SULPHIDE AND ALTERATION MINERAL CHEMISTRY OF LOW- AND HIGH-SULPHIDE CU-PGE-NI DEPOSITS IN THE FOOTWALL ENVIRONMENT, SUDBURY, CANADA

[1]Doreen E. Ames and [2]Ingrid Kjarsgaard

[1]Geological Survey of Canada, [2]14 Scotia Place Ottawa

Geological Survey of Canada with Provincial, and University Collaboration

TGI4 Ore Systems

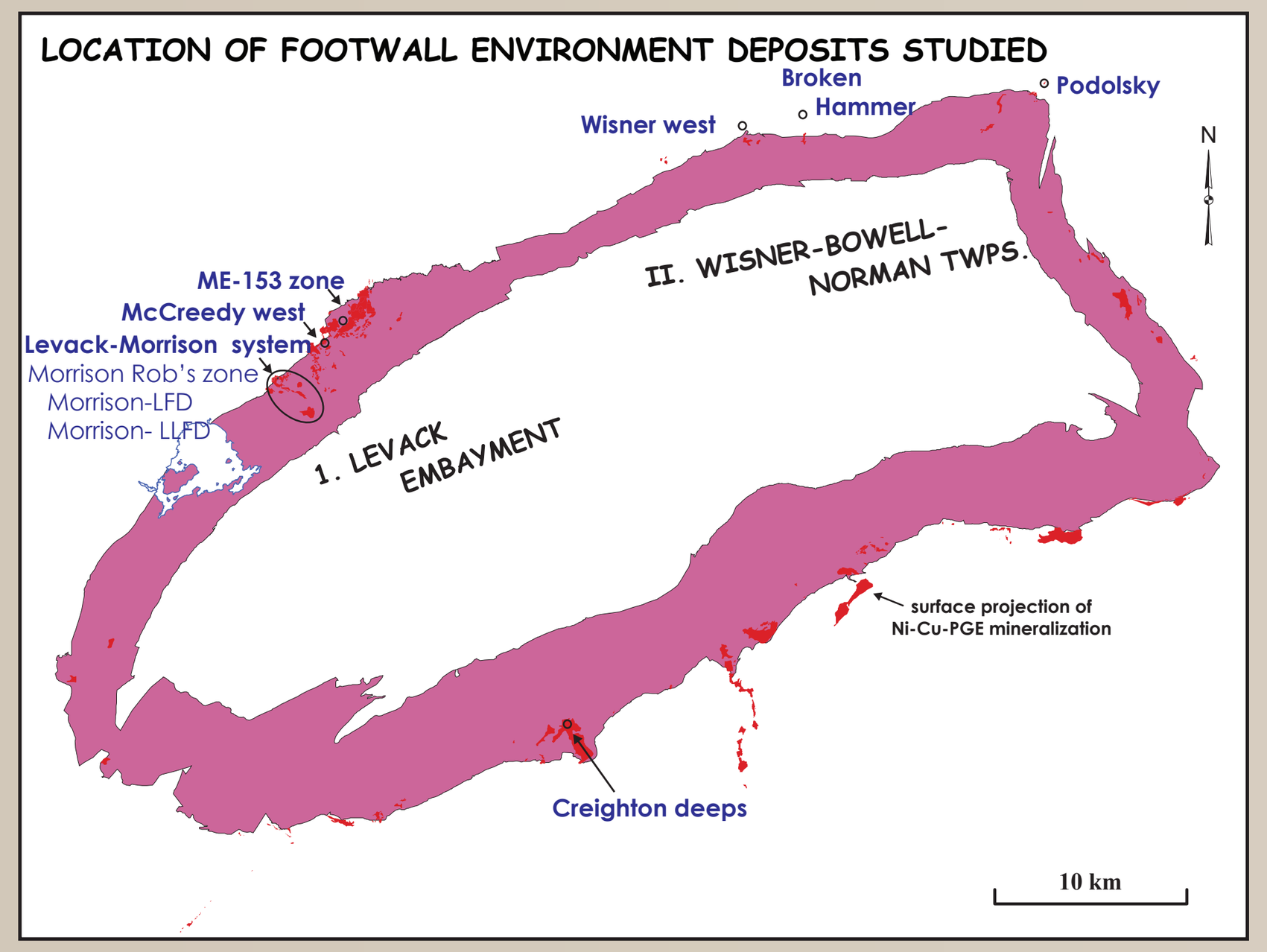
Ni-Cu-PGE-Cr Project

INTRODUCTION

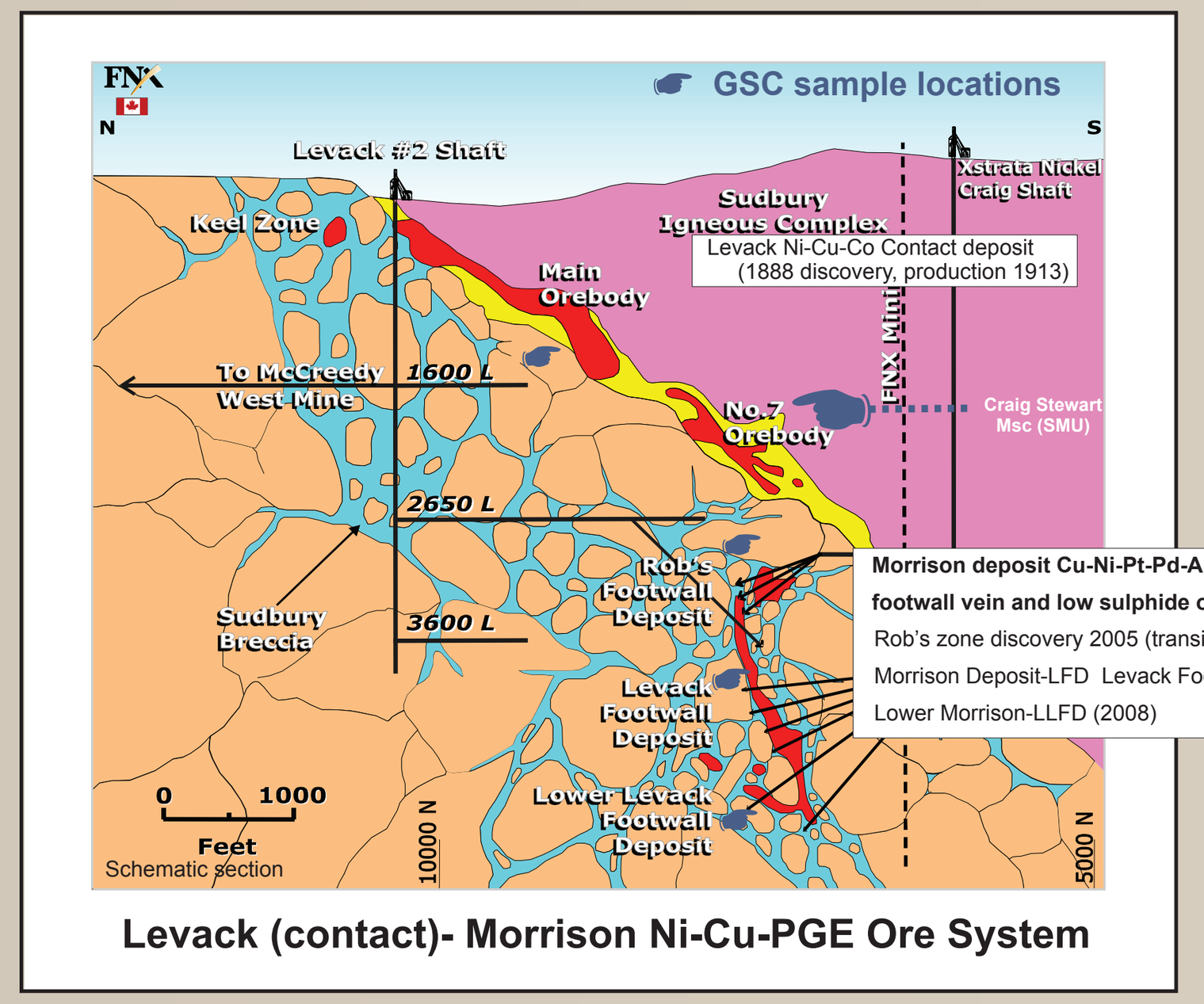
The beginning of this century witnessed the introduction of a new deposit style for the traditional Ni-Cu Sudbury mining camp. These "footwall" deposits provided a new challenge for exploration in Canada's premier base metal camp. Methodology is under development in the fourth Targeted Geoscience Program (TGI4) for the identification of distinct mineral chemical signatures to define robust tools to effectively explore for the lucrative deep footwall environment mineral resources.

Mineralogical, trace element and stable isotope results of a comprehensive study of the Ni-Cu-PGE orebodies in Sudbury are presented with emphasis on the Footwall vein and low sulphide-high PGE mineralization. The mineral chemical and bulk compositional signatures of the sulphide and low-sulphide targets were studied for ~ 6 Cu-(Ni)-Pt-Pd-Au deposits and occurrences across the North Range of the Sudbury Structure from over 200 footwall ore and wall rock alteration samples. This poster presents results that define the mineral composition of these magmatic-hydrothermal orebodies and their alteration footprint.

