Geologia Sudetica, 2000, 33: 131–141.

Heavy minerals in the serpentinite weathering cover of the Szklary massif

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Key words: heavy minerals, the Szklary massif, serpentinite, serpentinite weathering cover, laterite.

Abstract Forty minerals were identified belonging to the heavy mineral (d > 2.98 g/cm^3) suite of the Szklary massif. They are: actinolite, almandine, anthophyllite, apatite, biotite, brunsvigite, chlorite, chromite, chrysolite, zircon, enstatite, epidote, ferroplatinum, goethite, haematite, hornblende, clinochlore, leucoxene, magnesioferrite, magnetite, magnesite, molibdenite, monacite, muscovite, niggliite (PtSn), olivine, orthopyroxenes, an osmium-bearing phase (Ba_2CaOsO_6), native palladium, pyrope, native platinum, pleonaste, rutile, native silver, talc, tremolite, trevorite, tourmaline, native gold and zoisite. The mineralogical characteristics of the most common phases are presented in this paper, and three paragenetic groups of heavy minerals are distinguished.

Manuscript received 12 December 1999, accepted 13 December 2000

INTRODUCTION

The Szklary massif is one of several fragments of ancient oceanic crust making up part of the ophiolite sequence near the Góry Sowie Block (Majerowicz & Pin, 1994). It consists of serpentinite rocks occurring in the central part of the massif, and surrounding metamorphic and mylonitic rocks (Fig. 1). A thick layer of weathering cover formed on the serpentinite and country rocks.

The Tertiary, nickel-bearing, laterite weathering cover in Szklary has been known as a nickel ore for over one hundred years (Niśkiewicz, 1967). Apart from various types of the serpentinite weathering crust, gneiss and amphibolite weathering covers occur in that area (Niśkiewicz, 1967). The weathering cover thickness varies from several to a few dozen metres, with an average thickness of 20 m for the serpentinite weathering crust. 70% of the serpentinite outcrops in the Szklary massif are covered by this irregularly formed serpentinite weathering crust. Most of the weathering cover types occurring in Szklary were autochtonous, hence they preserved the parent rock textures. The dominating serpentinite weathering crust differs considerably from the country rock weathering covers. The serpentinite weathering cover is often accompanied by talc rocks and amphibole-chlorite rocks which are products of alterations at the contacts of the serpentinites with vein rocks. These accompanying rocks are also weathered. The weathering cover of the Szkary massif forms a typical laterite profile with a significant increase in the weathering level towards the top. The mineral composition and geological position of different types of the serpentinite weathering cover were described by e.g.: Spangenberg (1949), Skiba-Wyderko (1964), Ostrowicki (1965), Niśkiewicz (1967), and Dubińska (1995). The minerals of the serpentinite and accompanying rocks (metamorphic rocks, granitoids, rodingnites, vein rocks) were altered by hypergenic processes which led to the creation of saturated minerals such as serpentine, actinolite, chlorite, chlorite-vermiculite and others. The characteristics of these minerals suggest that they are products of the saturation or hydrolysis of basic rock minerals, especially serpentine. Water was the most important factor in the weathering process. The strong carbonisation suggests the influence of carbonic acid. The direction and the degree of the mineral decay, and the lithological weathering profile indicate that the weathering process took place under humid climate conditions with a high level of organic matter activity. The Szklary massif underwent weathering during Tertiary, when the residual nickel ore originated due to the weathering of Ni-rich olivines. Besides Ni-minerals, there is an abundance of the heavy minerals in the Szklary ore deposits.

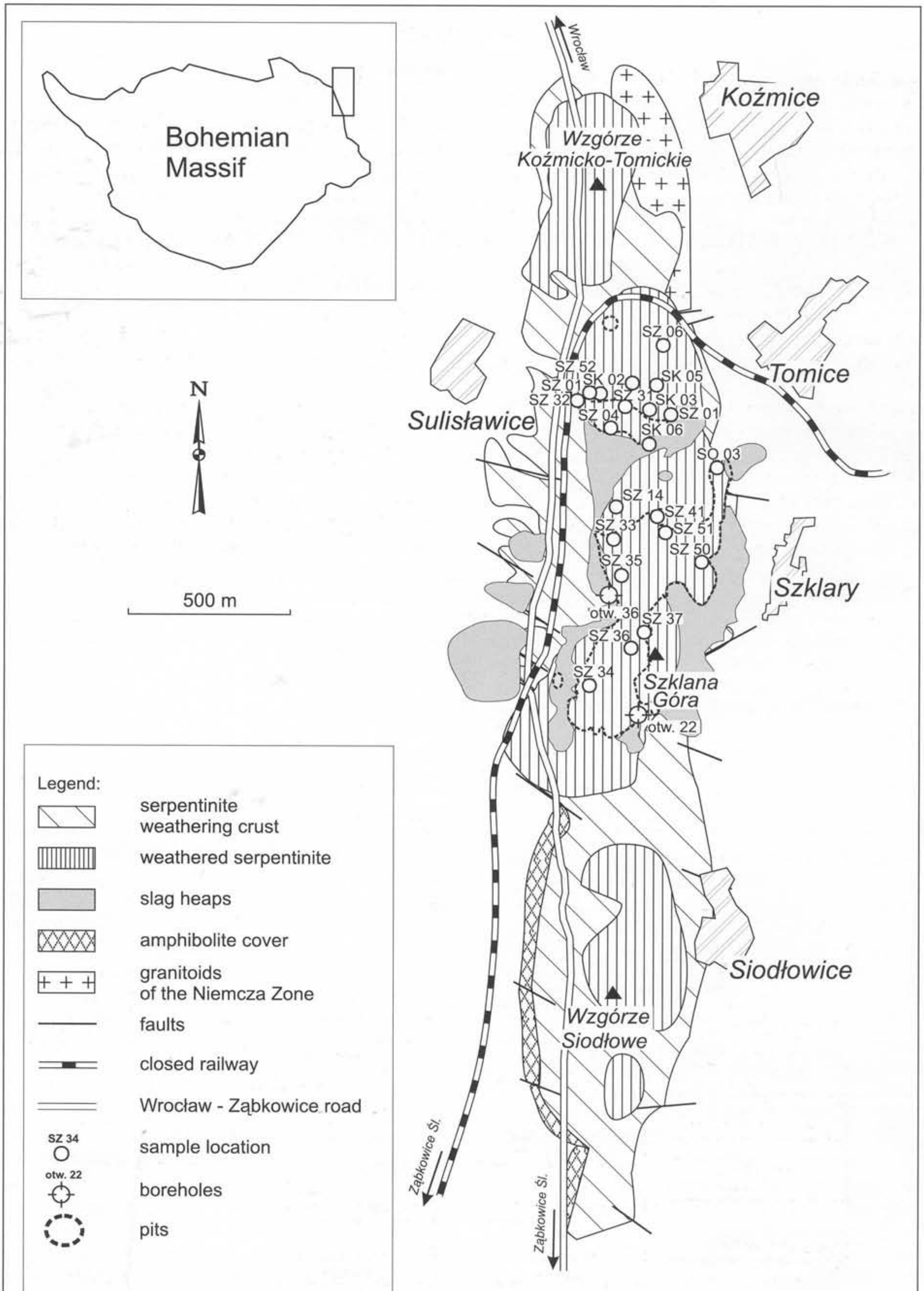

Fig. 1. Geological sketch of the Szklary massif (adapted from Niśkiewicz, 1967) with sample location.

