



GEM

Indicator Mineral Signatures of Base Metal Deposits: Examples From TGI3 and GEM Research

Mineral Exploration Roundup 2011
January 25, 2011



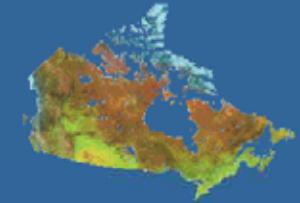
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Base Metal Indicator Minerals



Authors:

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- Mike Parkhill, *New Brunswick Dept of Natural Resources*
- Gaywood Matile, *Manitoba Geological Survey*



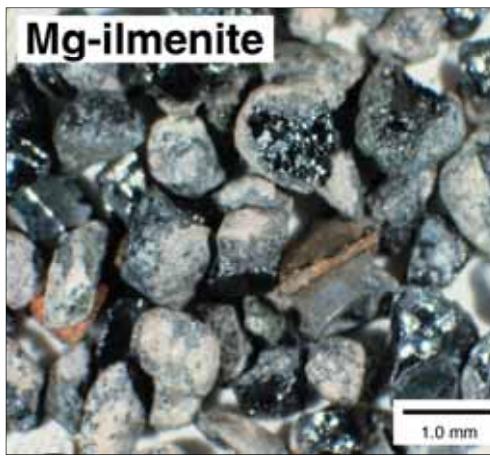
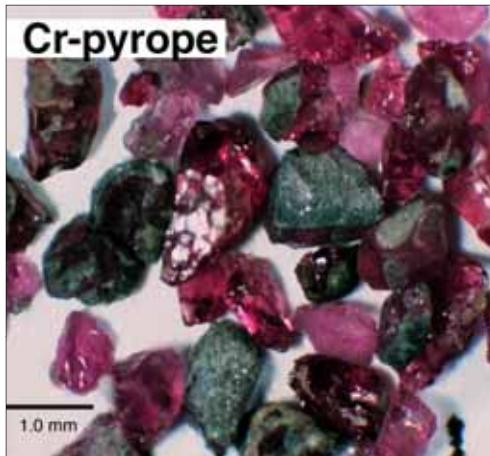
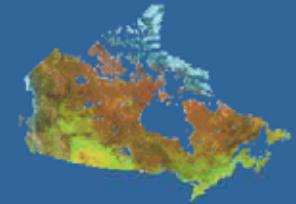
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Kimberlite Indicator Minerals



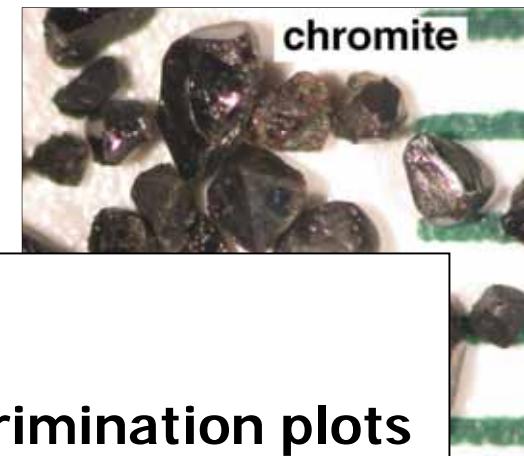
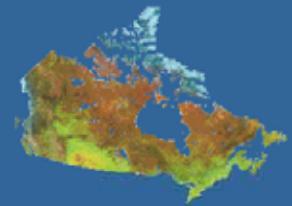
McClenaghan & Kjarsgaard, 2007



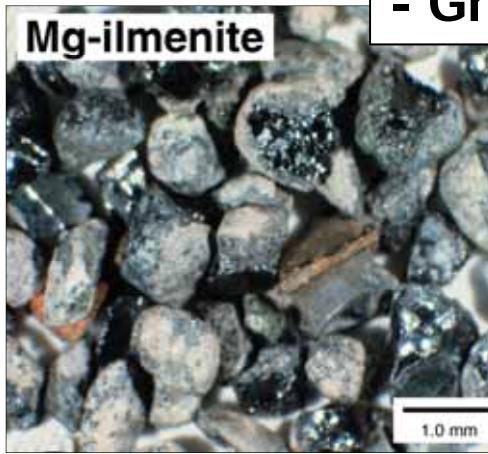
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- Mineral species
- Mineral abundance
- Mineral chemistry/discrimination plots
- Grain shape, textures



McClenaghan & Kjarsgaard, 2007



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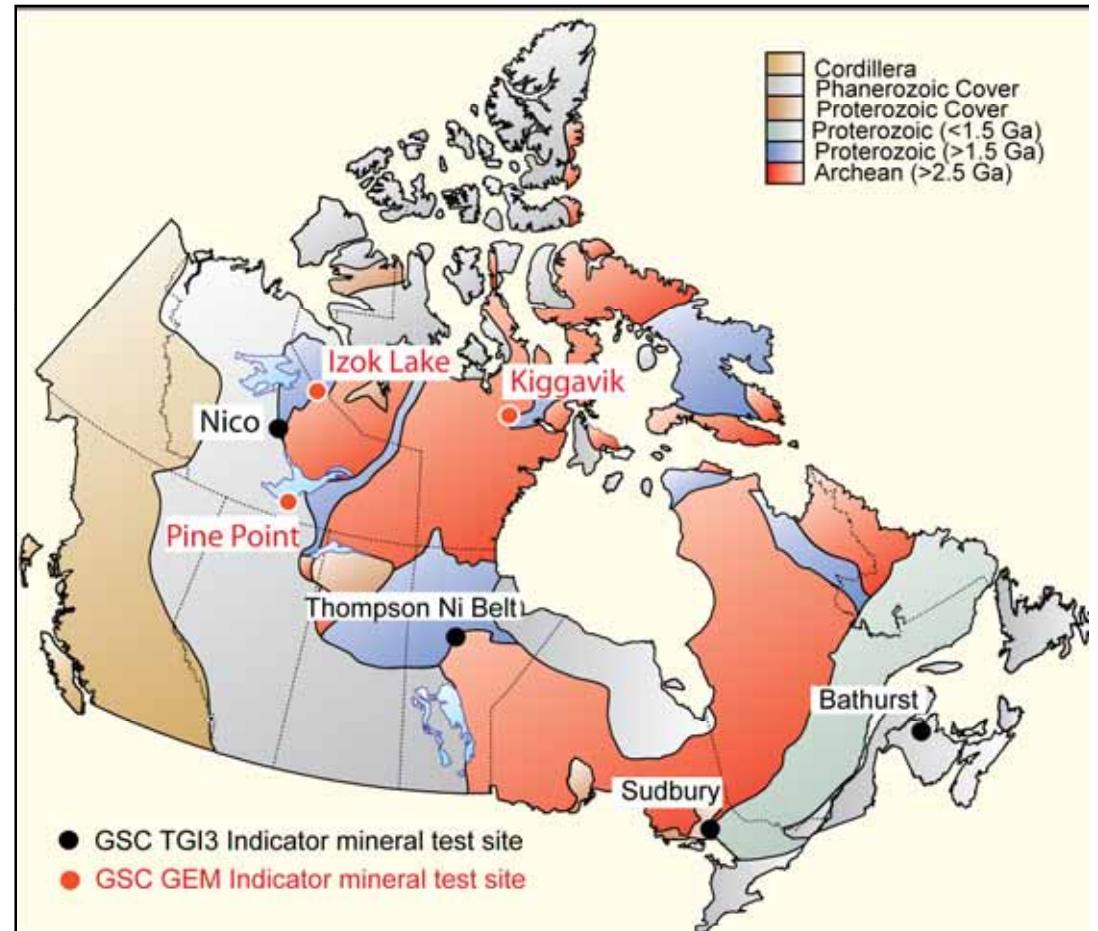


