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WP7 Historic Mine Sites revisited

Case Study

The Szklary saprolitic Ni deposit (Lower Silesia, SW Poland)

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STRATEGIC RAW MATERIALS NEEDS

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FORECASTING AND ASSESSING EUROPE'S
STRATEGIC RAW MATERIALS NEEDS

Table of Contents

1	Introduction	4
2	Geology.....	5
3	Mine history	6
4	Field work	7
5	Results of lab work/analysis	9
6	Conclusions	13



1 Introduction

In Poland the occurrence of weathered nickel ore deposits, occur on the Fore-Sudetic Block in the Lower Silesia. The considering Ni silicate ores have been known for over 100 years, which were exploited in Szklary deposit until 1983. The Szklary deposits of nickel of the saprolitic type are associated with Palaeozoic massifs of serpentinized mafic and ultramafic Devonian ophiolite formation surrounding from the east the Sowie Góry Block (Fig. 1).

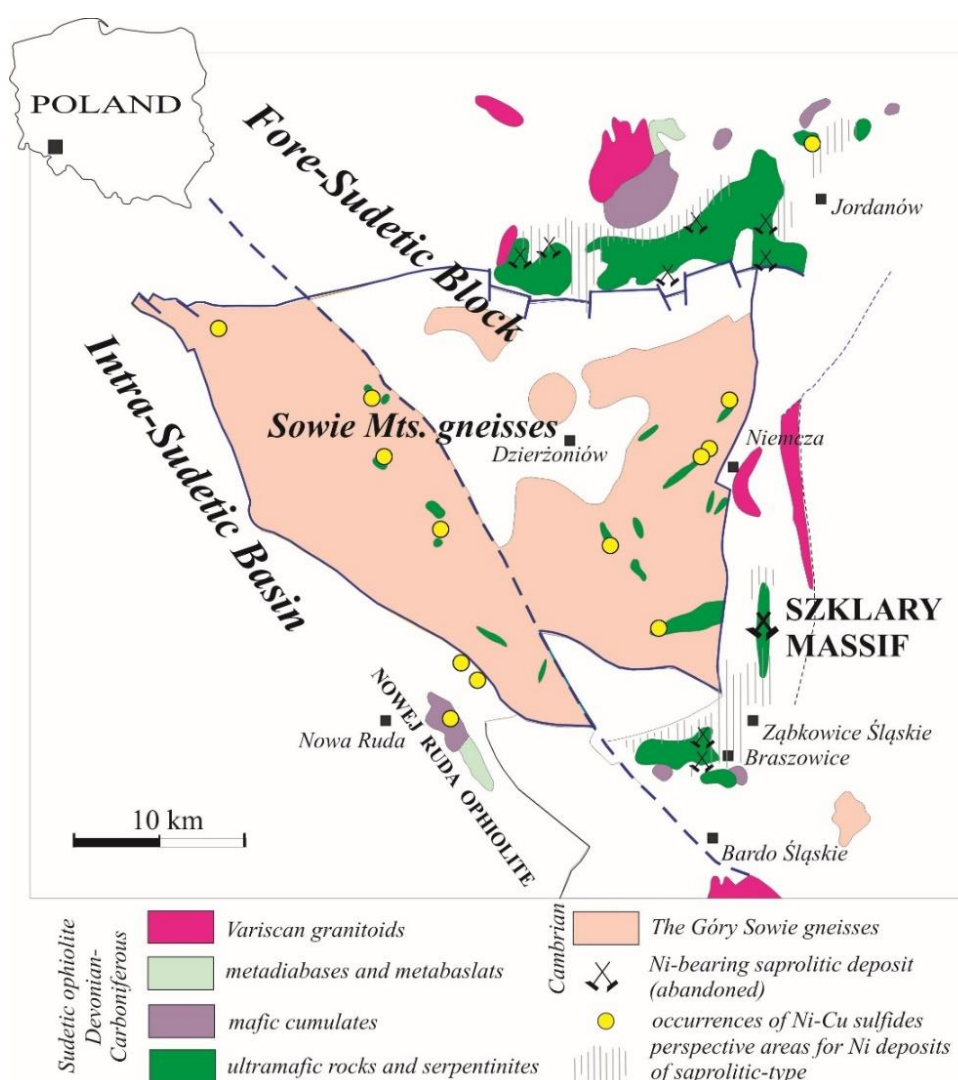


Figure 1: Location of the areas of prospective occurrence of nickel silicate ores together with documented weathering Ni ores and manifestations of Ni-Cu sulphide igneous mineralization around the Sowie Mountains gneisses massif (acc. to Mikulski and Sadłowska, 2020, modified).



