TARGET CHARACTERIZATION OF FOOTWALL CU-(Ni)-PGE DEPOSITS, SUDBURY

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Targeted Geoscience Initiative 3
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INTRODUCTION

The beginning of this century witnessed the introduction of a new deposit style for the traditional Ni-Cu Sudbury mining camp. These "footwall" deposits provided a new challenge for exploration in Canada's premier base metal camp. Methodology under development at the GSC in partnership with academia and industry include indicator mineral, indicator till and bedrock halogen (F,Cl,Br,I) studies for use in the search for Cu-(Ni)-PGE deposits.

Results of a comprehensive study of the orebodies in Sudbury focussing on the vein and low sulphide-high PGE footwall Cu- (Ni)- Pt-Pd-Au mineralization are presented. The mineral chemical and bulk compositional signatures of the sulphide and low-sulphide targets were studied for ~ 6 deposits and occurrences across the North Range of the Sudbury Structure (Figs. 1, 2) from ~130 Footwall ore samples.

RESEARCH TEAM

Doreen Ames, Beth McClenaghan, Judy Vaive, Paul Gammon (GSC)
Ingrid Kjarsgaard (mineralogist)
Jacob Hanley (SMU/ETH)
FNX, Vale-Inco, Wallbridge personnel (Industry)

Students
Gabriela Budulan (Ottawa U, Queen's U): Broken Hammer till study
Craig Stewart (St. Mary's U): Halogens (F, Cl, Br, I) in FWBX plume environment, Windy Lake & Levack embayments.

FOOTWALL STUDY AREAS

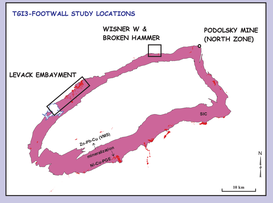


Fig. 1a) Location of study areas in TGI3- Deep Search method development in the Sudbury mining camp.

Footwall Environment
Cu-(Ni)-PGE mineralization spectrum

(after Farrow et al., 2005)

a) Vein deposit) (Broken Hammer, McCreedy Et-153 zone, Levack FW

b) Low sulphide-high PGE Footwall deposit?) (McCreedy W-PM zone, Wisner W, lower Levack

c) Hybrid (North zone-Podolsky deposit)

(Ores studied for TGI3 indicator mineral project)

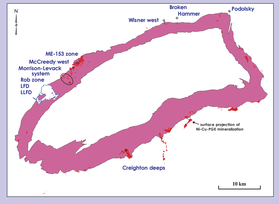


Fig. 1b) Deposit locations in study.

Broken Hammer Cu - (Ni) - PGE footwall resource: Indicator minerals of the resource include chalcopyrite, pyrite, sperrylite ($PtAs_2$) and gold. Sn-bearing indicator minerals found in bedrock samples include cassiterite (SnO_2). Pathfinder elements in the till geochemistry included: Cu, Pt, Pd, Au, Ni, Cd, Sb, Bi, and Te.

LEVACK - MORRISON
Ni-Cu-Pt-Pd-Au ORE SYSTEM

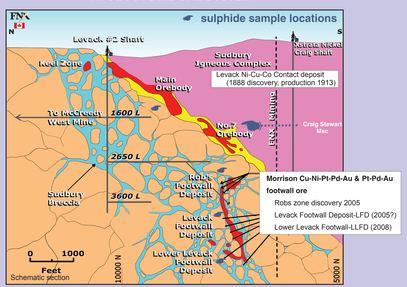


Fig. 2a) Schematic longitudinal section showing 2005-2008 ore sample locations (modified from FNX, Ames and Farrow, 2007).

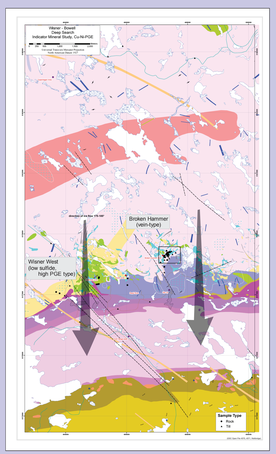


Fig. 2b) Geology map of Wisner West and Broken Hammer showings bedrock and till sample locations for the TGI3 indicator mineral study (base modified from Ames et. al., 2005).

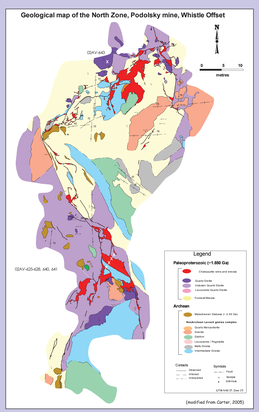
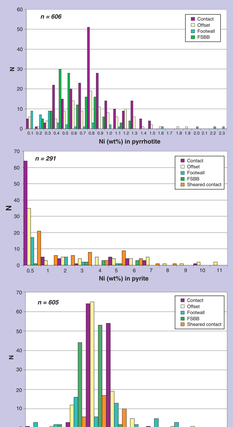


Fig. 2c) Surface exposure of chalcopyrite-PGM vein, North zone, Podolsky mine, Whistle Offset. Sample location map (modified from Carter, 2005).