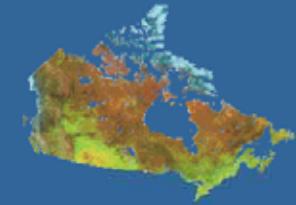
TGI3 Test sites

- Halfmile Lake Zn-Pb-Cu VMS deposit, Bathurst Camp
- Magmatic Ni-Cu deposits, Thompson Ni Belt
- Broken Hammer Cu-(Ni)-PGE occurrence, Sudbury
- Nico Co-Au-Bi IOCG deposit, Great Bear Magmatic zone

GEM Test Sites

- Izok Lake Zn-Cu-Pb-Ag VMS deposit, Nunavut
- Pine Point Pb-Zn MVT deposits, NWT
- Kiggavik U deposit, Nunavut

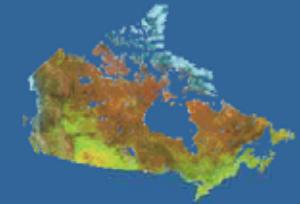




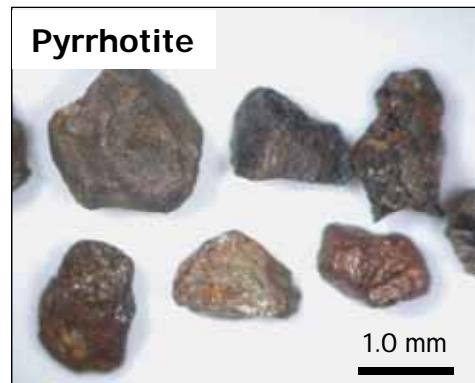
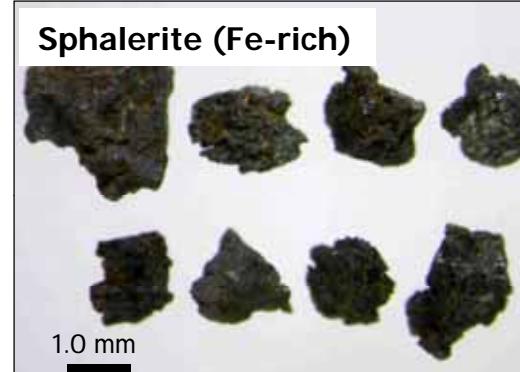
Common indicators of hydrothermal alteration zones associated with metamorphosed massive VMS deposits in glaciated terrain

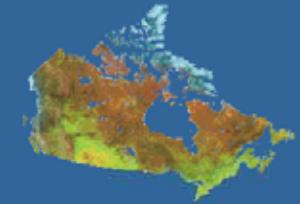
Indicator mineral	Chemical composition	Indicator elements
sillimanite	Al_2SiO_5	Al
kyanite	Al_2SiO_5	Al
corundum	Al_2O_3	Al
anthophyllite	$(\text{Mg},\text{Fe})_7\text{Si}_8\text{O}_{22}(\text{OH})_2$	Mg
orthopyroxene	$(\text{Mg},\text{Fe})_2\text{Si}_2\text{O}_6$	Mg
Mg–spinel	MgAl_2O_4	Mg, Al
sapphirine	$(\text{Mg},\text{Al})_8(\text{Al},\text{Si})_6\text{O}_{20}$	Mg, Al
staurolite	$(\text{Fe},\text{Mg},\text{Zn})_2\text{Al}_9(\text{Si},\text{Al})_4\text{O}_{22}(\text{OH})_2$	Mg ($\pm \text{Zn}$), Al
tourmaline	$(\text{Na},\text{Ca})(\text{Mg},\text{Fe})_3\text{Al}_6(\text{BO}_3)_3(\text{Si}_6\text{O}_{18})(\text{OH})_4$	Al, B
dumortierite	$\text{Al}_7(\text{BO}_3)(\text{SiO}_4)_3\text{O}_3$	Al, B
Mn–epidote	$\text{Ca}_2(\text{Al},\text{Fe},\text{Mn})_3\text{Si}_3\text{O}_{12}(\text{OH})$	Mn
spessartine	$\text{Mn}_3\text{Al}_2\text{Si}_3\text{O}_{12}$	Mn, Al
gahnite	ZnAl_2O_4	Zn, Al
franklinite	$(\text{Zn},\text{Mn},\text{Fe})(\text{Fe},\text{Mn})_2\text{O}_4$	Zn, Mn
willemite	Zn_2SiO_4	Zn
Cr–rutile	$(\text{Ti},\text{Cr})\text{O}_2$	Cr
barite	BaSO_4	Ba, S
chalcopyrite	CuFeS_2	Cu, S
cinnabar	HgS	Hg, S
loellingite	FeAs_2	As
native gold	Au	Au

Averill (2001)