2 Geology

The Sowie Góry Block representing a member of metamorphosed ultramafites of the ophiolite sequence (Majerowicz, Pin, 1994). The Szklary Massif is made up of several isolated hills stretching longitudinally, about 5 km long and 1 km wide. In the Cenozoic, serpentinites underwent intense weathering, which led to the formation of nickel silicate ores. Saprolite nickel ore occurs in the weathered serpentine rocks in the form of nests, pockets, veins and lenses arranged irregularly along the fracture and fault zones in the massif. The thickness of saprolite varies from a few to over 100 m, with an average of around 40 m (Niśkiewicz, 1967). Nickel ore, which is mainly composed of hydrated nickel-magnesium silicates, contains varying amounts from 0.7 to several % Ni. Rich ores are usually found in the bottom parts of the deposit, where the thickness of weathered water is the highest. The reasons for abandoning the exploitation of the deposit in Szklary were aspects of environmental protection and the high energy consumption of the metallurgical process.

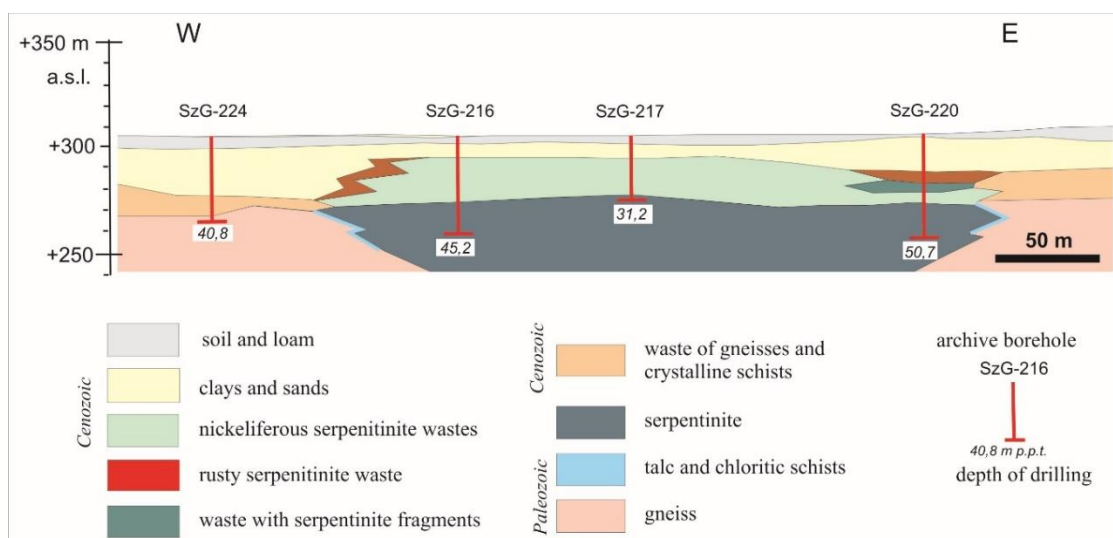


Figure 2: Schematic geological section cross the Szklary Siodłowe Hill Ni saprolite deposit in Szklary (modified after Mikulski 2012 and Gawrońska 1963).



