббровой жилы (*g*) с медным оруденением в серпентините. Фото Ю. Стаховяка

Фото 3. Зерна самородной меди (черные), заключенные в хлоритовой основной массе (*chl*) метародингита. Проходящий свет, с анализатором. Увел. 60×. Фото автора

Таблица III

Фото 4. Зерно самородной меди в везувиан (*we*)-хлоритовой (*chl*) породе. Проходящий свет, без анализатора. Увел. 60×. Фото автора

Фото 5. Неправильные скопления самородной меди (Cu) в метародингите. Отраженный свет, без анализатора. Увел. 80×. Фото автора

Фото 6. Остроребериые скопления самородной меди (Cu), замещаемой хлоритом (*chl*). Отраженный свет, без анализатора. Увел. 80×. Фото автора

Фото 7. Фрагмент прожилка самородной меди (Cu) в метародингите. В верхней части снимка в пределах медного прожилка заметны овальные включения куприта. Отраженный свет, без анализатора. Увел. 80×. Фото автора

Таблица IV

Фото 8. Выделенный из породы проволочный кристалл самородной меди. Сканирующий микроскоп. Увел. 144×. Фото Ю. Касснера

Фото 9. Трещина внутри проволоки самородной меди. Сканирующий микроскоп. Увел. 384×. Фото Ю. Касснера

Таблица V

Фото 10. "Клеточная" структура, заметная в поперечном сечении проволоки самородной меди. Сканирующий микроскоп. Увел. 1200×. Фото Ю. Касснера

Фото 11. Фрагмент пучка трубчатых кристаллов самородной меди. Сканирующий микроскоп. Увел. 2700×. Фото Ю. Касснера

Таблица VI

Фото 12. Электронное изображение контакта самородной меди (металлическая фаза с окисной фазой CuO и породой). На правой стороне снимка заметны овальные включения сульфидов фазы типа Cu_xS. Микрозонд. Увел. 750×. Фото Ю. Кубицы

Фото 13. Распределение SK_α в зернах, видных на фото 12

Фото 14. Распределение CuK_α в зернах, видных на фото 12

Фото 15. Распределение FeK_α в зернах, видных на фото 12

EXPLANATIONS OF PLATES

Plate I

Phot. 1. Western wall of abandoned quarry of serpentinite on S slope of Kozie Chrzepty hill. Apogabbroic vein (*G*) mineralized with copper and embedded in antigorite serpentinite (*S*). Phot. J. Stachowiak

Plate II

Phot. 2. Western wall of abandoned quarry of serpentinite on S slope of Kozie Chrzepty hill. A fragment of faulted apogabbroic vein (*g*), mineralized in copper and embedded in serpentinite. Phot. J. Stachowiak

Phot. 3. Native copper grains (black) embedded in chloritic groundmass (*chl*) of metarodingite. Transparent light, crossed polars, magn. 60×. Phot. by author

Plate III

Phot. 4. Native copper grain in vesuvianite (*we*)-chlorite (*chl*) rock. Transparent light, no analyzer, magn. 60×. Phot. by author

Phot. 5. Irregular concentrations of native copper (Cu) in metarodingite. Reflected light, no analyzer, magn. 80×. Phot. by author

Phot. 6. Sharp-edged aggregates of native copper (Cu) partly replaced by chlorite (*chl*). Reflected light, no analyzer, magn. 80×. Phot. by author

Phot. 7. Fragment of native veinlet (Cu) in metarodingite. Within this veinlet, in upper part of the photograph, oval inclusions of cuprite. Reflected light, no analyzer, magn. 80×. Phot by author

Plate IV

Phot. 8. Filiform crystal of native copper isolated from the rock. Scanning microscope image, magn. 144×. Phot. J. Kassner

Phot. 9. Fissures within filiform native copper crystal. Scanning image, magn. 384×. Phot. J. Kassner

Plate V

Phot. 10. "Cellular" structure observed in transverse section of a filiform copper crystal. Scanning image, magn. 1200×. Phot. J. Kassner

Phot. 11. Fragment of a cluster of tubular native copper crystals. Scanning image, magn. 270×. Phot. J. Kassner