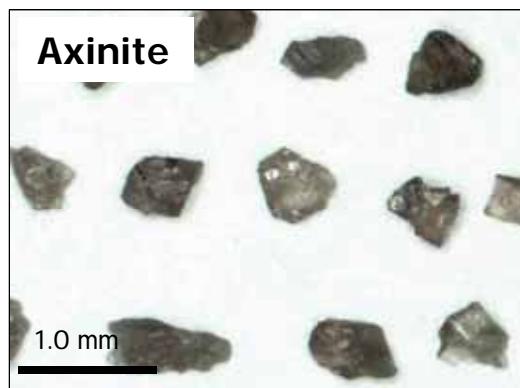
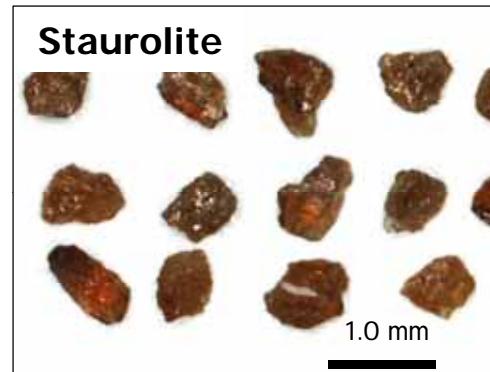
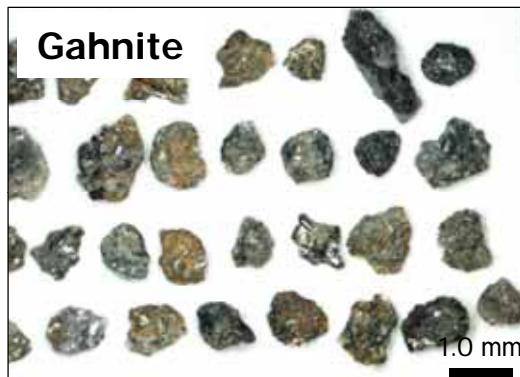