3 Mine history

The exploitation of silicate ores in Szklary was started at the end of the 19th century. However, a significant increase in extraction occurred with the launch of opencast mining from the First World War. In the post-war period, in 1950, the Szklary mine and steelworks were reopened. In the period from the beginning of the 1960s to the end of the 1980s, intensive drilling works (> 450 boreholes) were carried out, as a result of which new nickel ore resources were documented in the area of the Szklary deposits.

Table 1: Production of nickel from the Szklary deposit during 1955-1983.

Year	Ni-ore production [in thousand tons]	*Ni-metal production [in thousand tons]	Notice
1955	240	-	
1956	214	-	
1958	219	0.8	
1960	250	0.95	
1961	155.9	1.2	
1962	172.7	1.333	
1963	155.8	1.1	
1964	205.5	1.2	
1965	250	1.3	
1966	189.4	1.06	
1967	207.4	1.5	
1968	220	-	
1969	172	0.9	include 72t ***
1970	160	-	
1971	189	-	
1972	163	-	
1973	162	1.5	
1974	160	-	
1975	156.4	1.12	
1976	174	-	include 23t ***
1977	147**	-	6t ***
1978	139**	1.0 + 0.2***	+30t ***
1979	133**	1.2 + 0.03***	+3t ***
1980	129**	1.2	
1981	88**	1.0	
1982	91**	1.0	
1983	31**	0.3	
Mine closed in 1983			

- * Ferrous nickel product (Composed of: 8-10 % Ni and 90-92 % Fe)
- ** dry weight ore
- *** from mine dump waste



Figure 3: The ruins of the former nickel smelter in the Szklary (Lower Silesia, SW Poland)

In the last century, in addition to the Szklary deposit, nickel-bearing weathered deposits developed on the Braszowice-Brzeźnica and Gogołów-Jordanów massifs of serpentinized Palaeozoic ultra-basic rocks - peridotites. There were documented, according to the old balance criteria, as an accompanying mineral in magnesite deposits. The balance geological resources of nickel ore deposits in Poland, recognized in categories B and C1, amount to 17.21 million tons of ore and 125.0 thousand tons of metal (at a marginal content of 0.8% Ni). In the Grochów deposit only off-balance sheet resources amount to 21.32 million tons of ore and 84 thousand ton of metal were documented. In turn, the prognostic and prospective resources of nickel weathering ores in the prospective areas in the Cenozoic weathering of serpentinite massifs occurring around the gneiss block of the Sowie Mountains in Lower Silesia amount to almost 18.22 million tons of Ni ores, and the metal resources are approx. 67.3 thousand tons (Mikulski, Sadłowska, 2020; with references therein).

4 Field work

Measurements with a portable XRF spectrometer were performed on grated samples taken from the drill core every 0.5 m. A total of 135 chemical composition analyzes were performed. The recorded contents of selected elements are within the following limits: Ni 31 (+/- 4) - 18144 (+/- 91) ppm, Cr 39 (+/- 3) - 6944 (+/- 105) ppm, Fe 10146 (+ / - 60) - 203675 (+/- 1248) ppm, Sr 0 - 385 (+/- 5) ppm, Ti 0 - 4658 (+/- 56) ppm, V 0 - 88 (+/- 6) ppm, Cu 0 - 87 (+/- 12) ppm, Ba 0 - 468 (+/- 15) ppm.



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Figure 4: Photographs of archival Bobolice B-4 drilling cores (interval 14-25 m) tested for geochemical analyzes by use of portable XRF spectrometer in FRAME WP7 works.