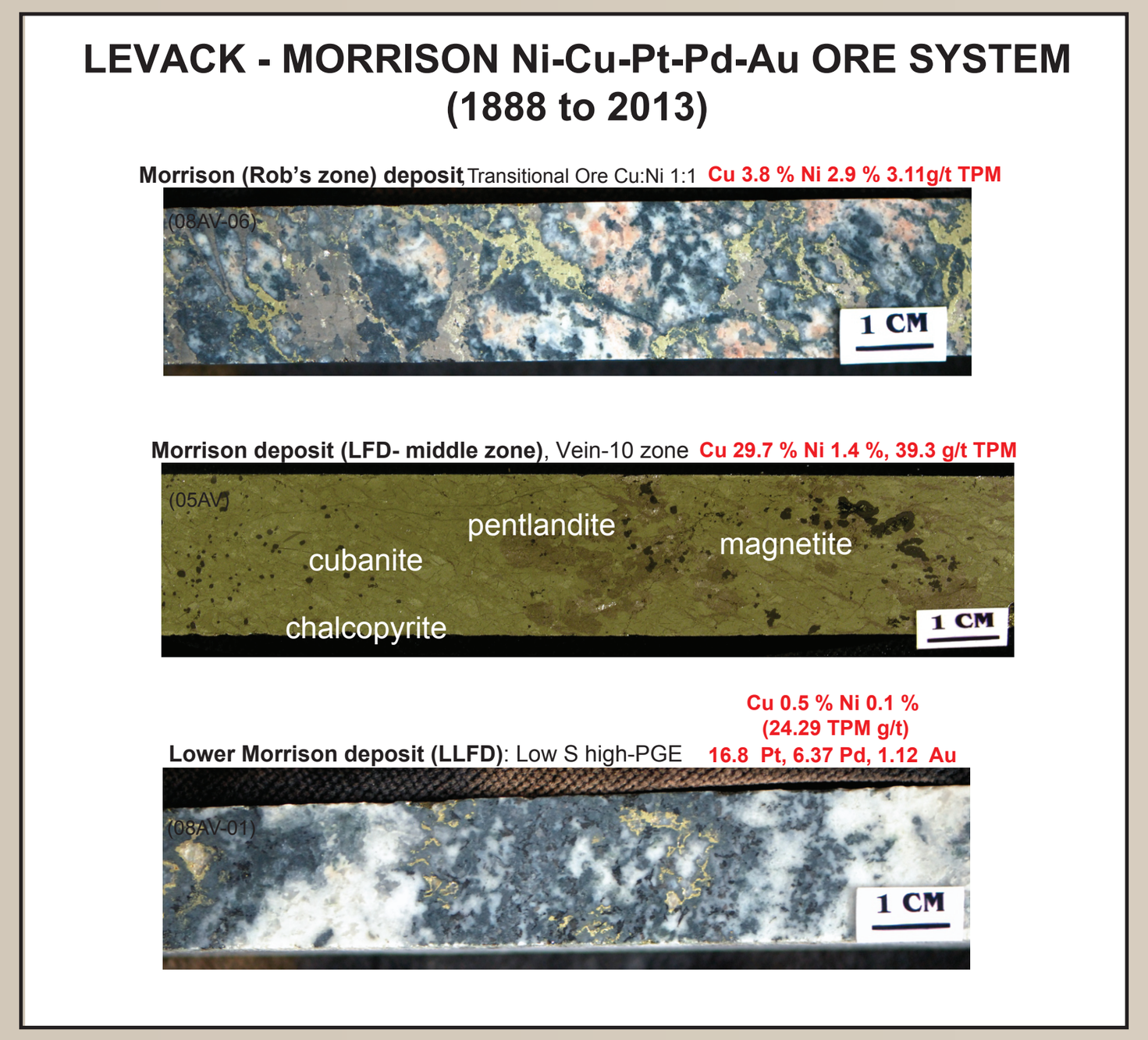
TGI4 FOOTWALL DEPOSIT STUDY AREAS



Location map of Footwall Cu-(Ni)-PGE mineralization deposits and occurrences analyzed mineralogically and sulphide geochemistry in the Sudbury mining district.



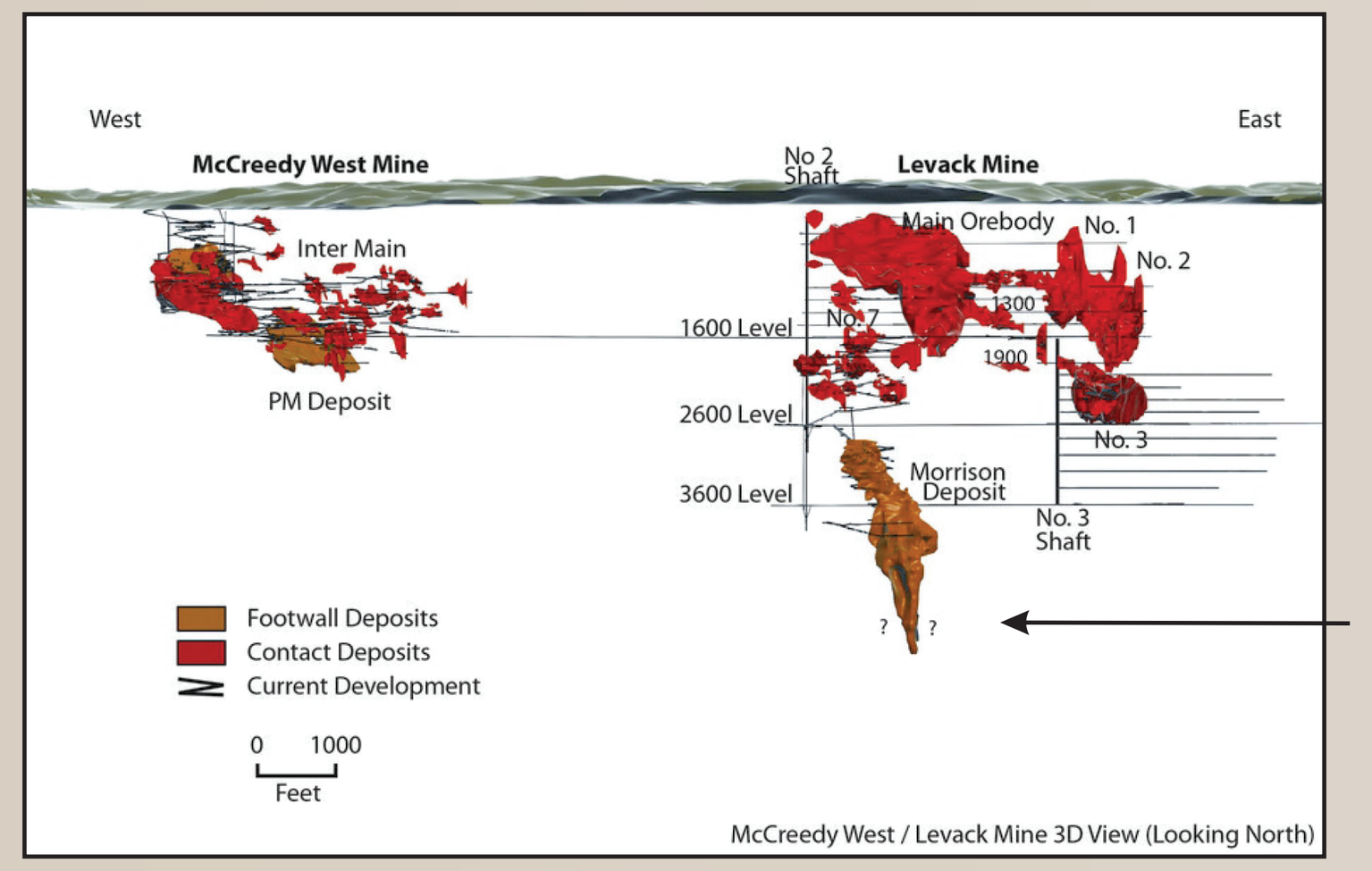
Schematic longitudinal section showing the relationship from contact Ni-Cu ore to Footwall Cu-PGE vein and Low sulphide PGE mineralization (Lower zone). Ore sample locations.