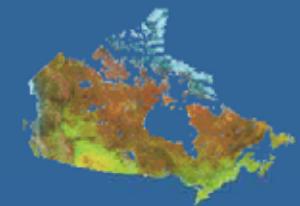
VMS deposits: indicator minerals





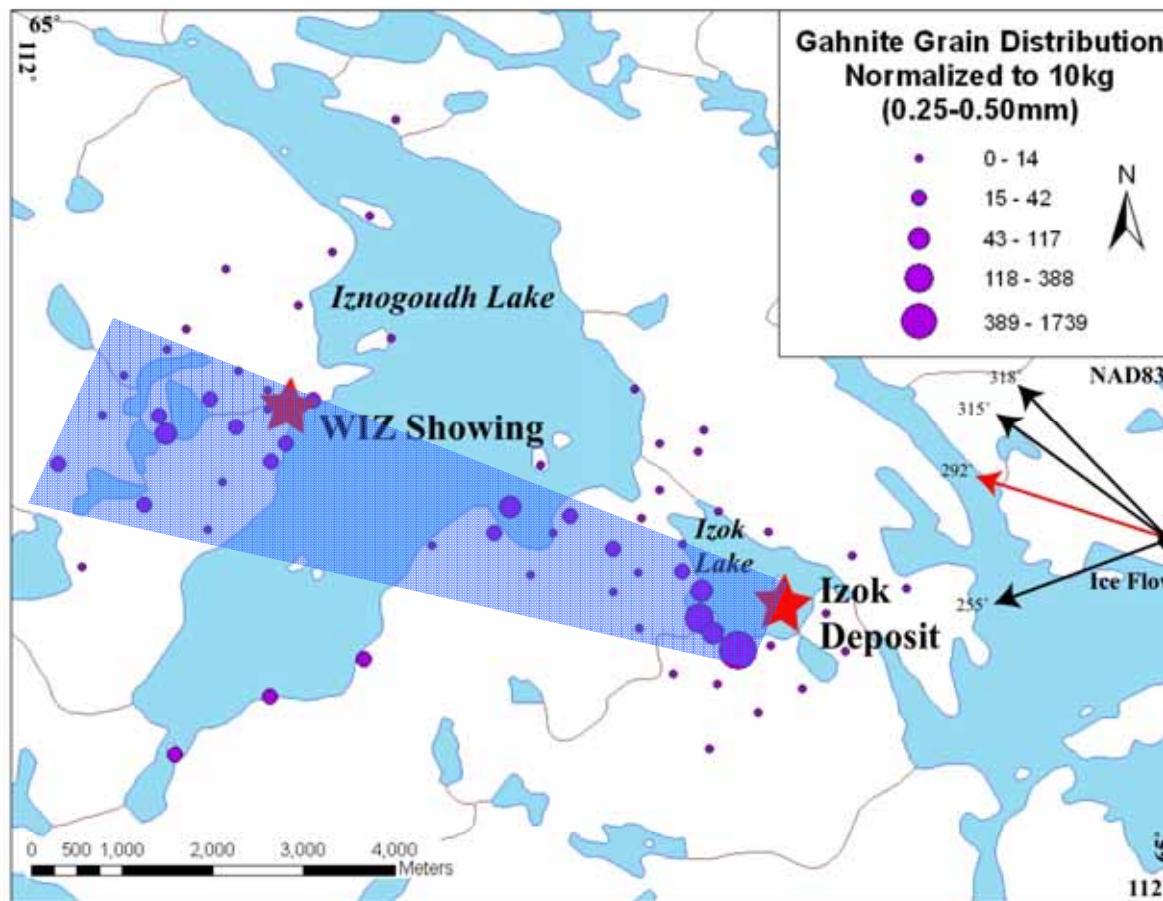
VMS deposits: indicator minerals





Example: Gahnite Distribution

Izok Lake VMS deposit, Nunavut-NWT: dispersal train

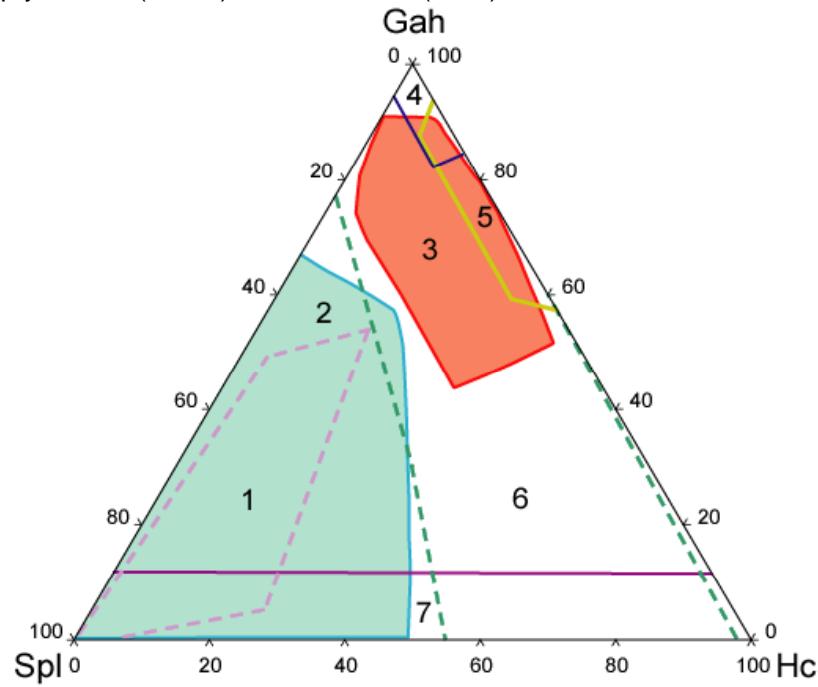


Hicken et al. 2010

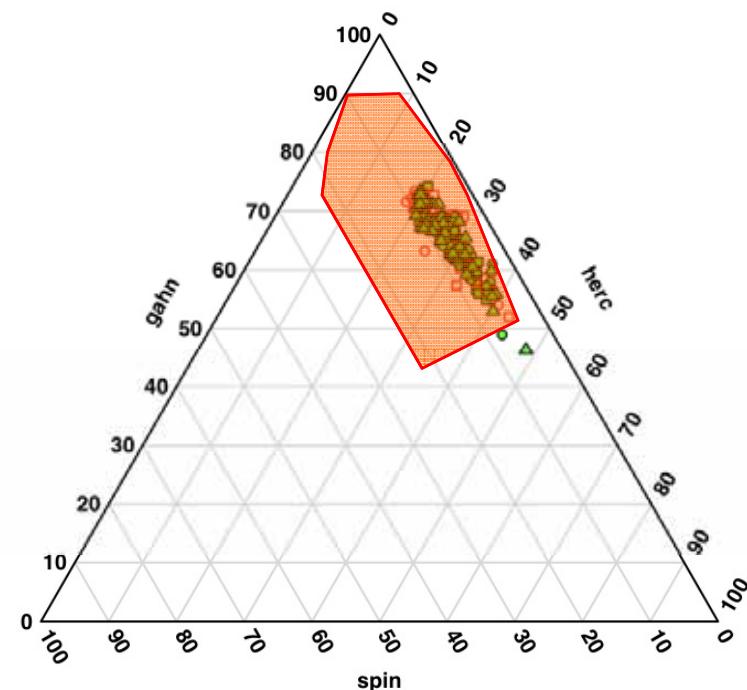


Example: Gahnite Chemistry

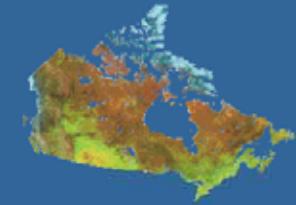
Composition of Gahnite in Natural Geological Settings
Spry & Scott (1986a); Heimann et al. (2005)



Gahnite in till, Halfmile Lake VMS deposit, Bathurst



1 Marbles; 2 Metamorphosed massive sulfide deposits and S-poor rocks in Mg-Ca Al alteration zones; 3 Metamorphosed massive sulfide deposits in Fe-Al metasedimentary and metavolcanic rocks; 4 Metabauxites; 5 Pegmatites; 6 Unaltered and hydrothermally altered Fe-Al-rich metasedimentary and metavolcanic rocks; and (7) Al-rich granulites



Common indicators of Ni-Cu massive sulphide deposits hosted by mafic/ultramafic rocks in glaciated terrain

Mineral	Melt fertility indicators Composition	Mineral	Cumulus indicators Composition	Mineral	Hybrid indicators Composition	Mineral	Indicators of mineralization Composition
Enstatite	$(\text{Mg},\text{Fe})_2\text{Si}_2\text{O}_6$	Enstatite	$(\text{Mg},\text{Fe})_2\text{Si}_2\text{O}_6$	Ruby corundum	$(\text{Al},\text{Cr})_2\text{O}_3$	Chalcopyrite	CuFeS_2
Forsterite	$(\text{Mg},\text{Fe})\text{SiO}_4$	Forsterite	$(\text{Mg},\text{Fe})\text{SiO}_4$	Hercynite	FeAl_2O_4	Isoferroplatinum	Pt_3Fe
Low-Cr diopside	$\text{Ca}(\text{Mg},\text{Cr})\text{Si}_2\text{O}_6$	Low-Cr diopside	$\text{Ca}(\text{Mg},\text{Cr})\text{Si}_2\text{O}_6$	Cr-andradite	$\text{Ca}_3(\text{Fe},\text{Cr})_2(\text{SiO}_4)_3$	Native palladium	Pd
Chromite	$(\text{Fe},\text{Mg})(\text{Cr},\text{Al})_2\text{O}_4$	Chromite	$(\text{Fe},\text{Mg})(\text{Cr},\text{Al})_2\text{O}_4$	Cr-grossular	$\text{Ca}_3(\text{Al},\text{Cr})_2(\text{SiO}_4)_3$	Native gold	Au
				Uvarovite	$\text{Ca}_3\text{Cr}_2(\text{SiO}_4)_3$	Sperrylite	PtAs_2
						Stillwaterite	Pd_8As_3
						Loellingite	$(\text{Fe},\text{Ni})\text{As}_2$
						Stibiopalladinite	Pd_5Sb_2

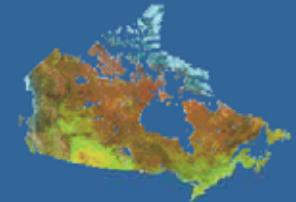
Averill (2009)