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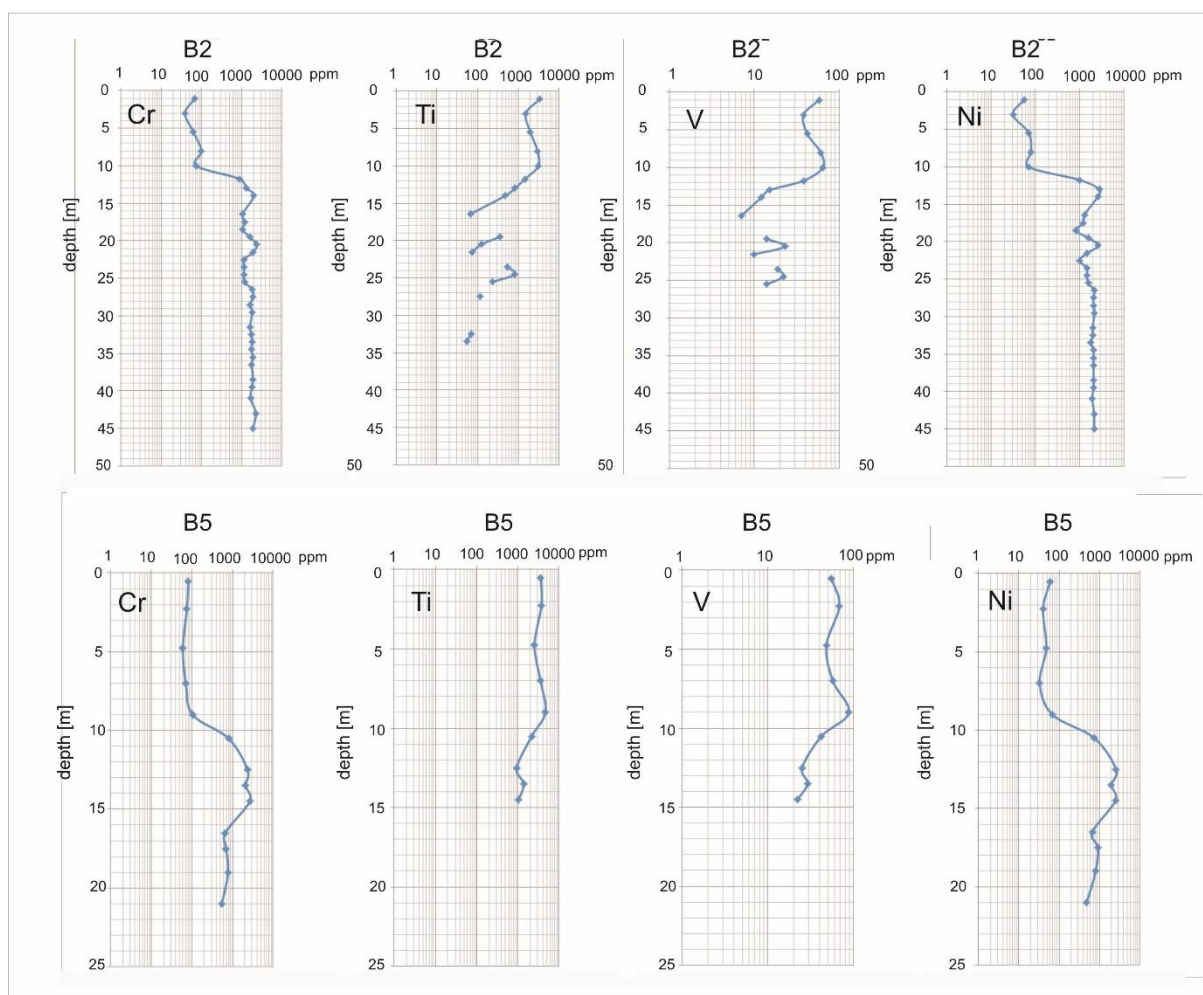


Figure 5: Distribution of Cr, Ti, V and Ni (in ppm) based on portable XRF spectrometer studies in the vertical profile of B2 and B5 boreholes with saprolitic nickel mineralization in the Szklary Wzgórze Siodłowe deposit in the Sudetes.

5 Results of lab work/analysis

In the current project 5 core samples from the historic boreholes located within the southern part of the Szklary Siodlowe Hill deposit, were subject of geochemical and mineralogical investigation by the Polish Geological Survey. Three samples were taken from the Bobolice B3 borehole at the 15-19 m depth interval (sample nos. 15/20/6-8 in tab. 6), and the remaining 2 samples (nos. 15/20/9-10) from the B4 borehole at the depth interval of 15.5-25.7 m.