MINERALOGY OF NORTH RANGE CU-(NI)-PGE DEPOSITS

Table 1. Ore Mineralogy of Footwall Cu-(ni)-PGE mineralization, North Range Sudbury

	Ore Mineral	Formula		Ore Mineral	Formula
Sulphides			*Oxides*		
1.	**Argentopentlandite**	$(Fe,Ni,Ag)_9S_8$	37.	**Cassiterite**	SnO_2
2.	**Benjaminite?**	$(Ag,Cu)_3Bi_7S_{12}$	38.	**Cuprite**	Cu_2O
3.	**Bornite**	Cu_5FeS_4	39.	**Magnetite**	$FeFe_2O_4$
4.	**Chalcopyrite**	$CuFeS_2$	40.	**Hematite**	Fe_2O_3
5.	**Covellite**	CuS	41.	**Tellurite**	TeO_2
6.	**Cubanite**	Cu_2FeS_4	*Tellurides*		
7.	**Digenite**	$Cu_{1.8}S_2$	42.	**Altaite**	PbTe
8.	**Emplectite**	$CuBiS_2$	43.	**Froodite**	$PdBi_2$
9.	**Galena (Se)**	Pb(S,Se) ±Bi, Ag	44.	**Hessite**	Ag_2Te
10.	**Gersdorffite**	(Ni,Co,Fe)AsS	45.	**Kotulskite**	Pd(Bi,Te)
11.	**Hauchecornite**	$Ni_9Bi_2S_8$	46.	**Maslovite**	PtBiTe
12.	**Heazelwoodite**	Ni_3S_2	47.	**Melonite**	NiTe
13.	**Mackinawite**	$(Fe,Ni)_9S_8$	48.	**Pd-melonite**	(Ni, Pd)Te
14.	**Marcasite**	FeS_2	49.	**Merenskyite**	$(Pd,Pt)(Te,Bi)_2$
15.	**Mathildite (Se)**	$AgBi(S,Se)_2$	50.	**Cu-merenskyite**	??
16.	**Millerite**	NiS	51.	**Michenerite**	PdBiTe
17.	**Nickeline**	NiAs	52.	**Moncheite**	$Pt(Te,Bi)_2$
18.	**Parkerite**	$Ni_3Bi_2S_2$	53.	**Sobolevskite**	PdBi
19.	**Pentlandite**	$(Ni,Fe)_9S_8$	54.	**Stützite**	Ag_5Te_4
20.	**Polydymite**	$NiNi_2S_4$	55.	**Tsumoite**	BiTe
21.	**Pyrite**	$(Fe,Co,Ni)S_2$	56.	***unknown***	$(Bi,Ag)_2Te_4$
22.	**Pyrrhotite**	$Fe_{1-x}S$	*Stannides*		
23.	**Siegenite**	$(Ni,Co)_3S_4$	57.	**Oulankite**	Pt_2PdSn
24.	**Sphalerite**	ZnS	58.	**Paolovite**	Pd_2Sn
25.	**Spionkopite**	$Cu_{39}S_{28}$	59.	**Niggliite**	PtSn
26.	**Tetradymite**	Bi_2Te_2S	*Other precious minerals*		
27.	**Troilite**	FeS	60.	**Sperrylite**	$PtAs_2$
28.	**ullmanite**	NiSbS	61.	**Silver**	Ag
29.	**Violarite**	$FeNi_2S_4$	62.	**Electrum**	Ag:Au
30.	**Witticheinite**	Cu_3BiS_3	63.	**Gold**	Au:Ag
31.	***unknown***	$CuBiPdS_3$			
32.	***unknown***	$(AgCuFe)_3S_2$			
Selenides					
33.	**Bohdanowiczite**	$AgBiSe_2$			
34.	**Clausthalite**	PbSe			
35.	**Kawazulite**	Bi_2Te_2Se			
36.	**Naumannite**	Ag_2Se		n=668 analyses, 58 samples	



Pyrrhotite: Both contact and offset deposits display a normal distribution for the Ni content of pyrrhotite in the mining camp with a median Ni content of 0.71 and 0.76 wt% Ni, respectively. Pyrrhotite from the Frood-Stobie deposits show a negative trend with a median Ni content of 0.46 while pyrrhotite in Footwall deposit types contain the least Ni at 0.26 wt% Ni.

Pentlandite: The nickel content is variable with up to 43.6 wt% Ni, avg. 35 wt% Ni in pentlandite. Argentopentlandite with 12-13 wt% Ag in pentlandite was found in the Creighton deeps (403 orebody), McCreedy W (PM zone) and McCreedy E (153 zone) orebodies. Victoria and Crean Hill deposits rarely contain Ag-bearing pentlandite with 1-3.9 wt% Ag. Pn is also a significant carrier of Co (1-3.5 wt%, avg. 1 wt%Co), minor Sn, Au and Hg.

Pyrite: Sudbury pyrite contains a significant Ni content (avg. 1.54 wt% Ni, n=291), trace Pt, Au, Hg and Pb.

