

## CHLORINE-BEARING AND OTHER UNCOMMON MINERALS IN THE STRATHCONA DEEP COPPER ZONE, SUDBURY DISTRICT, ONTARIO

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### ABSTRACT

A zone of copper-rich ore in the footwall of the Strathcona orebody in the Sudbury district, Ontario, contains a number of uncommon minerals. These include froodite, moncheite and niggliite as carriers of platinum and palladium, and iron hydroxy-chlorides that occur as fracture fillings and as inclusions in sulfide. Chlorine-bearing silicates also were found. Some of the silicates are rich in manganese.

*Keywords:* froodite, moncheite, niggliite, iron chloride, Sudbury, Strathcona mine, Ontario.

### SOMMAIRE

Une zone de minerai cuprifère située près du contact inférieur du gisement de Strathcona, dans le district de Sudbury (Ontario), contient plusieurs minéraux assez rares. L'association comprend froodite, monchéite et niggliite comme porteurs de platine et de palladium, et des chlorures hydroxylés de fer qui tapissent les fissures ou sont inclus dans les sulfures. Des silicates de chlore sont aussi présents. Certains silicates sont enrichis en manganèse.

(Traduit par la Rédaction)

*Mots-clés:* froodite, monchéite, niggliite, chlorure de fer, Sudbury, mine de Strathcona, Ontario.

### INTRODUCTION

The Strathcona mine is located on the north rim of the Sudbury Basin. The orebody is concentrated at the junction of the norite-micropegmatite igneous complex and its gneissic footwall. Detailed descriptions of the deposit have been given by Cowan (1968), Abel *et al.* (1979), and Coats & Snajdr (1984). The ore consists essentially of nickeliferous pyrrhotite, pentlandite, and chalcopyrite. In addition to the main norite-related ore, there are stringers of sulfide emplaced in the footwall rocks. Some of these stringers consist of massive chalcopyrite and extend 100–200 m away from the norite contact.

In 1979, a second, more extensive zone of copper-rich stringers was discovered, reaching even farther into the footwall. This zone has become known as the Strathcona Deep Copper Zone. In the following, a description is given of some of the unusual

minerals that were encountered during routine microscopic inspections of exploration samples.

### ORE MINERALS

Mineralization in the Deep Copper Zone consists mainly of chalcopyrite and cubanite, with minor pentlandite and pyrrhotite. Other minerals present are bornite, millerite, sphalerite and mackinawite. Galena occurs in trace amounts, mostly in the form of round inclusions in the major sulfides. It is associated with a number of uncommon ore minerals that were identified by electron microprobe. These are stibnite  $Sb_2S_3$ , hawleyite (cubic CdS), bismuthinite  $Bi_2S_3$ , altaite  $PbTe$ , hessite  $Ag_2Te$ , froodite  $PdBi_2$ , parkerite  $Bi_2Ni_3S_2$ , and gold alloy having a silver content between 53 and 65 wt.%. The main platinum carriers are moncheite  $(Pt,Pd)(Te,Bi)_2$  and tin-bearing minerals that appear to be related to niggliite  $Pt(Sn,Te)$ . Measured compositions of the Pt-bearing minerals are listed in Table 1.

The compositions quoted in the tables were derived from electron-microprobe data obtained with a Cambridge Mark 5 instrument fitted with two wavelength-dispersion spectrometers. The excitation voltage was 20 kV, and pure elements or pure oxides were used as standards except for the elements Cu, S, Cl and K, for which chalcopyrite, halite and orthoclase were employed.

Most of the uncommon minerals are less than 20  $\mu m$  across and are closely intergrown. Both moncheite and niggliite are creamy white, anisotropic and have high reflectivity. Pentlandite and pyrrhotite were found to contain less nickel than in the main Strathcona orebody. Typical compositions are given in Table 2, along with comparative data on pentlandite and pyrrhotite from the main orebody. Care was taken to avoid interference from the Cu-rich matrix when analyzing the pentlandite and pyrrhotite exsolution lamellae. Their unusual copper contents seem to be real, at least on a scale covered by electron-microprobe analysis.