METHODS

Nine 5-kilo and fourteen 20-kilo weathering cover samples were collected for heavy mineral analysis. They came from the main types of the serpentinite weathering cover and from the rocks accompanying the serpentinite. Figure 1 shows the sample locations, and Table 1 gives short descriptions of the samples.

The heavy mineral concentrations were obtained by gravitational separation and, in some cases, by magnetic separation. The gravitational separation was done both manually (using a bowl), on a concentration table (Willfy type) in the Mining Institute of the Wrocław University of Technology and by using heavy liquid (sodium polytungstate, d = 2.98 g/cm^3) in the Mineral Separation Laboratory of the Institute of Geological Science of Wrocław University.

Heavy minerals were identified with an electron microscope (SEM) combined with an EDS system (Jeol JSM 5800LV Oxford) in the Institute of Material Science and Applied Mechanics of the Wrocław University of Technology, and by XRD analysis (Diffractometre D - 5005 Simens) in the Institute of the Geological Sciences of Wrocław University.

The samples were dried and then sieved (2 mm diameter sieve). The prepared samples were separated in two ways. Firstly, the clay fraction was removed and next the remaining part was washed on a 0.5 mm diameter sieve. The 2.0–0.5 mm and < 0.5 mm fractions were separated gravitationally with a gold concentration bowl (Figure 2 and Figure 3 show the gravitational separation schemes). Using that procedure, so-called "grey schlich" was obtained, and was then separated into fractions using heavy liquid (sodium polytungstate).

Separation on a concentration table was the second method used. First the sifted debris was separated into two grain fractions: > 0.056 mm and < 0.056 mm diameter. Both fractions were enriched on the concentration table (Willfy type), each giving two samples of the heavy mineral concentrates of different grain size. Next, those concentrates underwent magnetic separation, which resulted in fractions with various magnetic susceptibility (strongly magnetic, medium magnetic, weakly magnetic and non-magnetic fractions) as shown in Figure 4. Table 2

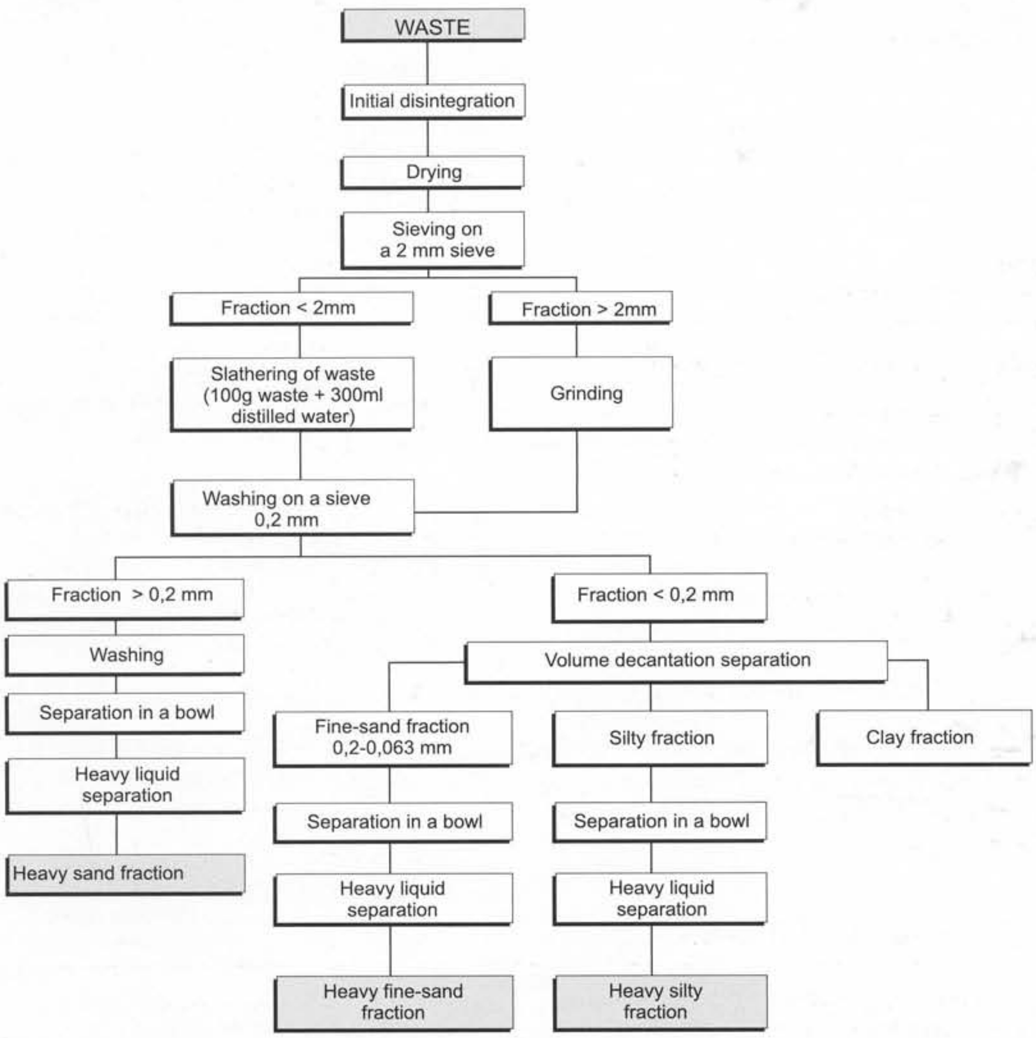

Fig. 2. Gravitational separation scheme for the serpentinite weathering cover of the Szklary massif.