Footwall environment
Cu-(Ni)-PGE mineralization spectrum

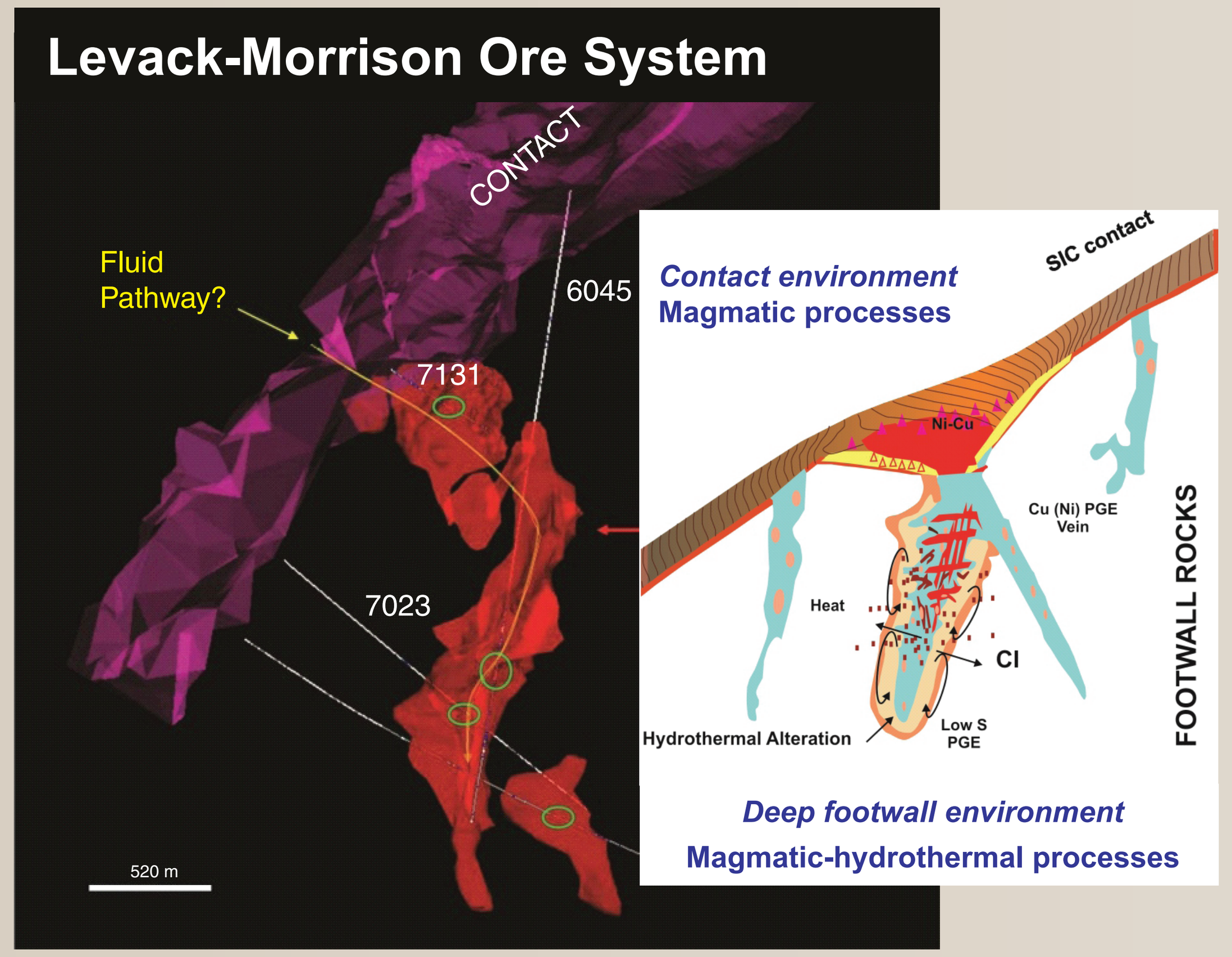
- Vein deposit (Broken Hammer veins, McCreedy E-153 zone, Morrison deposit)
- Low S-high PGE deposit (McCreedy W-PM zone, Wisner W, lower Morrison deposit)
- Hybrid deposit (North zone-Podolsky deposit, Broken Hammer)

(Footwall deposits in study)



LEVACK - MORRISON Ni-Cu-Pt-Pd-Au ORE SYSTEM (1888 to 2013)

The Levack - Morrison Ore system has a continuum of mineralization from the Ni-Cu ores at the basal contact of the SIC (Levack mine), Transitional (Ni:Cu= 1:1) orebodies of the Rob's zone, footwall Cu-PGE veins and low sulphide, PGE-rich mineralization of the lower Morrison deposit.



Processes to form the precious metal-rich Sudbury deposits include:

1) magmatic sulphide differentiation
2) hydrothermal transport and compositional modification of magmatic sulphide
3) vapour phase transport and deposition of precious-metals in the footwall environment of the SIC.