### CHLORINE-BEARING PHASES

Some of the ore samples were found to have a high

TABLE 1. CHEMICAL COMPOSITION OF THE PLATINUM-BEARING MINERALS

	Pt	Pd	Sn	Bi	Te	Total
Moncheite wt.%	28.7	3.27	-	54.6	12.0	98.5
Moncheite atoms	0.83	0.17	-	1.47	0.53	3
Niggilite wt.%	32.3	-	0.55	55.9	8.85	97.5
Niggilite atoms	0.98	-	0.03	1.58	0.41	3
Moncheite wt.%	36.7	-	11.2	31.1	16.1	95.1
Moncheite atoms	0.67	-	0.34	0.54	0.45	2
Niggilite wt.%	36.2	-	8.40	31.9	20.3	96.8
Niggilite atoms	0.65	-	0.25	0.54	0.56	2

TABLE 2. CHEMICAL COMPOSITION OF PENTLANDITE AND PYRRHOTITE

	Fe	Ni	Cu	S	Total
Pentlandite exsolution in cubanite	37.1	28.3	1.49	33.6	100.5
Blocky pentlandite	35.0	31.0	<0.10	33.7	99.7
Pyrrhotite exsolution in chalcopyrite	63.7	0.01	0.27	36.1	100.1
Pentlandite, Main Ore Body	29.7	35.7	0.07	33.0	98.4*
Pyrrhotite,	58.6	0.63	0.04	39.6	98.9

\*Includes 1.30% Co

TABLE 3. CHEMICAL COMPOSITION OF IRON CHLORIDE

	Fe	Mn	Cl	OH*	Total
Fracture filling wt.%	53.9	-	18.2	27.9	100.0
Fracture filling atoms	1	-	0.53	1.70	3.23**
Acicular Inclusion wt.%	43.5	7.14	32.2	17.2	100.0
Acicular Inclusion atoms	0.86	0.14	1.00	1.11	3.11**

\*OH content computed from difference of analysis total to 100%

\*\*Atomic proportions to basis of Fe+Mn = 1

TABLE 4. POWDER-DIFFRACTION DATA OF IRON CHLORIDE

d, Å	I rel	d, Å	I rel
5.62	4	2.12	5
5.16	2	2.05	1
4.63	0.5	1.87	2
4.17	1	1.80	1
2.86	6	1.745	2
2.585	0.5	1.652	5
2.33	10	1.597	1
2.28	1	1.453	0.5
2.185	1	1.406	1

114.6 mm Debye-Scherrer camera  
Fe-filtered Co radiation

TABLE 5. CHEMICAL COMPOSITION OF CHLORINE-BEARING SILICATES

	SiO <sub>2</sub>	MnO	FeO	Cl	Al <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	Total*
Pyrosmalite wt.%	33.3	19.6	33.6	12.4	-	-	98.9
Pyrosmalite cations	5.98	2.99	5.04	3.75	-	-	Si+Mn+Fe=14
Mica wt.%	33.5	1.18	35.2	2.09	15.2	9.73	96.9
Mica cations	5.73	0.18	5.03	0.60	3.06	2.13	Si+Mn+Fe+Al=14
Sepiolite wt.%	49.4	8.01	31.6	0.30	-	-	89.3
Sepiolite cations	6	0.82	3.22	0.02	-	-	Si+Mn+Fe=10.04
Grunerite wt.%	36.7	1.26	50.7	1.00	-	-	89.7
Grunerite cations	6.86	0.20	7.94	0.32	-	-	Si+Mn+Fe=15

\*Concentrations of MgO, CaO, Na<sub>2</sub>O and TiO<sub>2</sub> are less than about 1 wt.%

content of chlorine. Bulk concentrations of as much as 0.91% Cl were encountered. Chlorine occurs in the form of iron chlorides and in solid solution in some of the gangue silicates.