Plate VI

Phot. 12. Electron image of the contact of native copper grain (metallic phase covered with CuO) with the rock. On right side of the photo — oval inclusions of sulphide phase of Cu_xS type. Electron microprobe, magn. 750×. Phot. J. Kubica

Phot. 13. SK_α distribution in grains visible in Phot. 12

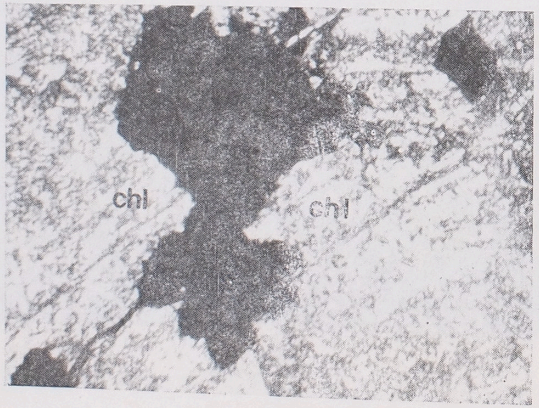
Phot. 14. CuK_α distribution in grains visible in Phot. 12

Phot. 15. FeK_α distribution in grains visible in Phot. 12

Phot. 1

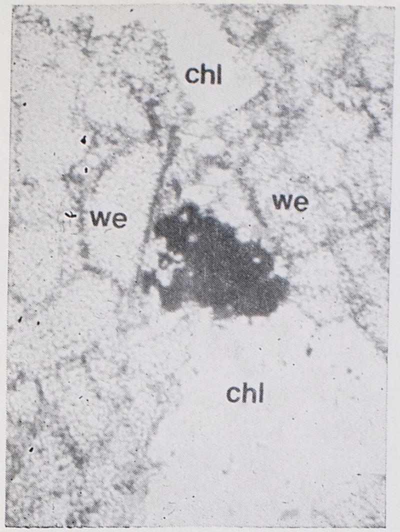
Piotr Gunia — Native copper from rodingitized gabbroic dykes in serpentinites of the Braszowice—
—Brzeźnica massif (Lower Silesia)

Phot. 2

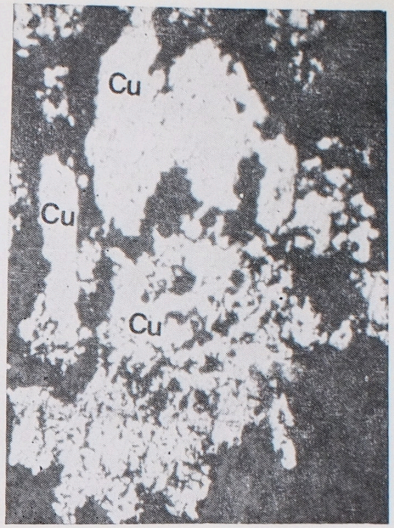


Phot. 3

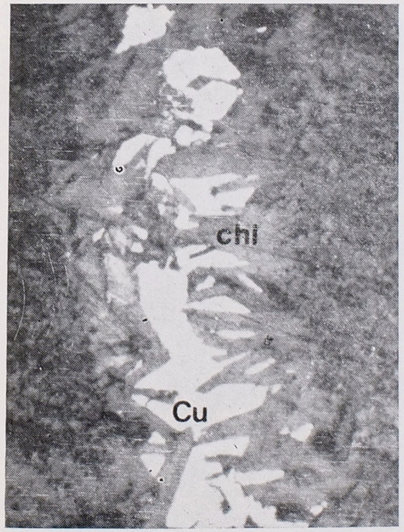
Piotr Gunia — Native copper from rodingitized gabbroic dykes in serpentinites of the Braszowice—
—Brzeźnica massif (Lower Silesia)