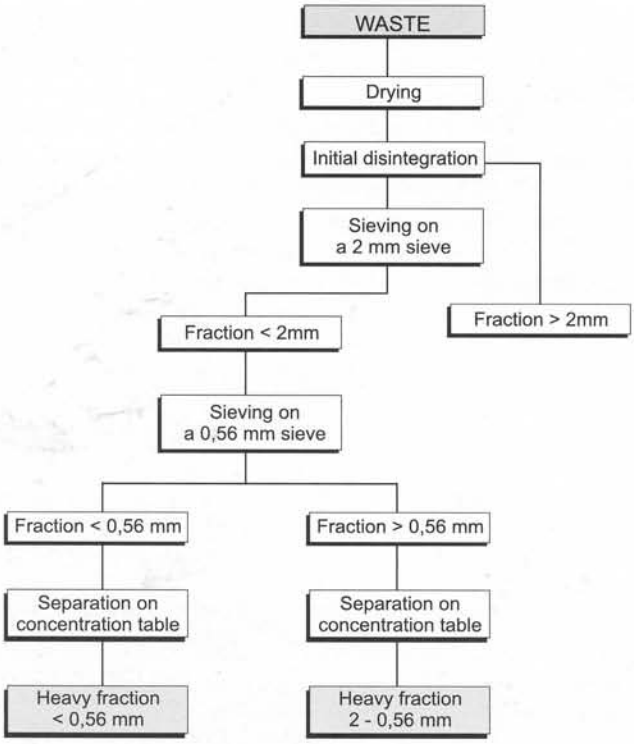

Fig. 3. Gravitational separation scheme (using a concentration table) for the serpentinite weathering cover of the Szklary massif.

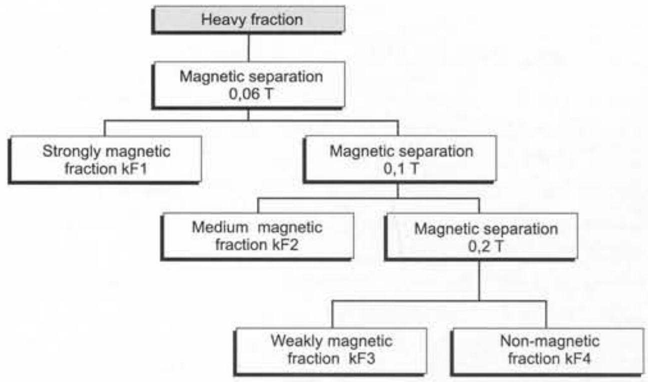

Fig. 4. Magnetic separation scheme for the serpentinite weathering cover of the Szklary massif.

shows the participation (in %) of different magnetic fractions in seven weathering crust samples.

In all the examined samples (both < 0.056 mm and > 0.056 mm), ferromagnetic minerals are the dominant phase. The non-magnetic fraction is up to 30% of the heavy minerals, but these minerals do not occur in the finer fractions. It indicates that various minerals in fine-grained fractions must contain small magnetite and chromite inclusions. The strongly magnetic fraction (susceptible to a magnetic field of 0.06 T intensity) varies from 20 to 70 wt. % of the heavy mineral content, and is most abundant in the brown weathering crust (Tab. 2).

The 2–0.5 mm fractions mainly consist of polymineral grains, grain aggregates and rock fragments, whereas monomineral grains are typical of the < 0.5 mm fractions. Only the 0.5–0.05 mm fractions were used for heavy mineral identification and establishing the quantitative ratios in the various weathering cover types. Identification was performed with the help of a petrographic and reflected light microscope, X-ray diffractometre, and an EDS system attached to an electron microprobe. Grains denser than 2.98 were also found. They have a large number of magnetite inclusions, and are e.g.: talc, chrysotile and clinochlore.

HEAVY MINERALS

During this research, 40 heavy minerals were identified (Tab. 3). X-ray data for the main minerals differentiated in the heavy fractions are shown in Table 4.

Almandine occurs as 0.2–0.8 mm, angular, grains

Table 1

List of samples

No.	Sample	Sample characteristics	Weight (kg)	Separation
1	Sz 01	Brown serpentinite crust	5	heavy liquid
2	Sz 02	Green serpentinite crust	5	
3	Sz 03	Green serpentinite crust	5	
4	Sz 04	Brown serpentinite crust	5	
5	Sz 07	Amphibole-chlorite rock crust	5	
6	Sz 14	Talc rock crust	5	
7	Sz 18	Cherry-red crust (gneiss)	5	
8	Sz 19	Brown serpentinite crust	5	
9	Sp 1/4	Green serpentinite crust with a high talc content	5	
10	Sz 31	Brown serpentinite crust with magnesite	20	
11	Sz 32	Green serpentinite crust with pimelite (from massive serpentine)	20	
12	Sz 33	Brown serpentinite crust (from weathered serpentine)	20	
13	Sz 34	Residual soil with chalcedony and opal veins	20	
14	Sz 35	Clay crust from the bottom of quarry 3A and from underneath the cherry-red crust	20	
15	Sz 36	Brown serpentinite crust with magnesite and chalcedony veins (quarry 3A, the eastern wall)	20	
16	Sz 37	Cherry-red crust (quarry 3A, eastern wall)	20	
17	Ssm 01	Calyey green serpentinite crust, preserving the postserpentinite texture	20	concentration table
18	Ssm 02	Clayey brown serpentinite crust with magnesite and rock fragments	20	
19	Ssm 03	Residual bron serpentinite crust with chalcedony and opal	20	
20	Ssm 04	Clayey brown serpentinite crust with chalcedony and opal	20	
21	Ssm 05	Massive, grey serpentinite crust, preserving post-serpentine texture, with fine chalcedone veins	20	
22	Ssm 06	Cherry-red crust	20	
23	Ssm 07	Brown serpentinite crust	20	

Table 2

The content of heavy mineral grains with various magnetic susceptebility coming from the Szklary massif

Fractions (wt. %)	Sample													
	Ssm 01		Ssm 02		Ssm 03		Ssm 04		Ssm 05		Ssm 06		Ssm 07	
	>0.056 mm	<0.056 mm	>0.056 mm	<0.056 mm	>0.056 mm	<0.056 mm	>0.056 mm	<0.056 mm	>0.056 mm	<0.056 mm	>0.056 mm	<0.056 mm	>0.056 mm	<0.056 mm
strongly magnetic 9KF1, KFd1)	26.51	20.18	57.12	27.29	41.82	22.55	37.64	24.81	19.25	27.53	22.19	38.22	37.18	25.15
medium magnetic (KF2, KFd2)	15.04	19.20	14.21	34.72	5.61	13.54	10.56	16.02	31.03	30.61	15.85	14.44	12.11	8.67
weakly magnetic (KF3, KFd3)	26.73	46.43	9.65	37.99	13.06	63.91	19.37	51.19	21.85	17.69	28.39	35.23	28.20	66.18
non-magnetic (KF4, KFd4)	31.72	14.18	19.02	-	39.51	-	32.43	7.98	27.87	24.17	33.57	12.11	22.51	-

which are transluscent and light pink in colour. It mainly occurs in the brown serpentinite weathering cover, especially in the central and northern part of the massif.