Two textural varieties of iron chloride were observed. The first type occurs as fracture fillings in chalcopyrite and pentlandite. The other forms acicular inclusions in chalcopyrite and cubanite. Electron-microprobe results are shown in Table 3. The compositions suggest that the acicular material is (Fe,Mn)(OH)Cl. The fracture filling appears to be Fe<sub>2</sub>(OH)<sub>3</sub>Cl. On exposure to air, the latter chloride converts to the tetragonal form of FeOOH, akaganeite, as was demonstrated by X-ray diffraction. Ore samples containing chloride tarnish readily and turn rusty brown.

No X-ray-diffraction data could be obtained of the acicular inclusions, which are only 10 × 100 micrometers in size, but relatively unaltered material from the fracture filling gave the diffraction lines listed in Table 4. The pattern is similar to that of β-Mg<sub>2</sub>(OH)<sub>3</sub>Cl (PDF 12-410), an orthorhombic phase. Further definition must await new sampling, which will be possible once the newly discovered mineralized area is exploited.

Four chlorine-bearing silicates were recognized. Electron-microprobe data are given in Table 5. A tentative identification is mainly based on these measurements. Pyrosmalite is the most common of these gangue minerals. It usually surrounds magnetite and is optically characterized by high birefringence and a fibrous habit. The ideal formula of pyrosmalite is (Fe,Mn)<sub>8</sub>Si<sub>6</sub>O<sub>15</sub>(OH,Cl)<sub>10</sub>.

Mica is commonly intergrown with pyrosmalite. In some cases it seems to form epitaxial layers on pyrosmalite. The mica is pale yellow to deep green and seems to be a phlogopite with the ideal formula K<sub>2</sub>(Fe,Mn)<sub>6</sub>(Si,Al)<sub>8</sub>O<sub>20</sub>(OH,Cl)<sub>4</sub>.

The silicate labeled sepiolite occurs in the form of acicular inclusions in the sulfide matrix. The inclusions measure about 100 × 5-20 μm. The atomic proportions given in Table 5 are in good agreement with the ideal formula (Fe,Mn)<sub>4</sub>Si<sub>6</sub>O<sub>16</sub>•7H<sub>2</sub>O. The mineral is thought to be an iron-rich analogue of sepiolite Mg<sub>4</sub>Si<sub>6</sub>O<sub>16</sub>•7H<sub>2</sub>O. X-ray data have not yet been obtained.

The mineral tentatively called grunerite was identified as an amphibole by X-ray diffraction. The present material appears to be rich in ferric iron and is close to ideal (Fe,Mn)<sub>7</sub>(Si,Fe)<sub>8</sub>O<sub>22</sub>(OH,Cl)<sub>2</sub>.

A manganese-rich garnet with 29.9% MnO also was observed. It is a fairly common inclusion in the sulfide matrix. It contains 72 mol.% spessartine, 4% grossularite and 24% almandine.

Although the previous identifications are tentative, they demonstrate nevertheless the unusual minerals in the gangue. Further study is planned when production material becomes available.

## DISCUSSION

The unusual mineral content of the Deep Copper Zone has implications both for the processing of the ore and for further exploration. The precious metal content is considerably higher than in the main Strathcona orebody. *PGE* contents of more than 10 ppm have been measured. In order to recover the *PGE* values, new milling procedures are being developed. A treatment separate from the regular ore is being envisaged to avoid losses through pyrrhotite tailings.

The chlorine content of the ore is expected to lead to increased chlorine contents in the water circulating in the mine. There are already indications of this change. Accelerated corrosion of metallic fixtures and, hence, higher maintenance costs are anticipated.

The high copper content and the presence of chlorine minerals have led to speculation that the ore of the Deep Copper Zone was formed by a unique process that is different from the formation of the main Sudbury ore. Hydrothermal fluids appear to have played a role in the genesis of this interesting deposit. This conclusion raises questions about ore that may conceivably occur even farther away from the footwall contact of the Sudbury Igneous Complex.

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