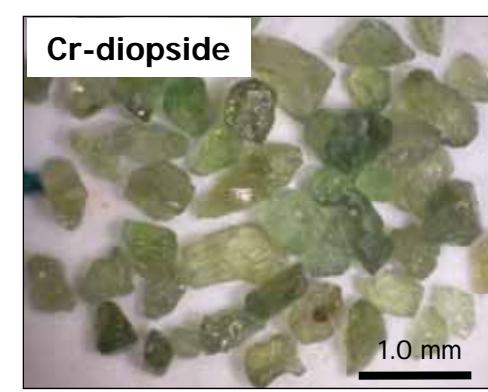
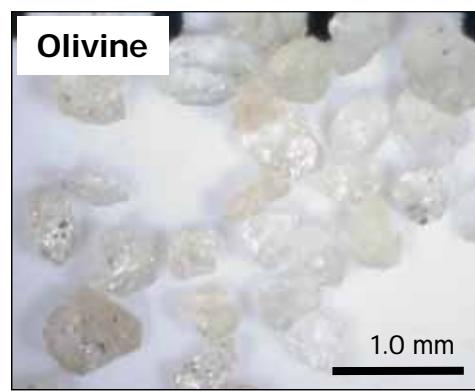
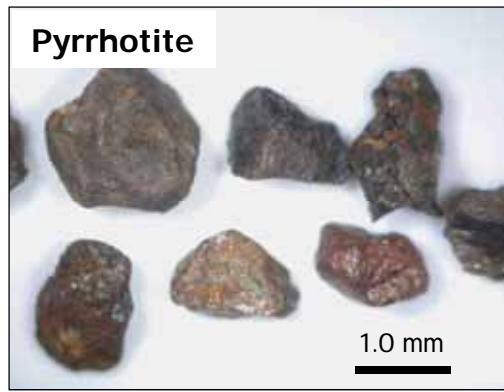
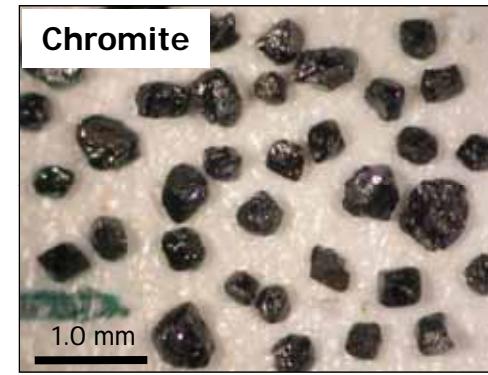
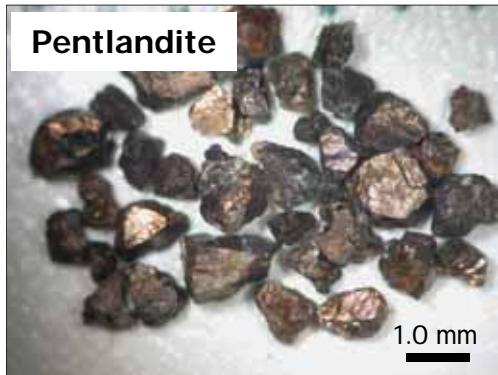
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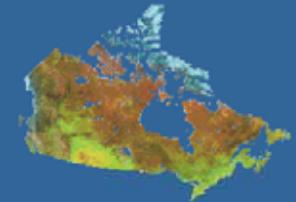
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Ni-Cu-PGE: indicator minerals





Ni-Cu-PGE: indicator minerals

Pentlandite

Olivine:

- smaller, paler colour
- paramagnetic due to inclusions of Cr-magnetite/Fe-chromite

Pyrrhotite

Chromite:

- sharper edged crystals, no resorbed surfaces

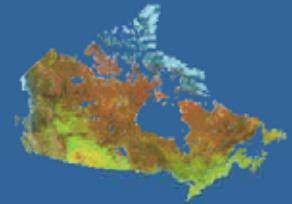
Cr-diopside:

- lower Cr content, paler green colour

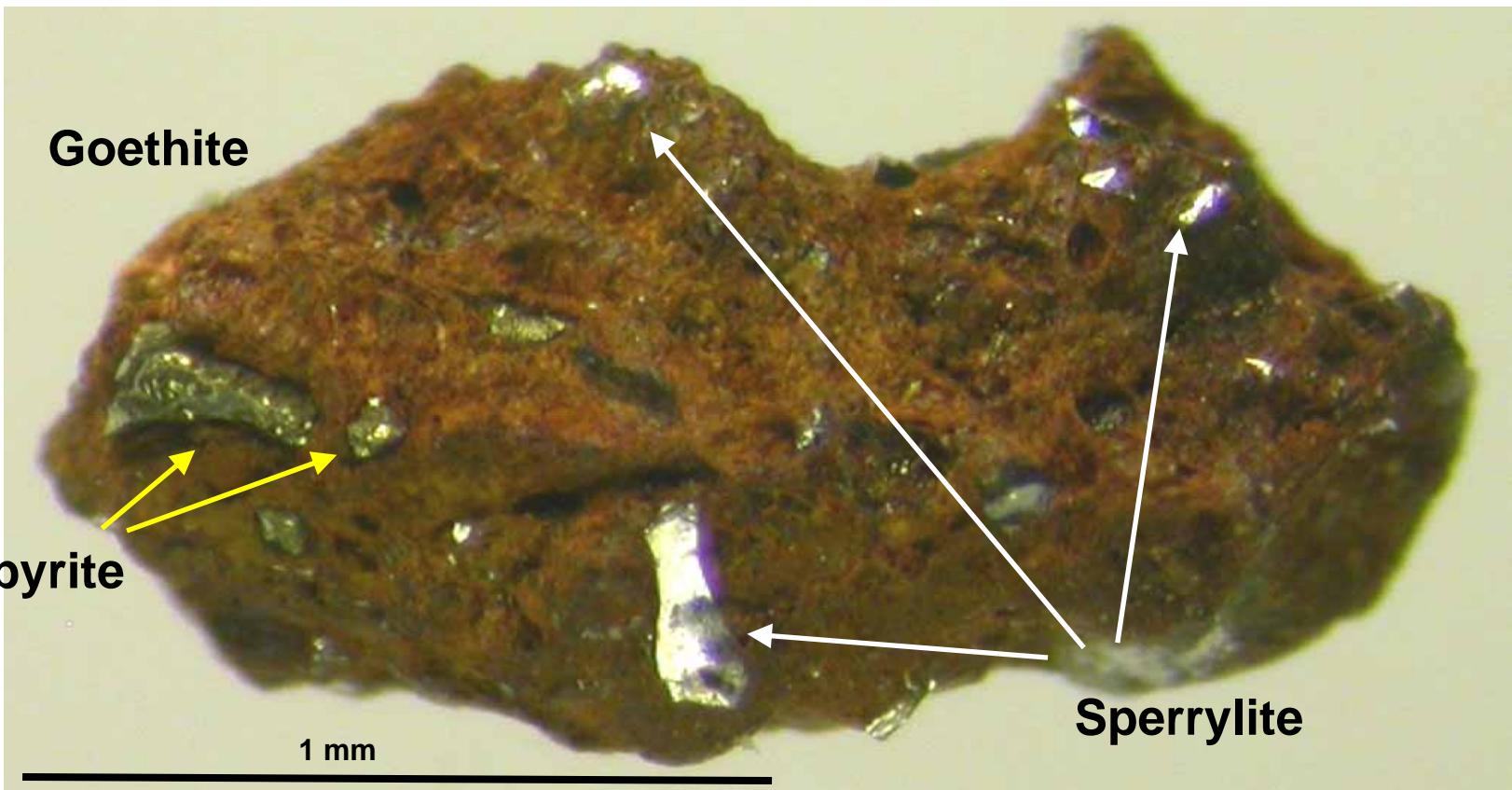
Comparison to Kimberlite indicator minerals