These processes are not mutually exclusive in the Ni-Cu-PGE Ore System

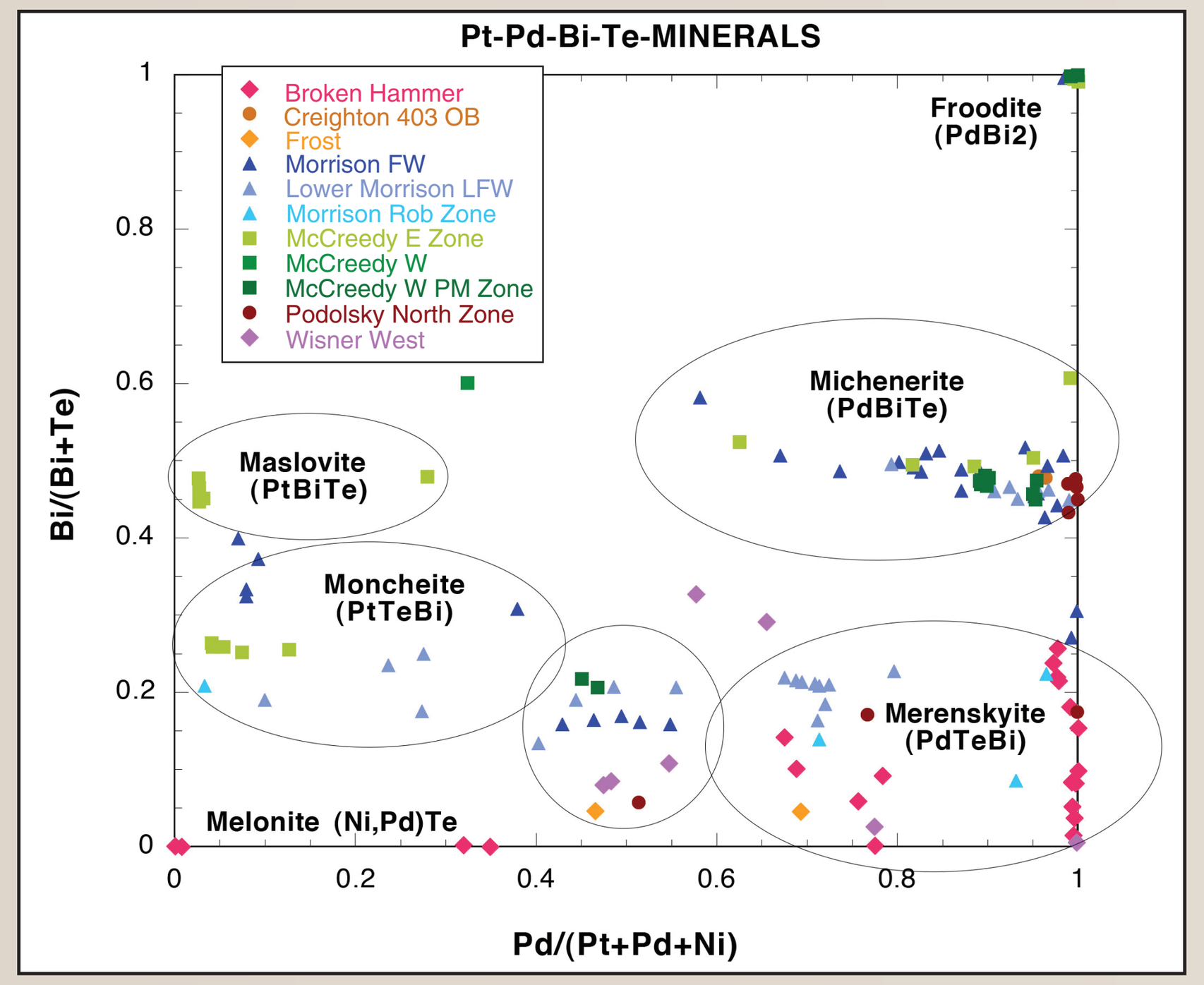
MINERALOGY OF CU-(NI)-PGE DEPOSITS

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

	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_3FeS_4			
7.	**Digenite**	Cu_5S_9	*Tellurides*		
8.	**Emplectite**	$CuBiS_2$	42.	**Altaite**	PbTe
9.	**Galena (Se)**	Pb(S,Se) ±Bi, Ag	43.	**Froodite**	$PdBi_2$
10.	**Gersdorffite**	(Ni,Co,Fe)AsS	44.	**Hessite**	Ag_2Te
11.	**Hauchecornite**	$Ni_9Bi_2S_8$	45.	**Kotulskite**	Pd(Bi,Te)
12.	**Heazelwoodite**	Ni_3S_2	46.	**Maslovite**	PtBiTe
13.	**Mackinawite**	$(Fe,Ni)_9S_8$	47.	**Melonite**	NiTe
14.	**Marcasite**	FeS_2	48.	**Pd-melonite**	(Ni, Pd)Te
15.	**Mathildite (Se)**	$AgBi(S,Se)_2$	49.	**Merenskyite**	$(Pd,Pt)(Te,Bi)_2$
16.	**Millerite**	NiS	50.	**Cu-merenskyite**	??
17.	**Nickeline**	NiAs	51.	**Michenerite**	PdBiTe
18.	**Parkerite**	$Ni_2Bi_2S_2$	52.	**Moncheite**	$Pt(Te,Bi)_2$
19.	**Pentlandite**	$(Ni,Fe)_9S_8$	53.	**Sobolevskite**	PdBi
20.	**Polydymite**	$NiNi_2S_4$	54.	**Stützite**	Ag_7Te_4
21.	**Pyrite**	$(Fe,Co,Ni)S_2$	55.	**Tsumoite**	BiTe
22.	**Pyrrhotite**	$Fe_{1-x}S$	56.	***unknown***	$(Bi,Ag)_3Te_4$
23.	**Siegenite**	$(Ni,Co)_3S_4$			
24.	**Sphalerite**	ZnS	*Stannides*		
25.	**Spionkopite**	$Cu_{39}S_{28}$	**57.**	**Oulankite**	PtPdSn
26.	**Tetradymite**	Bi_2Te_2S	**58.**	**Paolovite**	Pd_2Sn
27.	**Troilite**	FeS	**59.**	**Niggliite**	PtSn
28.	**ullmanite**	NiSbS			
29.	**Violarite**	$FeNi_2S_4$	*Other precious minerals*		
30.	**Wittichenite**	Cu_3BiS_3	**60.**	**Sperrylite**	$PtAs_2$
31.	***unknown***	$CuBiPdS_3$	**61.**	**Silver**	Ag
32.	***unknown***	$(AgCuFe)_3S_2$	**62.**	**Electrum**	Ag:Au
			63.	**Gold**	Au:Ag
Selenides					
33.	**Bohdanowiczite**	$AgBiSe_2$			
34.	**Clausthalite**	PbSe			
35.	**Kawazulite**	Bi_2Te_2Se			
36.	**Naumannite**	AgSe	n=668 analyses, 58 samples		

Precious minerals
Deposit type variations and trace elements

Sudbury PGMs mainly bismuth tellurides.
PGE associations with As (South Range) and Sn (North Range)
reflect contributions from local country rocks into the initial melt.



Bismuth telluride minerals and sperrylite (PtAs2), although significant locally is less common in the North Range Footwall deposits.