The considering samples representing Ni-bearing strongly weathered serpentinite (saprolite). The mineral crystalline compositions of saprolite were determined by means of X-ray powder diffraction (PXRD). Different percentages of individual minerals in the samples were found. The main minerals of nickel carriers are pseudo-clinoclhor-Ni and nickel-manganese oxide. The percentage of these minerals varies and in the case of the nickel-manganese oxide content in the samples from the B4 borehole it was approx. 4%, and pseudo-clinoclhor-Ni from 2 to 13%. Besides, Ni-montmorillonite, Ni-vermiculite, and pimelite are subordinate. There are also numerous veinlets of cryptocrystalline silica colored by Ni admixture in a greenish color - chrysoprase. Among the gangue minerals present in saprolite ores there are mainly in crystalline form vermiculite, quartz, talc, tremolite, calcite, aragonite, lizardite, enstatite, and locally also ferroholmquistite, zinnwaldite and magnetite. The geochemical results of ICP-MS, WD-XRF and GF AAS measurements are presented in table 7. The conducted geochemical studies of 5 representative saprolitic rock samples confirmed increased concentrations of such strategic elements as cobalt and platinum, which are associated with Ni saprolitic ores.

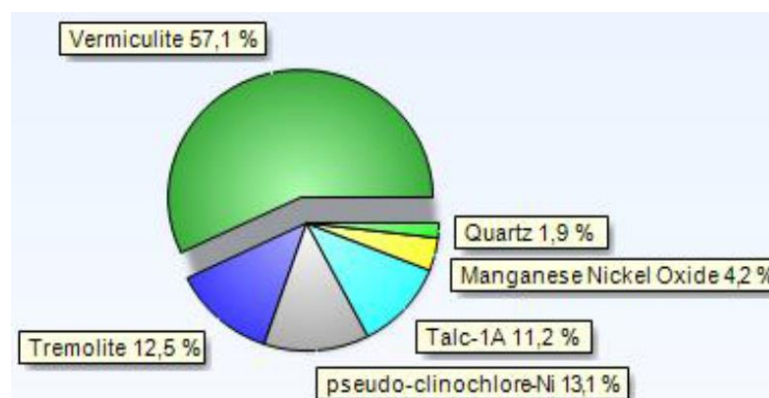


Figure 6: Pie chart (in %) of the content of individual mineral phases in sample B4 / 02 based on PXRD tests

The maximum concentrations determined in a single sample were for: cobalt - 1332 ppm, and platinum – 150 ppb. The presence of cobalt correlates with the appearance of Zn (correlation coefficient $r = 0.84$ for $n=5$ samples), Bi ($r = 0.78$), W and Zr ($r = 0.75$) and weaker with Pt, Pd ($r = 0.58$) and Ni ($r = 0.55$), (Figs. 27-28). The arithmetic means of the contents of some elements were as follows: Ni = 1.35% ($n=5$), Cr = 0.65%, Co = 702 ppm, Zn = 257 ppm and Pt = 130 ppm.



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STRATEGIC RAW MATERIALS NEEDS