Anthophyllite occurs as fibrous concentrations. They are colourless, yellow, orange or pink (dyed by Fe oxides) without clear pleochroism. Anthophyllite is quite common in the green weathering cover.

Apatite is rare, and occurs particularly in the green weathering cover as sub-angular prisms up to 0.5 mm long.

Chromite occurs most often as oval grains or as xenomorphic grains with complex surface (Figs. 5 and 6). It often forms aggregates with talc or serpentine and it is strongly magnetic. It is less common than magnetite. The fine chromite grains are sometimes brown and transparent.

Chrysotile fibres occur sporadically, mostly in the brown weathering cover (S 19). Some fibres have fine magnetite inclusions and some are connected with magnesite.

Zircon occurs in the weathering crust as automorphic crystals (Fig. 7), or as sub-angular grains up to 0.5 mm long. It usually forms long prismatic, colourless, yellow or brownish crystals. Zircons from the Szklary massif have forms of {211}>{101} and {110}>{100}. Zircon is most abundant in the brown weathering cover.

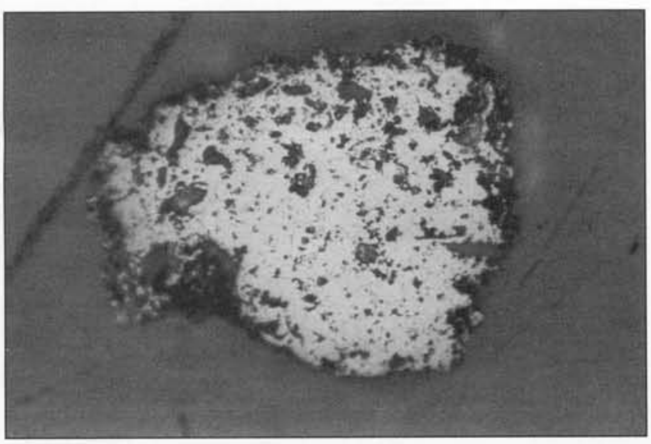

Fig. 5. Xenomorphic zircon grain (longer edge of photo is 2.5 mm).

Epidote forms colourless or greenish prisms up to 0.3 mm long. It is a rare component of the green weathering cover and the talc rocks.

Haematite (Fig. 8) forms during the magnetite martitisation process and as a result of magnetite decay. It is particularly common in the red-cherry weathering cover, where it occurs as massive concentrations and dusty pigment together with Fe hydroxide (especially goethite).

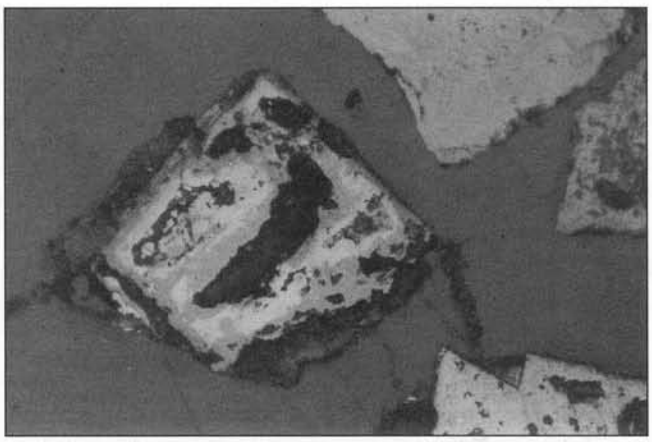

Fig. 6. Zircon with corroded core (longer edge of photo is 2.5 mm).

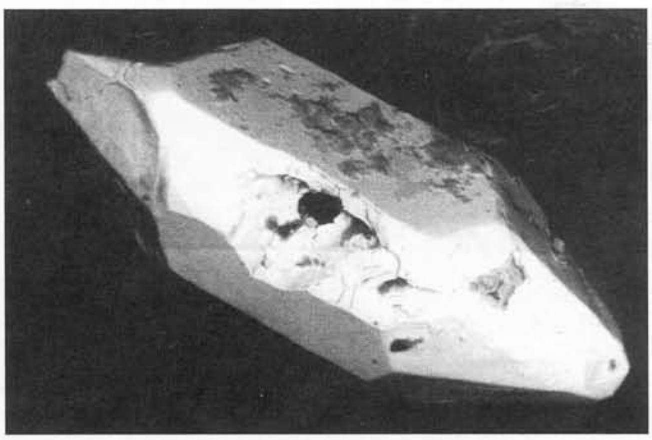

Fig. 7. Zircon crystal (longer edge of photo is 0.4 mm).

Table 3
Heavy minerals from the weathering cover of the Szklary massif

Mineral	Identification methods				
	Stereo-zoom and petrographic microscope	Reflected light microscope	X-ray	Electron microscope with EDS	Electron microprobe
Actinolite	+		+	+	+
Almandine	+		+		
Antophyllite	+		+		
Apatite	+		+		
Biotite	+		+		+
Brunsvigite	+		+		+
Chlorite	+		+		+
Chromite		+	+	+	+
Chrysotile	+		+	+	+
Zircon	+			+	+
Enstatite	+		+		
Epidote	+				
Ferroplatinum				+	+
Goethite	+	+			
Haematite	+	+			
Hornblende	+				+
Clinochlore	+		+		
Leukoxene	+			+	+
Magnesioferrite	?		+		
Magnetite	+	+	+	+	+
Magnesite	+				
Molibdenite					
Monazite	+			+	
Muscovite					+
Niggliit (PtSn)				+	+
Olivine	+				+
Ortopiroxene			+		+
Osmium-bearing phase Ba_2CaOsO_6			+		
Native palladium				+	
Pyrope	+				
Native platinum				+	
Pleonaste	+				
Rutile	+				
Native silver				+	
Talc	+		+		
Tremolite	+		+		
Trevorite	?		+		
Tourmaline	+				+
Native gold	+	+		+	
Zoisite	+		+		

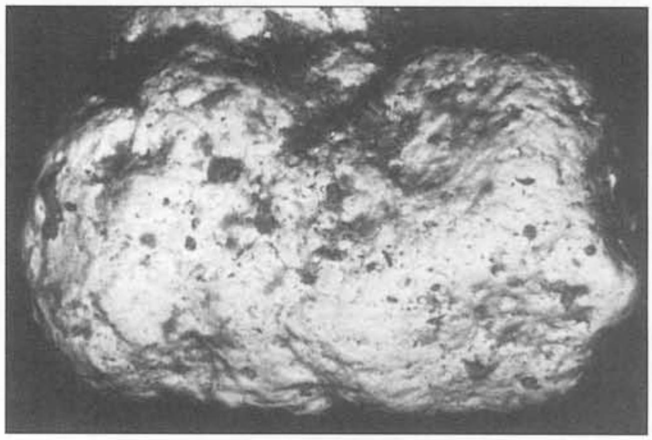

Fig. 8. Haematite (longer edge of photo is 0.27 mm).