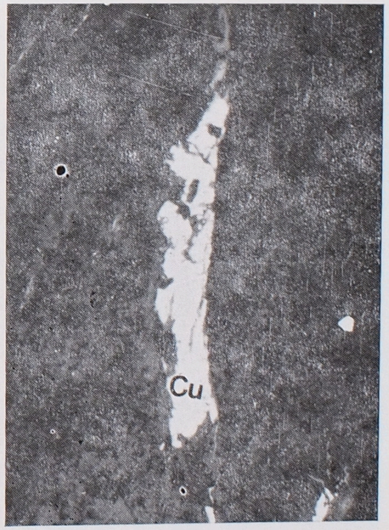
Phot. 4



Phot. 5

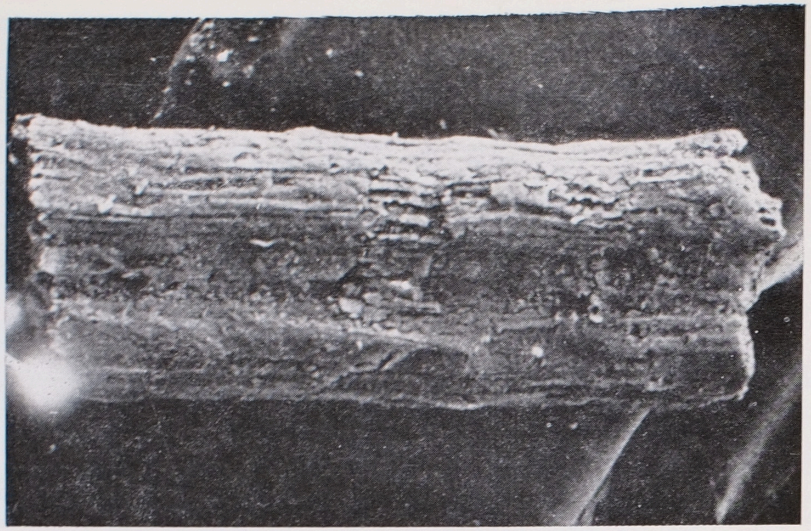


Phot. 6



Phot. 7

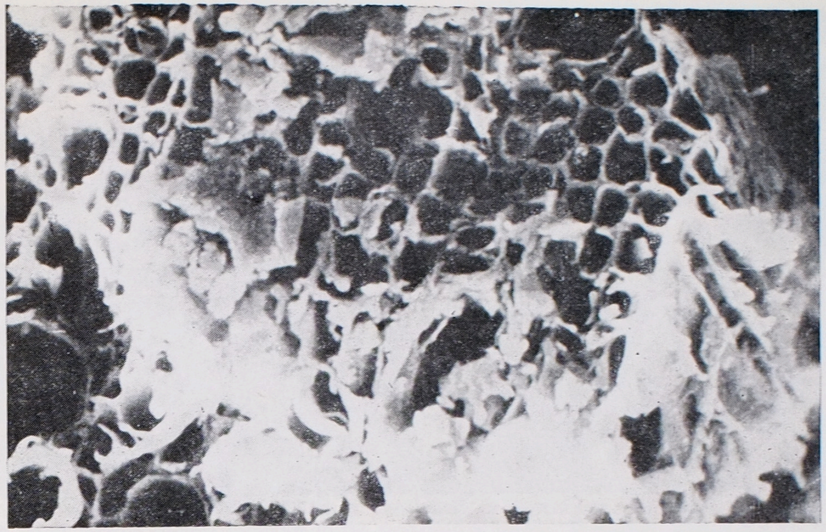
Piotr Gunia — Native copper from rodingitized gabbroic dykes in serpentinites of the Braszowice—
—Brzeźnica massif (Lower Silesia)