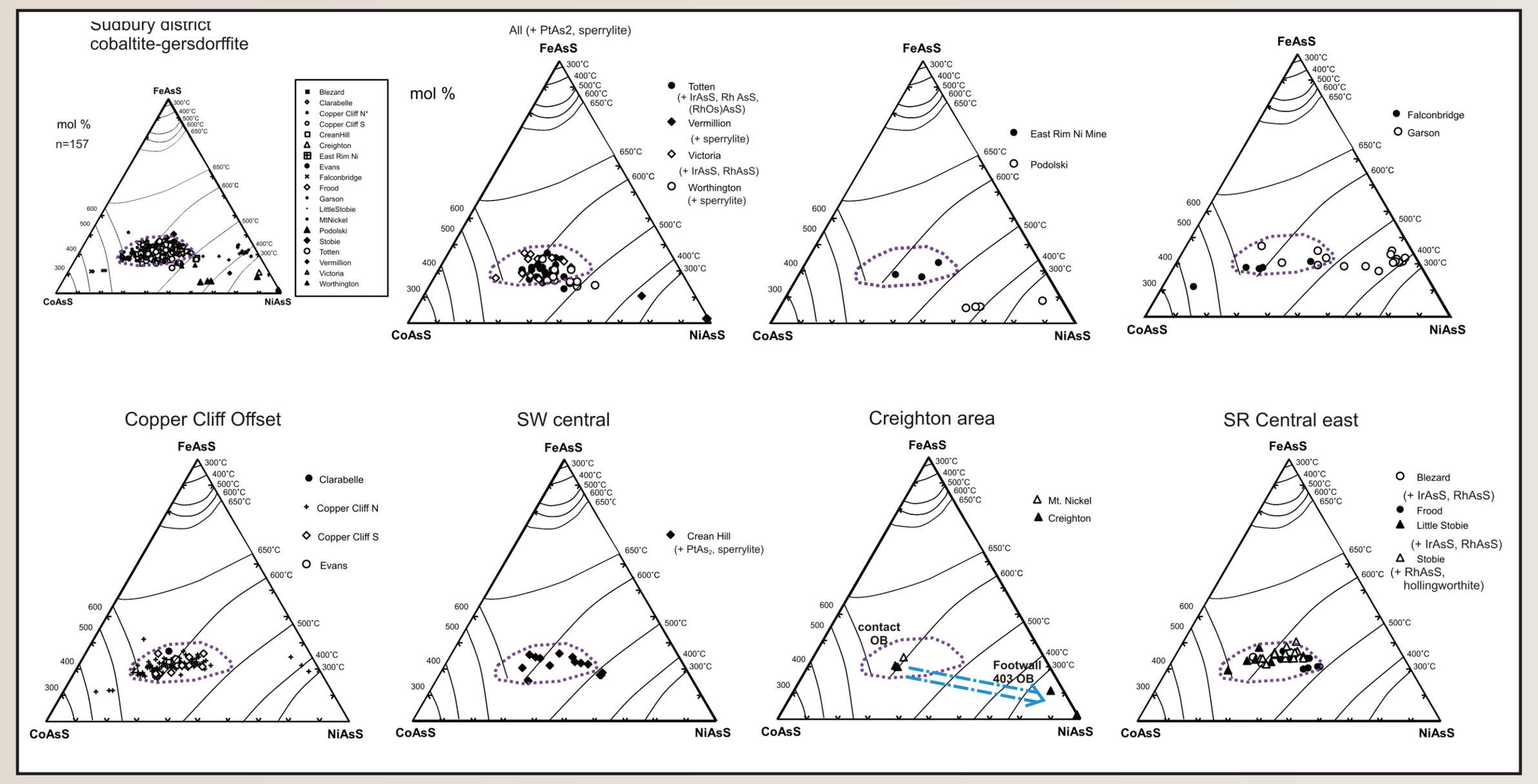
Tin also bonds with Pt and Pd in four PGE-bearing stannide and oxide minerals that are found only in North Range footwall deposits.

Cassiterite (SnO2) associated with other high fO2 assemblages (ie. Specular hematite), serves as a good robust indicator mineral for the low sulphide precious metal deposits along with sperrylite (PtAs2).

Cobaltite-gersdorffite solid solution, a dominant South Range ore mineral, is not only a major host of Pd (~23%; Cabri, 1981) but is associated with Pt, Ir, Ru and Rh arsenides and other PGMs. In this diagram, isotherms define the upper limit of immiscibility from 300-650°C (Klemm, 1965) and show a range of exsolution and solidification temperatures in various deposit environments.

Most Sudbury sulpharsenides crystallized at high temperatures (500- 600°C) although low crystallization temperatures are evident at the Creighton footwall 403 orebody relative to the contact orebody deposit and SE range tectonically modified deposits.

Arsenic was incorporated into the melt early and precipitated as a magmatic mineral phase.