Clinochlore is a common component of the serpentinite weathering cover. It forms green and colourless flakes and angular aggregates. It also has subnormal interference colours (brown and gaudy).

Mica was generally removed during the preparation of the heavy mineral concentrations (washing in the gold bowl, separation on the concentration table). There are occasional individual white mica flakes, often with magnetite inclusions. There were also numerous biotite flakes in the sample of amphibole-chlorite rock weathering cover (Sz 07).

Magnesioferryt and trevorite were identified using X-ray analysis. The occasionally observed automorphic opaque, brown-black spinel crystals probably represent these minerals. They usually occur in the green weathering cover.

Magnetite (Fig. 9) forms two grain types. The first type is represented by xenomorphic or hipidiomorphic grains – this is primary magnetite, the second one forms granular or massive concentrations or inclusions in various minerals, mainly in bladed minerals and amphiboles – this is secondary magnetite. In the weathering cover of the amphibole-chlorite rock (sample Sz 07), it is characteristic for the magnetite to occur as fine, round or oval grains. The massive and granular concentrations of the secondary magnetite are commonly replaced by haematite. Magnetite is the predominant component of the heavy mineral suite.

Magnesite (Fig. 10) is quite rare in the heavy fraction and mainly appears in the brown weathering crust, where it forms massive, white or yellowish concentrations.

Monazite is an especially rare component of the brown weathering cover, forming automorphic crystals, up to 0.2 mm in diameter.

Olivine forms rare, fine (to 0.2 mm diameter), greenish or yellow grains. It sometimes contains magnetite inclusions forming parted, amoebiform grains. Some olivine grains are strongly altered into serpentine.

Pleonaste occurs as automorphic or octahedral, pale green crystals of diameter c. 0.2 mm. It is extremely scarce.

Pyrope forms well-rounded grains (diameter up to 0.2 mm). It occurs sporadically.

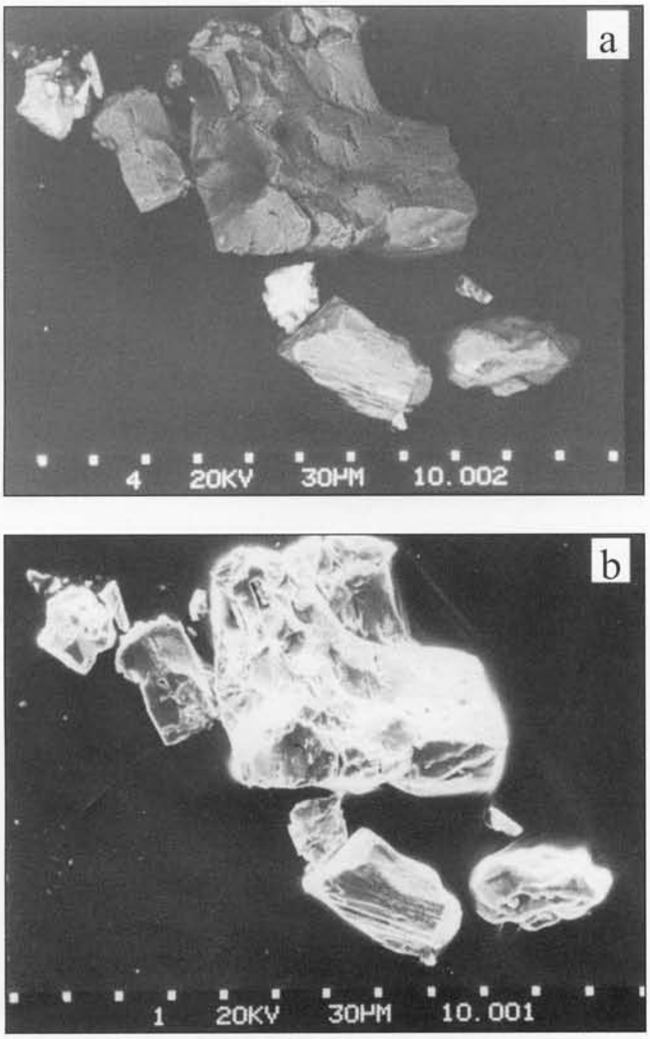

Fig. 9. Scanning electron micrograph (**a**) and back-scattered electron image (**b**) of magnetite (light grains on a), almandine (large grain on top) and tremolite (in the middle bottom part of the photo).

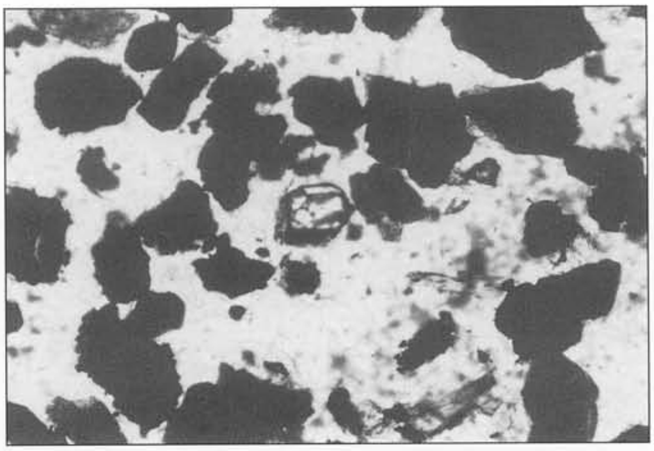

Fig. 10. Monazite grain among Cr-spinels (longer edge of photo is 2.5 mm).

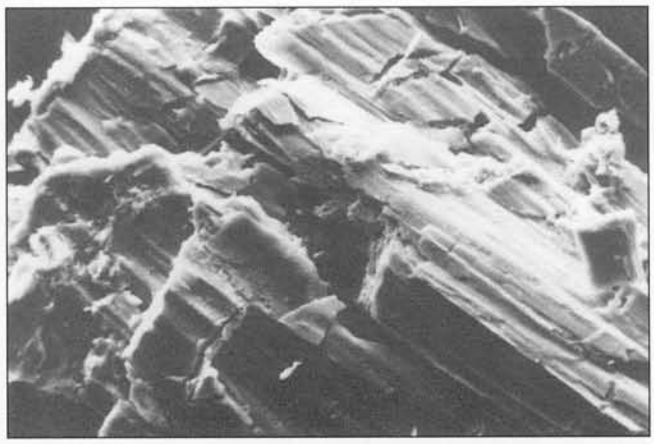

Fig. 11. Aciculate tremolite - tremolite asbestos (longer edge of photo is 0.2 mm).