1.0 mm

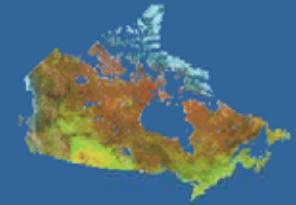




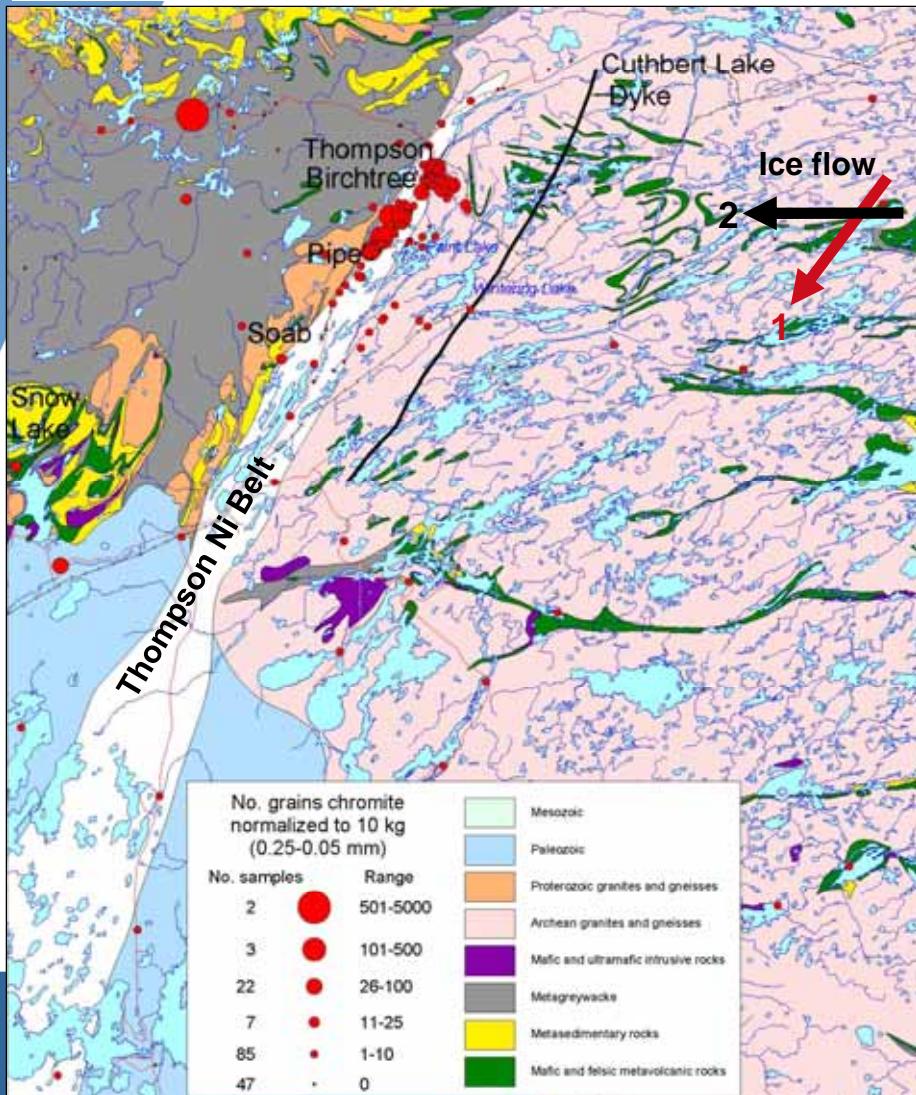
Ni-Cu-PGE: indicator minerals



Broken Hammer Cu-(Ni)-PGE occurrence, Sudbury (Averill, 2009)