ALTERATION MINERALOGY EPIDOTE AND OTHER SILICATE MINERALS

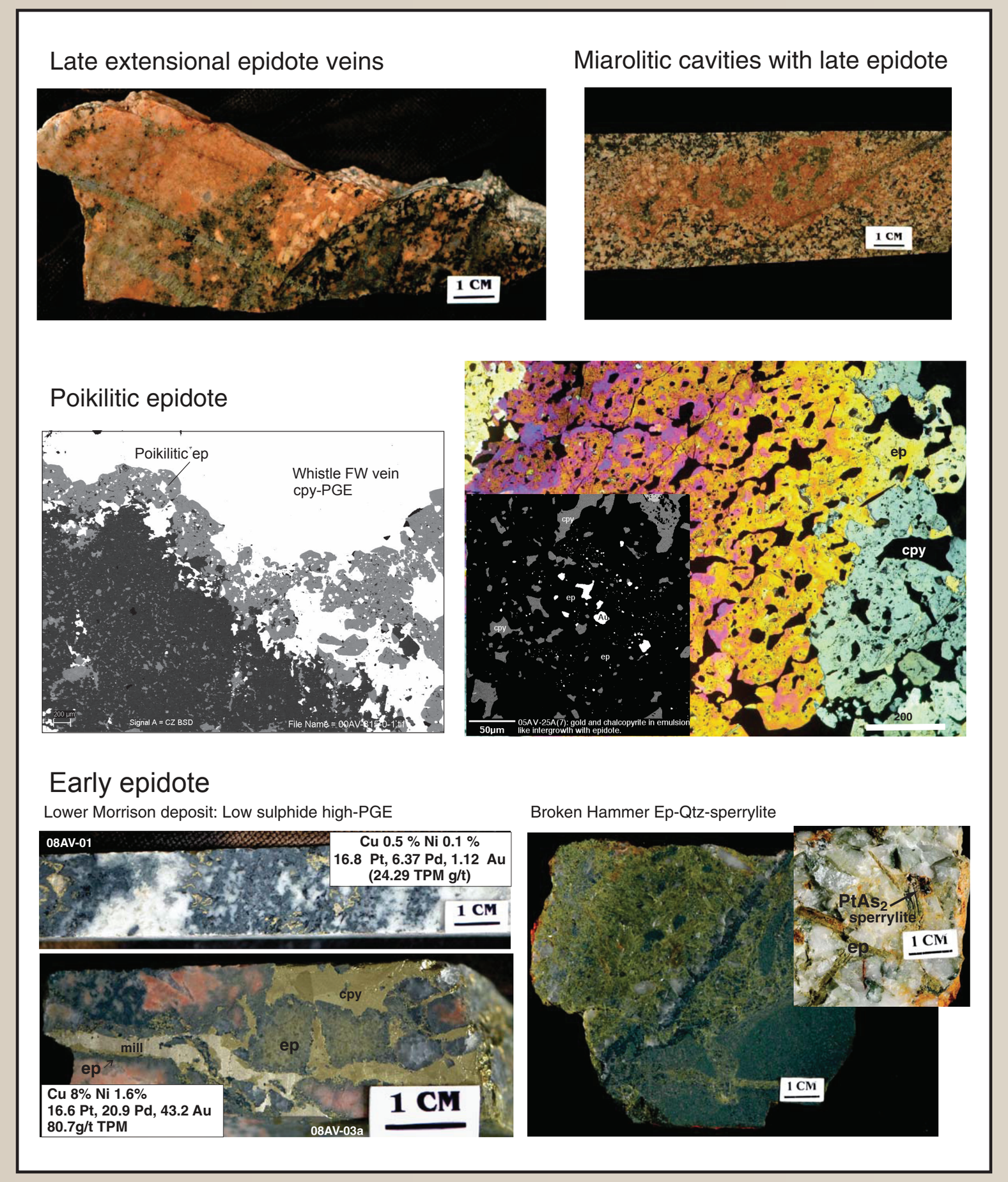
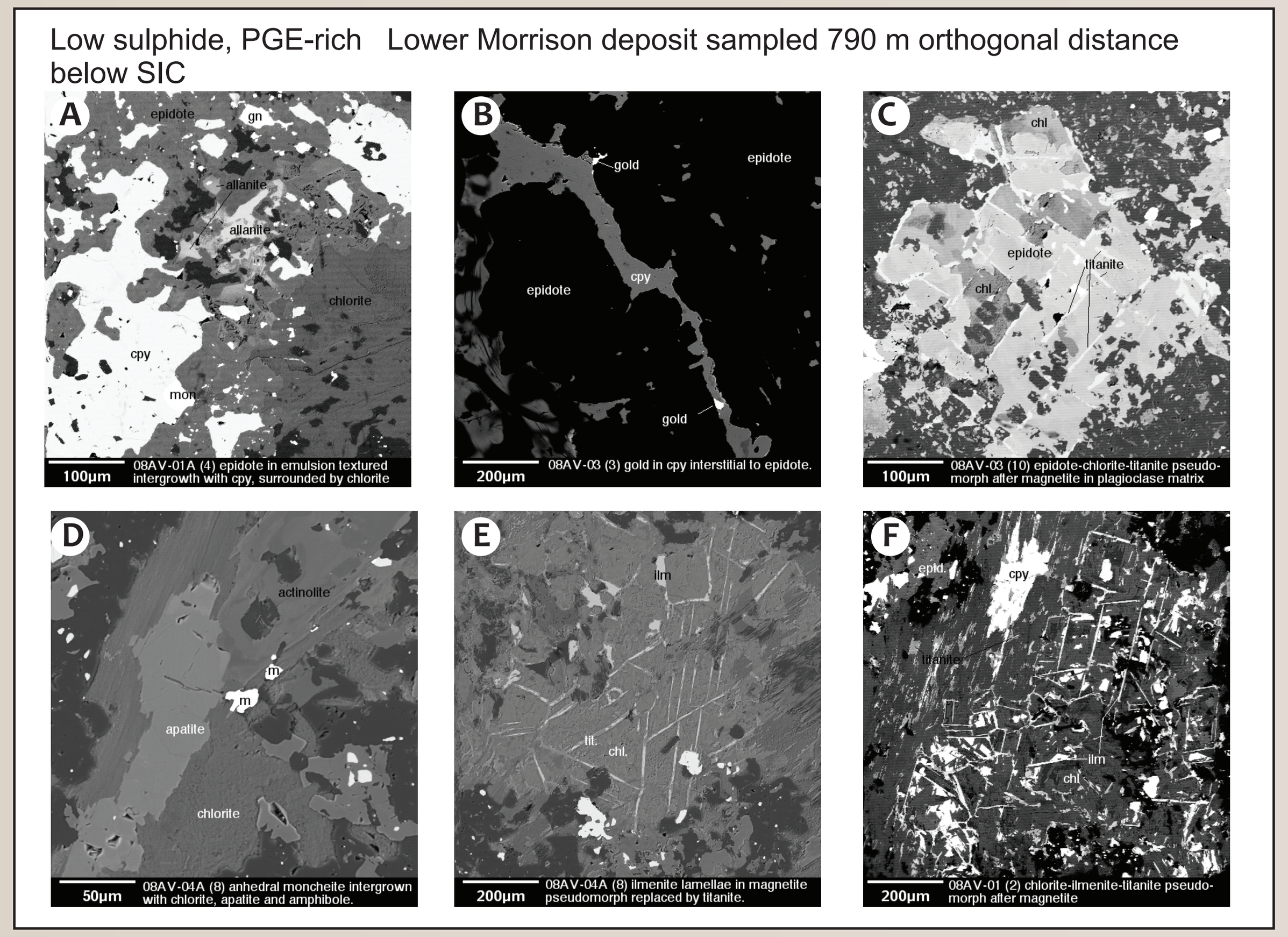


Figure 3: Polished rock slabs showing the textural styles of epidote within fertile and barren parts of the Sudbury Ni-Cu-PGE ore system.