Rutile forms sub-angular, short prismatic grains up to 0.3 mm long. It rare, generally occurring in the brown weathering cover.

Talc occurs as colourless or occasional pale green plates together with chlorite and mica. It is mainly associated with the talc rocks, and is also present in small amounts in the green serpentinite weathering cover.

Tremolite (Fig. 11) forms fine, usually colourless prisms with long striped walls, and aggregates which are either parallel or bundle grown. Some of them are yellow or greenish with weak pleochroism. Their extinction angle is 18–20°. Tremolite is common in finer weathering cover fractions.

Tourmaline occurs as broken or unbroken elongated prisms. The tourmaline crystals display strong pleochroism: olive-green and grey-brown, and their size ranges from 0.1 to 0.5 mm long. Tourmaline is typical of the green weathering cover from the northern part of the Szklary massif.

Native gold (Fig. 12) occurs as fine blades up to a few dozen micrometers in size. It was identified in this form using the electron microscope with the EDS system. Blades of native gold were positively identified occurring in the green weathering crust (sample Sp 1/4) and in the weathering cover of the amphibole-chlorite rocks (sample Sz 07) having fringed forms reaching 0.2 mm.

Zoisite is a relatively frequent component in the finest heavy mineral fractions. Two zoisite types exist: colourless, forming fine prisms or concentrations of rods and blue (tansanite), generally present as individual ink-blue prismatic crystals. Some crystals exhibit characteristic zonation; the core is white and the rim is coloured. Sizes of up to 0.4 mm are recorded for the tansanite-type grains.

Native elements, alloys, and intrametalic compounds

The occurrence of native elements in the marginal part of the Góry Sowie Block. Block is connected with precious metal ore mineralization: platinum group (Popiel & Waleńczak, 1978; Muszer & Speczik, 1997), gold (Fedak & Magdziarz, 1971; Speczik & Piestrzyński, 1995;

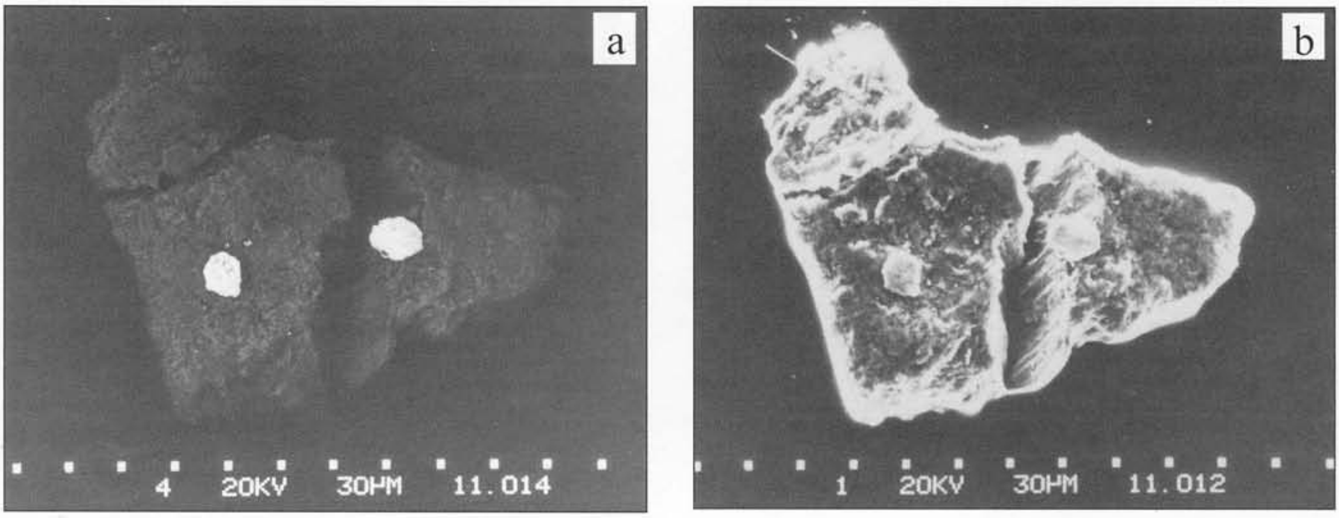

Fig. 12. Scanning electron micrograph (**a**) and back-scattered electron image (**b**) of two grains of native gold on a large magnetite grain.

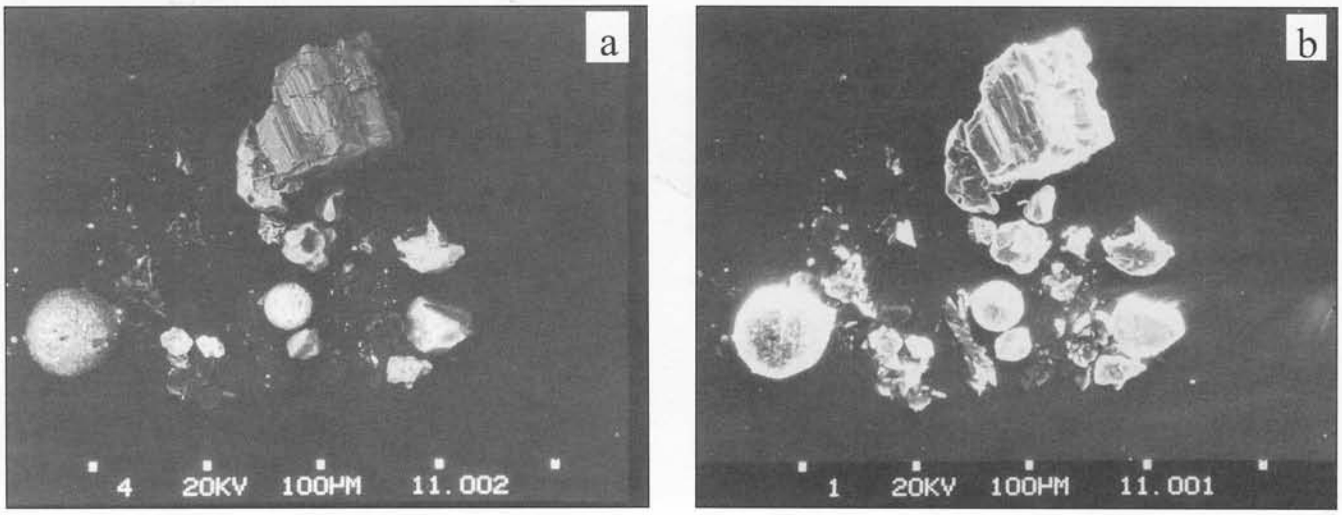

Fig. 13. Scanning electron micrograph (**a**) and back-scattered electron image (**b**) of anthropogenic components (alloy, balls), magnetite and chromite grains, and one large anthophyllite grain (on top of the photo).