FSBB: Frood-stobie breccia belt.

Fig. 3). Deposit type variations in the Ni content of the main sulphide minerals.

MINERAL CHEMISTRY HIGHLIGHTS

Precious minerals

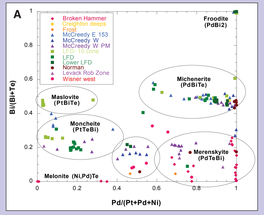


Fig. 4a) Bismuth telluride minerals are the major residence site for Pt and Pd in deposits in the footwall environment on the North range.

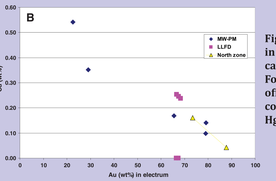


Fig. 4b) Trace elements in electrum include cadmium and mercury. Footwall and some offset deposits may contain up to 8 ppm Hg, avg. 2 ppm Hg.

Silicate minerals

Nickel is found in epidote, stilpnomelane, biotite, and chlorite within Footwall alteration assemblages.

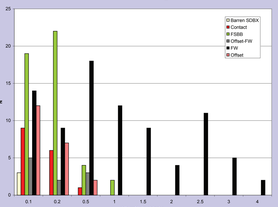


Fig. 6) **Chlorite:** The nickel content of chlorite is highest in the Footwall type deposits relative to the other Sudbury Ni-Cu-PGE deposit types. Footwall vein and low sulphide high PGE mineralization contains chlorite with up to 3.6 wt% Ni, averaging 0.15 wt% Ni compared to chlorite mineral chemistry from the Contact and Offset deposits.

Sphalerite mineral chemistry

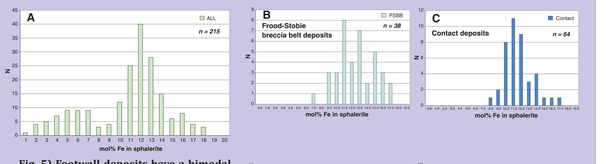


Fig. 5) Footwall deposits have a bimodal distribution of sphalerite chemistry with low-Fe sphalerite (~ 4 mol% Fe) and high Fe sphalerite (~11 mol% Fe) which is more typical of the contact and offset type deposits. These variations in sphalerite chemistry are variable within one deposit (i.e. LFD, ME-153 and MW-PM deposits).

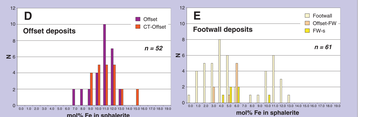


Fig. 7) **Biotite:** Similar to chlorite, biotite contains trace Ni but in lower amounts. Footwall biotite grains typically contain up to 1 wt% however concentrations up to 2.5 wt% Ni are found.

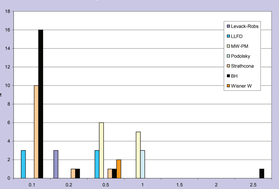


Table 2: Silicate mineralogy of Footwall Cu-(Ni)-PGE mineralization, North Range Sudbury

	Mineral	n (analyses)
1.	Al-celadonite	8
2.	Allanite	5
3.	Amphibole	52
4.	Anthophyllite(Mn)	1
5.	Berthierine ?	6
6.	Biotite	55
7.	Chlorite	108
8.	Diopside	6
9.	Epidote	124
10.	Ferropyrosmalite	1
11.	K-feldpsar	5
12.	Orthopyroxene	1
13.	Sericite	5
14.	Stilpnomelane	1
15.	Talc	1
16.	Titanite	62
17.	Apatite	77
18.	Rutile	2
19.	*unidentified*	17
	Electron microprobe analyses	n=537

IMPLICATIONS FOR INDICATOR MINERALS

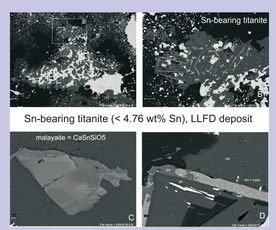


Fig. 8) **Malayaite - the tin analog of titanite was identified in the lower Levack Footwall Deposit in 2008.**
It occurs in an alteration assemblage with chlorite pseudomorphous after magnetite. Ilmenite lamellae within the pseudomorphs contain malayaite and or cassiterite. The Sn-bearing titanite in the LLFD "malayaite" contains up to 4.76 wt % Sn in the crystal structure and serves as an indicator mineral for Cu-(Ni)-PGE deposits in the Footwall environment.

Till and bedrock samples were processed at Overburden Drilling Management Ltd.'s heavy mineral processing lab in Ottawa to recover indicator minerals from the 3 sizes of the non-ferromagnetic heavy mineral (>3.2 specific gravity) fraction: 0.25-0.5 mm, 0.5-1.0 mm and 1.0-2.0 mm. Oxide, silicate and metallic indicator minerals were examined and counted. The till indicator mineral site survey at the Broken Hammer deposit found cassiterite, sperrylite and gold down-ice from the surface deposit. Selected grains were picked and are being analyzed using electron microprobe techniques.

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