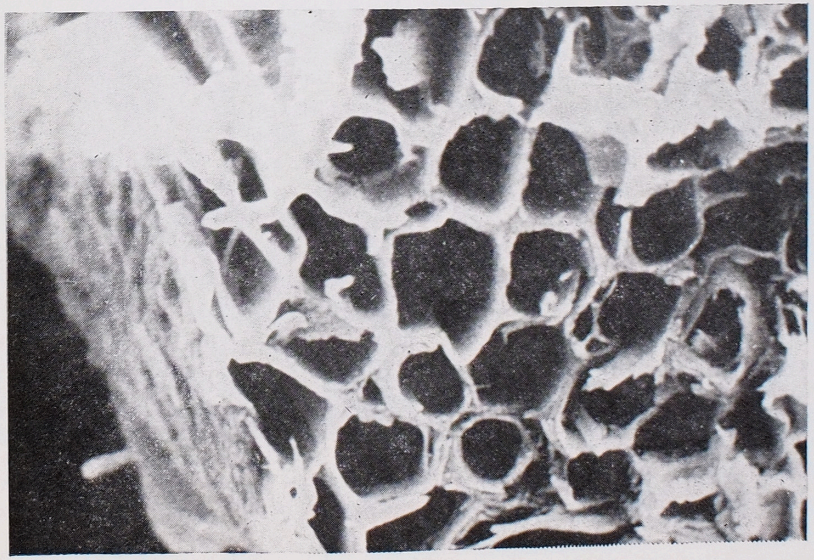
Phot. 8

Phot. 9

Piotr Gunia — Native copper from rodingitized gabbroic dykes in serpentinites of the Braszowice—
—Brzeźnica massif (Lower Silesia)

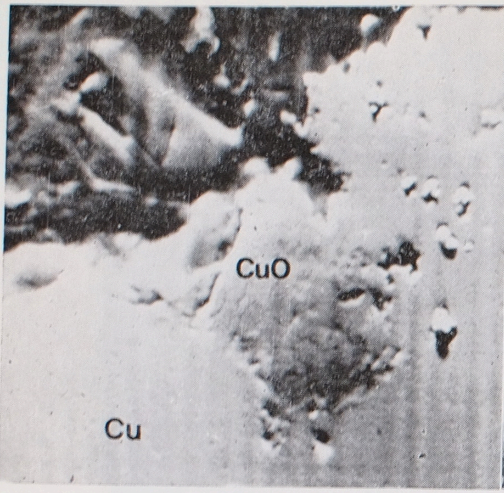


Phot. 10

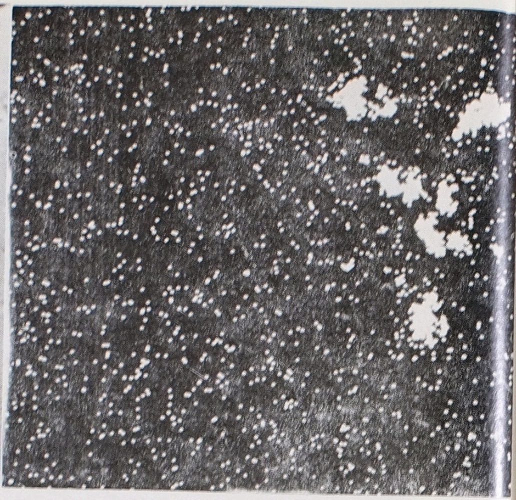


Phot. 11

Piotr Gunia — Native copper from rodingitized gabbroic dykes in serpentinites of the Braszowice—
—Brzeźnica massif (Lower Silesia)

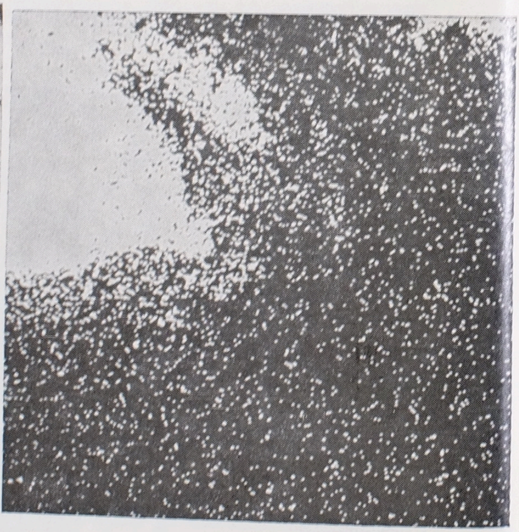


Phot. 12



Phot. 13

Phot. 14



Phot. 15

Piotr Gunia — Native copper from rodingitized gabbroic dykes in serpentinites of the Braszowice—Brzeźnica massif (Lower Silesia)