Dubińska *et al.*, 1986; Sachanbiński & Łazarienkow, 1993; Niczyporuk, 1996) and native copper (Gunia, 1986). Native gold in the Szklary massif was found both in borehole profiles and in the heavy mineral concentrations obtained from surface samples. The size of the gold blades varies from several micrometers to 0.2 mm. The gold occurs as small layers or bordering, showing its secondary origin. Apart from native gold, individual grains of the gold-bearing phase (Au + Sb + Cu) were also found (using the EDS method Au > Sb > Cu). The gold is very rarely found as detrital grains associated with the rock-forming silicates (e.g. enstatite and tremolite) whereas gold associations with magnetite and chlorite grains are more common.

Native silver was identified in the brown weathering crust from Szklary (Sz 31). It occurs within a flake mineral which has been tentatively identified as Ni-vermiculite. Native silver has thusfar not been found in the Szklary massif. Fine, metallic-black grains which may be oxidised native silver were observed in the native platinum, native palladium, ferroplatinum, niggilite (PtSn) and alloy (Pt, Pb, Zn, Fe) were identified for the first time in the Szklary weathering cover (Sachanbiński & Muszer, 2000).

The anthropogenic components

Anthropogenic components are relatively common components of in the heavy mineral assemblages of the Szklary massif, and are mainly connected with the "Szklary" Mine-Metallurgical Factory, which ceased operations in 1985. These components reached the surface zone along with dust from the factory chimneys. Metallic alloy balls (Fig. 13), siliceous vitro balls, blades of ferronickel (Fig. 13) and grains of synthetic moissanite (SiC) were distinguished.

DISCUSSION AND CONCLUSIONS

The residual serpentinite weathering cover in Szklary is strongly differentiated. The main distinguishing criterion is colour. As a rule brown weathering cover of various shades of brown and yellow-brown dominates. Green or grey-green weathering cover occurs in smaller amounts. It is usually massive and enriched in nickel. Within the residual weathering cover, surrounding rock and vein rock weathering crusts are also distinguishable. The most widely distributed of these is the cherry-red, gneiss weathering crust. The second commonest type characteristic for the massif is dark green or grey-green amphibole rock weathering cover. Chlorite-talc-sericite rock weathering cover which forms silvery-grey coloured zones within the serpentinite weathering crust is the next most common type.

The heavy mineral content in various weathering cover types ranges from 0.3% (talc rock weathering crust Sz14) to 1.6% (brown weathering crust Sz19). Table 5 shows the average heavy mineral composition of the main weathering cover types. The data were gathered through identification of 300 to 500 mineral grains in the heavy mineral concentrations obtained from each sample by heavy fluid separation.

Most of the opaque mineral grains are strongly magnetic (magnetite, chromite, haematite – which form growths with magnetite or as martite, magnesioferryt and trevorite). Some of the transparent mineral grains (talc, tremolite, anthophyllite, enstatite etc.) which have a lot of magnetite inclusions also show magnetic properties.

The cherry-red weathering cover is characterised by the highest amount of haematite and goethite, which give the weathering cover its characteristic colour. Haematite usually occurs as a product of the magnetite martitisation and in intergrowths with its relics. There is a significiant amount of clinochlore and a smaller amount of enstatite and tremolite present in the heavy fraction of this weathering crust. Almandine and rutile were identified among the accessory minerals, whereas native gold and other precious metals are not present.

There is a characteristic, almost complete lack of chromite in the amphibole rock weathering cover. Magnetite occurs as oval concentrations, up to 1 mm in size, often intergrown with clinochlore. A high content of zoisite, tremolite and anthophyllite is typical of this weathering cover. The talc rock weathering crust is dominated by talc (up to 0.5 mm in diameter) usually intergrown with fine, secondary magnetite or with clinochlore.

The heavy mineral suite of the green weathering cover has the highest content of enstatite, zoisite and anthophyllite. The green weathering crust displays the largest diversity of heavy minerals and an especially wide variety of accessory minerals. It is possible to identify frequent almandine, apatite, tourmaline, tansanite, magnesioferryt and trevorite, and less common olivine, pleonaste, native metals intrametalic alloys among others. The brown weathering cover has a relatively large variety of heavy minerals with the dominant opaque mineral content.

The variety of mineral compositions of the Szklary weathering cover is a result of the great diversity of the

Table 4

X-ray, DSH, CuKα data of selected heavy minerals from the Szklary massif

almandine		antophyllite		chromite		clinochlore		magnesio-ferryt		magnetite		talc		tremolite		trevorite		zoisite	
d (nm^{-1})	I	d (nm^{-1})	I	d (nm^{-1})	I	d (nm^{-1})	I	d (nm^{-1})	I	d (nm^{-1})	I	d (nm^{-1})	I	d (nm^{-1})	I	d (nm^{-1})	I	d (nm^{-1})	I
4.22	3	9.14	2	4.79	5	14.2	9	2.96	4	4.87	7	9.21	8	8.35	8	4.82	3	8.11	3
2.87	4	8.13	8	2.95	6	7.08	10	2.53	10	2.94	4	4.76	2	8.18	6	2.95	5	5.16	2
2.57	10	7.10	4	2.518	10	4.72	10	2.09	2	2.518	10	3.11	10	4.11	2	2.52	10	4.03	3
2.35	2	4.53	4	2.413	1	3.54	9	1.715	3	2.411	1	2.86	2	3.22	3	1.910	1	2.86	5
2.25	2	4.10	6	2.088	7	2.83	7	1.612	3	2.088	5	2.584	1	3.11	10	1.610	5	2.78	2
2.097	2	3.57	6	1.706	4	2.58	2	1.480	4	1.706	1	2.167	1	2.96	1	1.493	2	2.69	10
1.866	3	3.22	8	1.612	9	2.53	1	1.324	2	1.611	4	1.840	2	2.74	2	1.264	1	2.065	3
1.661	3	3.04	10	1.470	9	2.375	1			1.480	4	1.766	1	2.58	1			2.021	1
1.596	3	2.74	4			2.057	1					1.543	2	2.334	2			1.870	2
1.538	5	2.485	1			2.006	2					1.499	1	2.230	1			1.617	2
		1.840	2			1.870	4							2.162	1			1.348	2
		1.766	1			1.558	4							2.022	4				
		1.690	1			1.493	1							1.888	2				
		1.613	2			1.393	4							1.843	4				
		1.543	2											1.676	1				
		1.501	1											1.644	4				
														1.558	4				
														1.554	2				
														1.435	4				