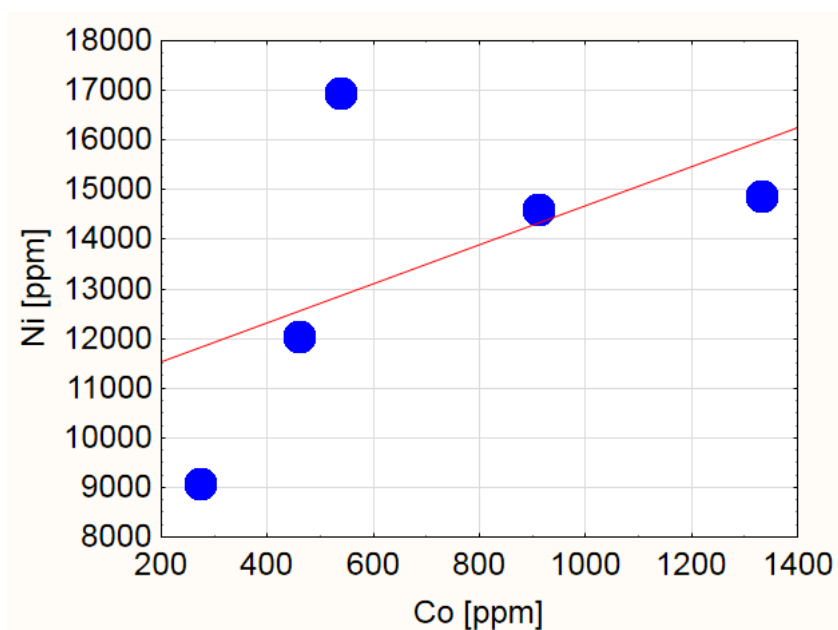


Figure 7: Bivariate plot of Ni vs. Co in bulk-rock samples of Ni-bearing saprolite ores from the core samples of the Bobolice B3 and B4 boreholes in the Szklary Siodlowe Hill deposit.

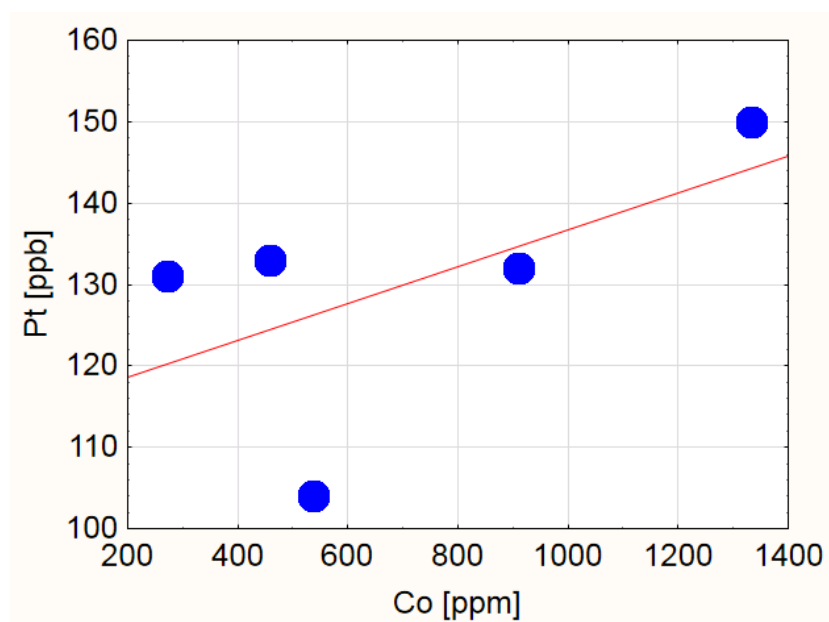


Figure 8: Bivariate plot of Pt vs. Co in bulk-rock samples of Ni-bearing saprolite ores from the core samples of the Bobolice B3 and B4 boreholes in the Szklary Siodlowe Hill deposit.



Table 2: Results of geochemical investigation (ICP-MS, WD-XRF and GFAAS) of 5 samples from historic boreholes at Szklary Siodlowe Hill deposit Lower Silesia (NE Bohemian Massif, SW Poland)