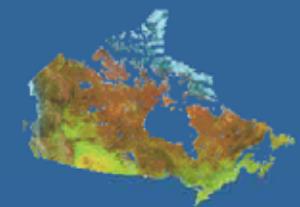
Chromite grains/10 kg



Chromite Distribution

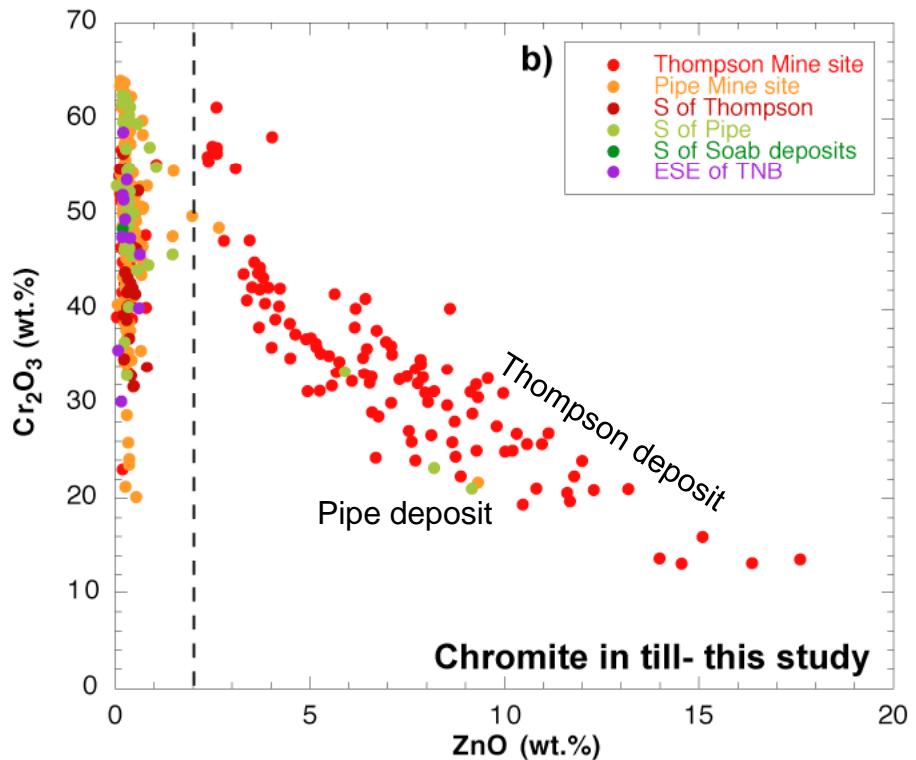
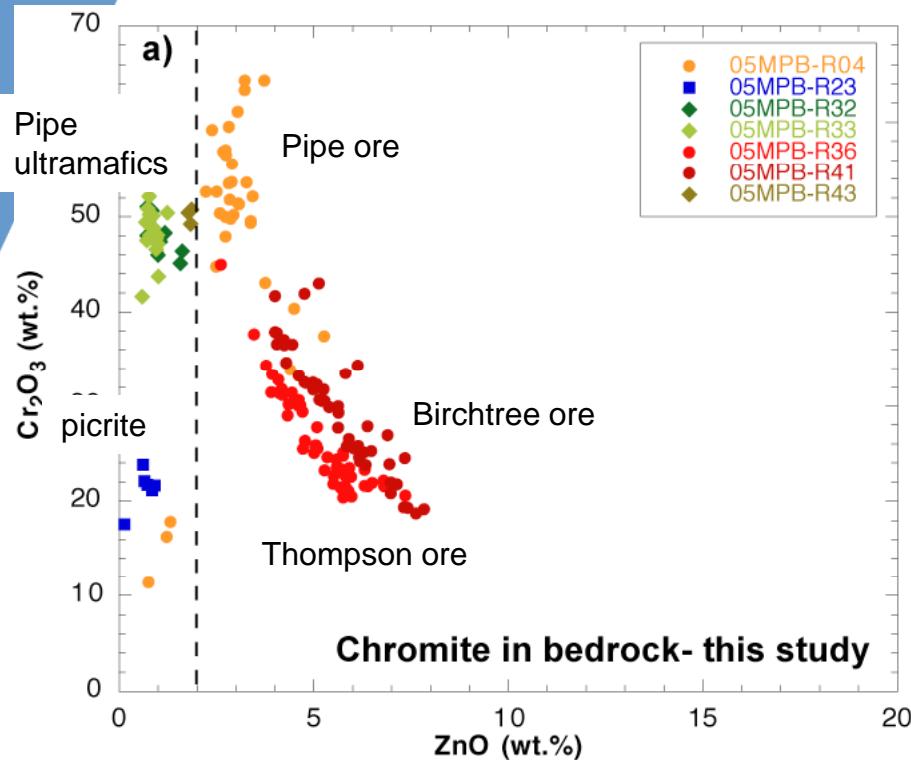
Thompson Nickel Belt

- Highest counts associated with mineralized rocks and ultramafic intrusions
- Unknown sources west and east of belt



Chromite Chemistry

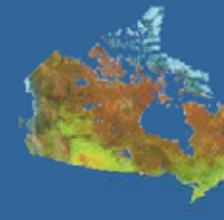
Thompson Nickel Belt



McClenaghan et al., 2009

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GEM Indicator Mineral Data Compilation

- Database of indicator mineral sample locations, abundance and EMP mineral chemistry data for surficial (till, esker, stream) sediment samples collected by government and industry surveys.
- Compliment to KIDD database
- Includes all indicator minerals (e.g., kimberlite, precious metals, base metals, uranium)

The screenshot shows the homepage of the Natural Resources Canada Geoscience Data Repository. The header includes the Canadian flag, the text "Natural Resources Canada" and "Resources naturelles Canada", and a search bar. Below the header, there are links for "Français", "Home", "Contact us", "Help", "Search", and "canada.gc.ca". The main content area features a large image of a forested landscape and a rocky cliff. A sidebar on the left is titled "Geoscience Data Repository" and contains links for "Home", "Canadian Geochemical Surveys", "Home/ Download data", "About", "Browse metadata by category", "Help for application", "See also...", "Terms and conditions", "System requirements", "Alternate access to data", "What's new?", "Tell us what you think!", "Related data", "Related links", "Site map", "Contact us", and "Help". The main content area has a section titled "Canadian Geochemical Surveys" with text about the history and scope of the surveys, and a "Launch application to search the catalogue" button. Another section provides "See also:" links for "Browse by category", "Help for application", "System requirements", "Terms and conditions", and "Alternate access to data". At the bottom, there is a "Search the catalogue:" input field with a list of search methods: "by VIEWING a map-based interface", "by BROWSING index tables organised by category", "by QUERYSING a periodic table interface", and "by USING Internet search engines". A "User manual" link is also present. The footer includes the Geological Survey of Canada logo, the text "Date Modified: 2010-08-05", "Top of page", and "Important notices".



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Geoscience Data Repository: Canadian Geochemical Surveys

Metadata for 840
geochemical and indicator
mineral government surveys

Queries based on project,
location maps, surveys,
publications, or element on
periodic table

The screenshot shows the Natural Resources Canada Geoscience Data Repository website. At the top, there are links for French and English, Home, Contact us, Help, Search, and the URL canada.gc.ca. Below this is a banner for the Canadian Geochemical Surveys. The main area has a search interface on the left with fields for Survey count (set to 840), Province (All), Year (All), Organisation (All), Title, Survey-type (All), Abstract, and Location (Longitude, Latitude, or NTS). There are also buttons for Submit Search and Reset. To the right is a map of Canada with green and grey survey areas overlaid. Below the map are buttons for 1: 39492305, 250K, 50K, and Redraw.