Table 5

The mineral composition of the heavy fractions from weathering cover of the Szklary massif

Weathering crust type	Number of samples	Average mineral contents in the heavy fraction													
		Almandine	Antofyllite	Chromite	Zircon	Enstatite	Epidote	Goethite	Hematite	Clinochlore	Magnetite	Talc	Tremolit	Zoisite	Others
Cherry-red crust	2	-	-	3	3	6	7	17	21	15	21	-	7	-	chrysotile, rutile, almandine
Amphibole-chlorite rock crust	1	-	3	-	-	5	4	4	3	18	32	-	18	13	mica (biotite), native Au
Talc rock crust	1	-	-	13	-	2	7	-	-	16	19	39	-	4	mica
Green crust	5	-	15	11	3	16	4	-	-	4	28	-	-	19	almandine, olivine, tourmaline, magnesioferryt, trevoryt, pleonast, apatite, narive Au
Brown crust	7	3	3	19	2	9	-	4	9	-	38	-	10	3	olivine, tourmaline, rutile, monazite

parent rocks, the varying level of weathering, and the varying influence of the surrounding rocks, the vein rocks accompanying the serpentinities, and the components of the Quaternary cover. Although the heavy mineral suite is similar in the various weathering covers, it varies considerably from the serpentinite weathering crust to the country rock weathering crusts (cherry-red gneiss crust, amphibole rock crust) and talc rock weathering cover. A difference between the heavy mineral composition of the brown and green weathering covers exist. This is related both to certain differences in the mineral composition of the parent rocks (various serpentinite types) and to the character and degree of weathering, and varying influence of the surrounding and accompanying rocks.

The heavy minerals of the serpentinite weathering cover belong to three paragenetic groups:

1) connected with the country rocks: amphiboles, epidotes (tremolite, anthophyllite, epidote, zoisite) and accessory minerals (zircon, rutile, apatite),

2) connected with the vein rocks cutting the serpentinite massif: almandine, tourmaline, anatase, zircon, rutile, monazite, apatite, pleonaste, molibdenite,

3) connected with the serpentinities and of their alteration products: magnetite, chromite, haematite, goethite, magnesite, talc, chrysotile, and native gold.

REFERENCES

DUBIŃSKA, E., 1995. Budowa zwietrzeliny ze Szklar. *Przewodnik LXVI Zjazdu PTG, Wrocław*, pp. 207–212. {in Polish only}

DUBIŃSKA, E., JELITTO, J. & KOZŁOWSKI, A., 1995. Origin and evolution of the granite/serpentinite reaction zones at Wiry, Lower Silesia. *Acta Geologica Polonica*, 45/1-2: 41–82.

MICHALIK, R., SACHANBIŃSKI, M. & NIŚKIEWICZ, J., 1997. Wstępne dane o geochemii złota w zwietrzelinach serpentynitowych masywu Szklar. In: *Metale szlachetne w NE części Masywu Czeskiego i w obszarach przyległych – geneza, występowanie, perspektywy – materiały konferencyjne. Jarnołtówek 19–21.06.1997*, pp. 81–85.

NIŚKIEWICZ, J., 1967. Budowa geologiczna masywu Szklar (Dolny Śląsk). *Rocznik Polskiego Towarzystwa Geologicznego*, 37: 387–416.

NIŚKIEWICZ, J. & SACHANBIŃSKI, M., 1995. Mineralizacja Ni, $MgCO_3$, Pt i Au w strefie wietrzenia. *Przewodnik LXVI Zjazdu PTG, Wrocław 1995*, pp. 214–216. {in Polish only}

SAMAMA, J. C., 1989. Ore fields and continental weathering. Russian edition. *"Mir", Moskwa*, pp. 115–121.

MUSZER, A. & SPECZIK, S., 1997. Związek okruszcowania Ni-Sb z PGE w serpentynitach z Nasławic (ofiolit Ślęży). *Przegląd Geologiczny*, 45/3: 282–286.

GUNIA, P., 1986. Native copper from rodingitized dykes in serpentinites of the Braszowice–Brzeźnica massif (Lower Silesia). *Mineralogia Polonica*, 17/1: 63–75.

FEDAK, J. & MAGDZIARZ, A., 1972. Złoto w strefie wietrzenia masywu ultrazasadowego Gogołów–Jordanów na Dolnym Śląsku. *Przegląd Geologiczny*, 6: 289–292. {in Polish only}

NICZYPORUK, K., 1997. Platynowce i złoto w zasadowych i ultrazasadowych skałach Dolnego Śląska; In: *Metale szlachetne w NE części Masywu Czeskiego i w obszarach przyległych – geneza, występowanie, perspektywy – materiały konferencyjne. Jarnołtówek 19–21.06.1997*, pp. 126–128. {in Polish only}

OSTROWICKI, B., 1965. Minerały niklu strefy wietrzenia serpentynitów w Szklarach (Dolny Śląsk). *Prace mineralogiczne PAN - Kraków*, 1: 1–92. {in Polish only}

SACHANBIŃSKI, M. & ŁAZARIENKOW, W.G., 1994. Platynowce i złoto w masywie serpentynitowym Szklar (Dolny Śląsk). *Przegląd Geologiczny*, 42/11: 933–934.

POPIEL, H. & WALENCZAK, Z., 1978. Platyna i pallad w ultramaficznych skałach Dolnego Śląska. *Archiwum Mineralogiczne*, 34: 107–111.

SACHANBIŃSKI, M. & MUSZER, A., 2000. Platinum-group minerals in lateritic covers from the serpentinite massifs of Lower Silesia, SW Poland. In: Rammlmair et al. (Eds). *Applied Mineralogy*, 1: 421–423.

SKIBA-WYDERKO, M., 1964. Krzemianowe rudy niklu ze Szklar (Dolny Śląsk). (Wstępne dane cz. 1. Ruda szara). *Rudy i Metale Nieżelazne*, 9: 288–290. {in Polish only}

SPANGENBERG, K. & MÜLLER, M., 1949. Die lateritsche

Zersetzung des Peridotitsbei der Bildung der Nikielerzlagerstätte von Frankenstein in Schlesien. *Heidelberger Beitrage zur Mineralogie und Petrographie*, 1(5, 6): 560–572.
SPECZIK, S. & PIESTRZYŃSKI, A., 1995. Au -mineralization from the Ślęża ophiolite complex, SW Poland, In: *Mineral deposits: from their origin to their environmental impacts. Proceedings of the Biennial SGA Meeting, Prague, Czech Republic, 28–31 August 1995*, pp. 191–193.