Sample description	As	Ba	Bi	Ce	Co	Cr	Cu	Ga	Hf	La	Mo	Nb	Ni	Pb	Rb	Sr	Th	U
	ppm [WD-XRF]																	
olive-gray saprolite with Ni-bearing clay-loam and thin veinlets of Ni silicates (15/20/6)	19	991	11	14	1332	2269	<5	<3	4	84	<2	5	14885	<3	11	37	<3	3
olive saprolite with Ni-bearing minerals and Mn-oxides (15/20/7)	8	1189	6	<5	459	4754	<5	<3	<3	20	<2	4	12053	<3	11	29	<3	3
yellow-brownish soft "earthy ore" with fine chrysoprase veils (15/20/8)	10	239	11	<5	537	11030	<5	<3	6	75	<2	4	16952	<3	8	24	<3	4
nickel-bearing greenish clay with numerous veins of Ni silicates (15/20)	10	101	9	<5	911	7638	<5	<3	<3	<5	<2	3	14613	<3	10	42	<3	3
rusty brown, weathered serpentine with pale-greenish thin veins of Ni-bearing silicates and Mn minerals with talc and chlorites (15/20/10)	21	87	<3	<5	272	6659	<5	<3	<3	<5	<2	4	9066	<3	8	27	<3	3
Sample description	V	Y	Zn	Zr	Br	Cd	Sn	Se	Ag	In	Sb	Te	W	Re	Tl	Au	Pd	Pt
	ppm [WD-XRF]							mg/kg [ICP-MS]							µg/kg [GFAAS]			
olive-gray saprolite with Ni-bearing clay-loam and thin veinlets of Ni silicates (15/20/6)	30	49	335	41	3	14	<2	2	<0,3	<0,05	1,4	<0,5	101,6	<0,05	1,10	2	15	150
olive saprolite with Ni-bearing minerals and Mn-oxides (15/20/7)	69	16	264	20	3	10	<2	<2	0,4	<0,05	0,8	<0,5	44,2	<0,05	0,47	1	11	133
yellow-brownish soft "earthy ore" with fine chrysoprase veils (15/20/8)	129	24	257	17	5	11	<2	<2	<0,3	<0,05	0,5	<0,5	28,0	<0,05	0,29	1	18	104
nickel-bearing greenish clay with numerous veins of Ni silicates (15/20/9)	88	<3	303	10	3	10	<2	<2	<0,3	<0,05	<0,5	<0,5	18,7	<0,05	0,23	1	14	132
rusty brown, weathered serpentine with pale-greenish thin veins of Ni-bearing silicates and Mn minerals with talc and chlorites (15/20/10)	77	<3	126	5	4	11	<2	<2	<0,3	<0,05	1,0	<0,5	15,4	<0,05	0,36	3	<5	131



6 Conclusions

The saprolite nickel deposit in Szklary, closed in 1983, still has significant amounts of nickel in the amount of over 125 thousand tons of metallic Ni. Moreover, on the basis of geochemical studies of Ni ores from the Siodlowe Hill in Szklary, the resources of cobalt and chromium were estimated (Mikulski, Sadłowska, 2020). The strategic element – cobalt, accompanies the main minerals and occurs in Ni ores in the amount of 100–300 ppm. The estimated resources of cobalt in the nickel deposit in Szklary in balance ores amount to 1.7 thousand tons, and taking into account off-balance ore, a total of 5.2 thousand tons was estimated only for the Szklary deposit. On the other hand, chromium resources, which are most often present in the amount of 0.1–0.4%, can be estimated at 55.1 thousand tons in balance resources and 23.8 thousand tons in off-balance sheet resources. Besides, taking into account additional prospective Ni resources in this area and in other regions on the Fore-Sudetic Block in Lower Silesia the possibility of the occurrence of much greater resources of cobalt and chromium together with nickel-bearing saprolite seems to be justified. With the currently high demand for cobalt, there is a chance for a revival in the small mining of nickel saprolite ores in Europe. Moreover, it is noteworthy that the presence of also other elements in Ni-bearing saprolite deposits is significantly increased in relation to their average content in the earth's crust (e.g. Re, Cd, Pt, Pd and Sc). Additionally, in the weathering profile of the Ni deposits, there are levels with magnesite, which has often been of economic importance in the past.

Our geochemical work confirmed the increased concentrations of cobalt, chromium and platinum in the nickel-bearing saprolite in the Szklary Siodlowe Hill deposit. Further work is required in the field of comprehensive recognition of the distribution and possible recovery of elements in the processing of nickel saprolite ores.



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