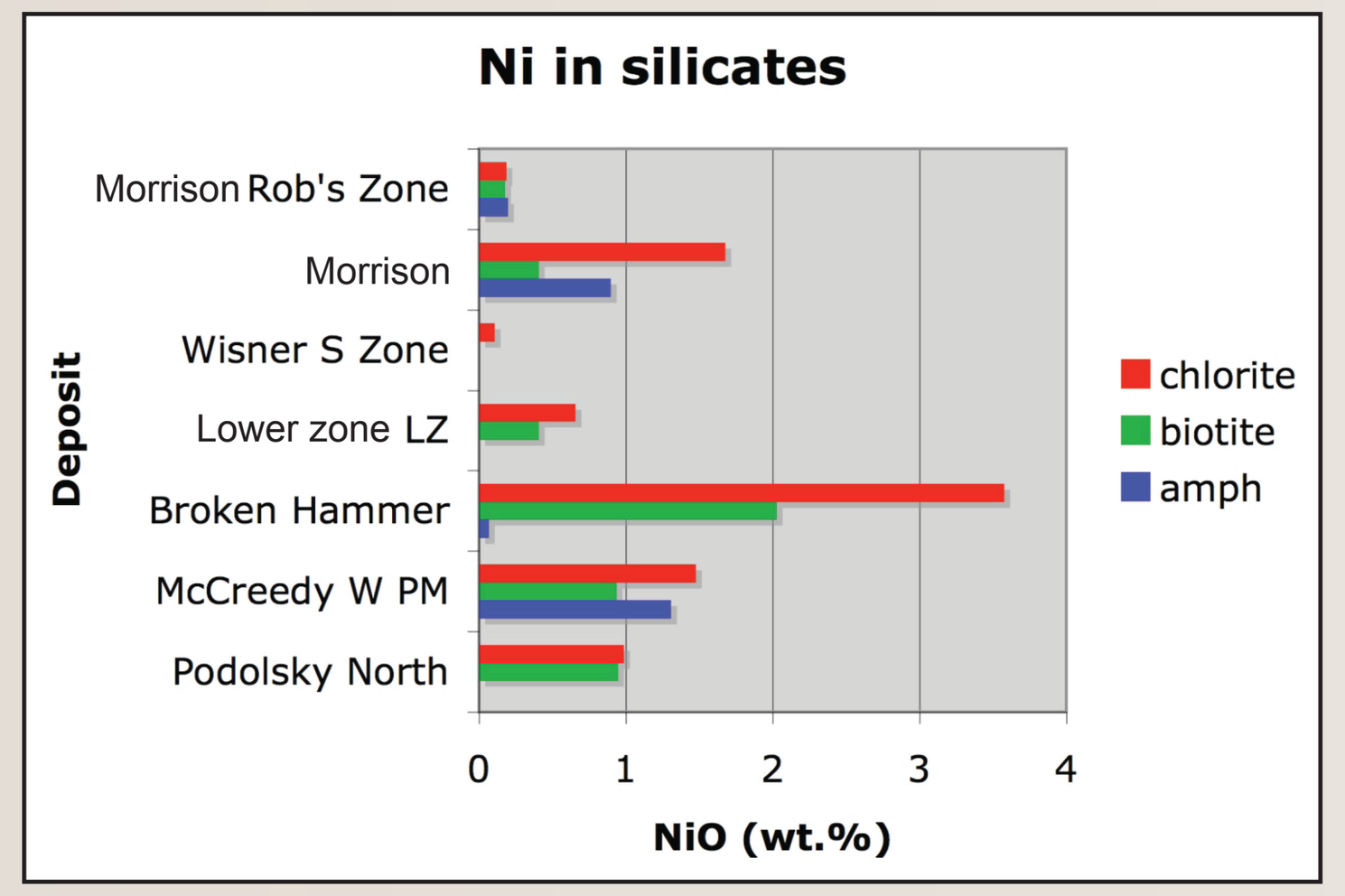
Low sulphide-high PGE mineralization is associated with the typical greenshist hydrothermal alteration assemblage:

Epidote-qtz-albite-chl-titanite-allanite +/- act, calcite



Representative SEM backscatter photos of textures and mineral associations in PGE S-poor mineralization reflecting oxidizing conditions. Tin is a robust indicator element along with Co, Ni and Pb.

- An epidote-Ni chlorite- titanite assemblage hosts Cu, Pt and Au bearing minerals (A-D).
- Primary magnetite is replaced by hydrothermal chlorite (E, F) +/- epidote with relict ilmenite lamellae replaced by titanite, malayaite (Sn analog of Ttn) and cassiterite (SnO_2).



Nickel is found in epidote, stilpnomelane, biotite, and chlorite Ni content is highest in chlorite within the Footwall alteration assemblages.

Chlorite>> Biotite>> Amphibole

References

Cabri, L.J., 1981. The platinum group minerals, in Cabri, L.J. (ed), Platinum-Group Elements: Mineralogy, Geology, Recovery: Canadian Institute of Mining and Metallurgy, v. 23, p. 136-138.

Klemm, D.D., 1965. Synthesen und Analysen in den Dreiechdiagrammen FeAsS-CoAsS-NiAsS und FeS2-COS2-NiS2; Neues Jahrbuche fuer Mineralogie, Abhandlungen, v. 103, p. 205-255.

Available from

This publication is available for free download through GEOSCAN (http://geoscan.ess.nrcan.gc.ca/).

Recommended Citation

Ames, D.E., Kjarsgaard, I.M., 2013. Sulphide and Alteration Mineral Chemistry of Low- and High-sulphide Cu-PGE-Ni Deposits in the Footwall Environment, Sudbury, Canada: Geological Survey of Canada, Open File 7331, poster. doi:10.4095/292707

OPEN FILE
DOSSIER PUBLIC
7331
GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA
2013

Publications in this series have not been edited; they are released as submitted by the author.

Les publications de cette série ne sont pas révisées; elles sont publiées telles que soumises par l'auteur.