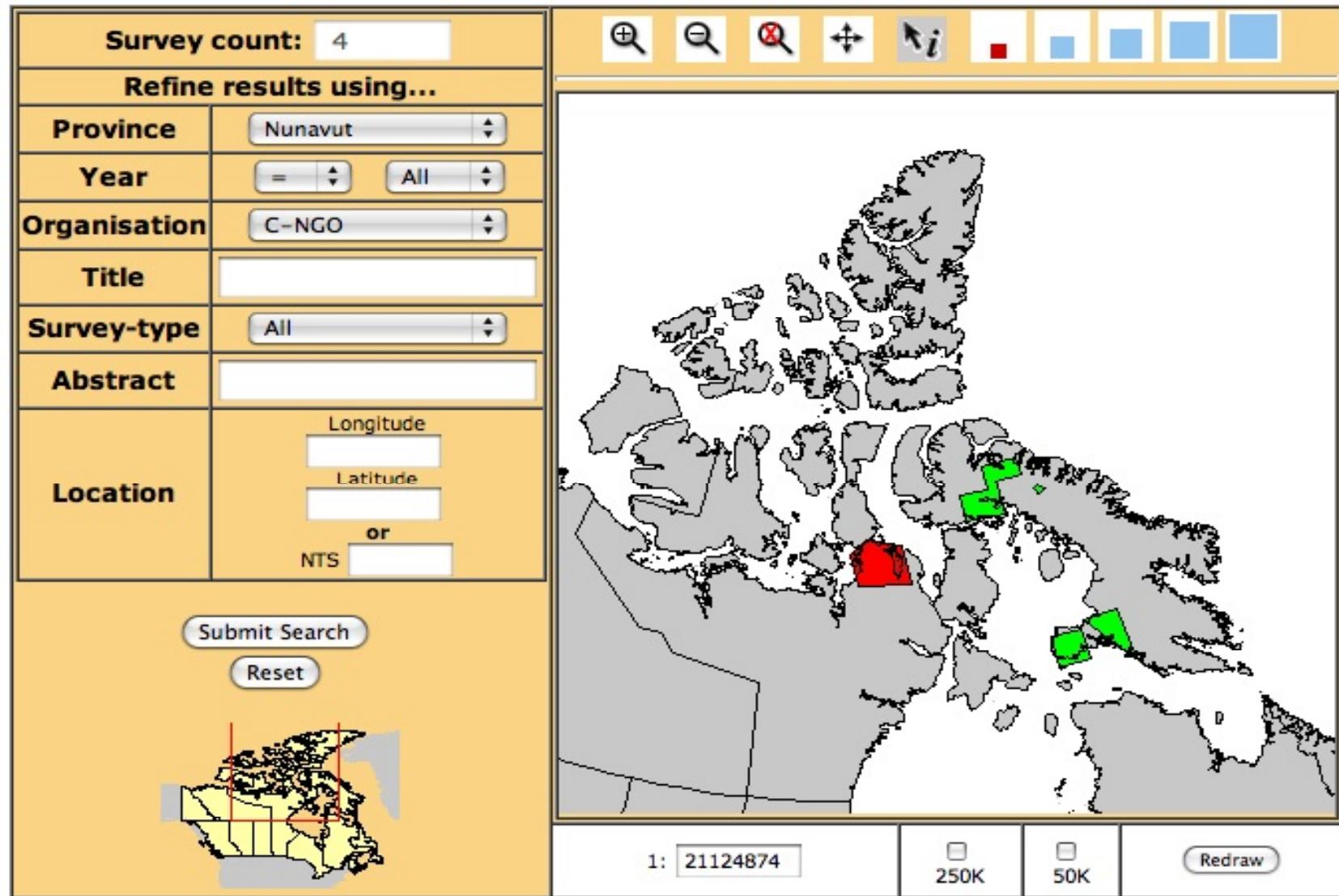


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http://gdr.nrcan.gc.ca/geochem/index_e.php



Query Results				
Info	Grouping	Organisation	Survey Year	Dataset
more	Till, Esker, Indicator minerals	C-NGO	2005	Till and esker sampling survey, NTS 57A, B, C, D, Boothia mainland area, Kitikmeot region, Nunavut, 2005 and 2007.

GEM

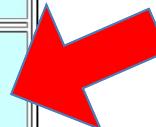
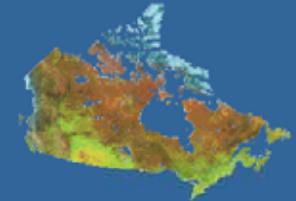


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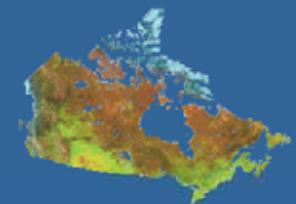
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Index	Year	# analysed	Analytical sample bundle			Spreadsheet	Details
			N	H	T		
1	2005	64	C-NGO 2005/2007 Boothia Peninsula HMC samples (more)				
Index	Sample material	Prep Lab material	Suite	Technique	Decomposition	Details	
1	Till	HMC separation (ODM standard)	ODM IM grain separation	Mineral grain separation	None		
2	Till	HMC separation (ODM standard)	ODM VG count	Mineral grain separation	None		
3	Till	HMC separation (ODM standard)	ODM MMSIM count - HMC 0.25-0.5 mm fraction	Mineral grain separation	None		
4	Till	HMC separation (ODM standard)	ODM KIM count - HMC 0.25-0.5 mm fraction	Mineral grain separation	None		
5	Till	HMC separation (ODM standard)	ODM MMSIM count - HMC 0.5-1.0 mm fraction	Mineral grain separation	None		
6	Till	HMC separation (ODM standard)	ODM KIM count - HMC 0.5-1.0 mm fraction	Mineral grain separation	None		
7	Till	HMC separation (ODM standard)	ODM MMSIM count - HMC 1.0-2.0 mm fraction	Mineral grain separation	None		
8	Till	HMC separation (ODM standard)	ODM KIM count - HMC 1.0-2.0 mm fraction	Mineral grain separation	None		
9	Esker	HMC separation (ODM standard)	ODM IM grain separation	Mineral grain separation	None		

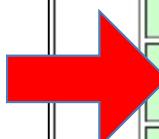


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Index	Year	# analysed	Analytical sample bundle			Spreadsheet	Details		
			N	H	T				
1	2005	64	C-NGO 2005/2007 Boothia Peninsula HMC samples (more)				[]		
			Index	Sample material	Prep Lab material	Suite	Technique	Decomposition	Details
			1	Till	HMC separation (ODM standard)	ODM IM grain separation	Mineral grain separation	None	[]
			2	Till	HMC separation (ODM standard)	ODM VG count	Mineral grain separation	None	[]
			3	Till	HMC separation (ODM	ODM MMSIM count -	Mineral grain separation	None	[]



Z	Till	HMC separation (ODM standard)	ODM MMSIM count - HMC 1.0-2.0 mm fraction	Mineral grain separation	None	[]					
Index	Quantity	Units	Det Limit	# analysed	# missing	# discarded	# > 0	Minimum	Percentile	Maximum	KML
1	MMSIM DI	count		35	0		6	0	0 0 0	2	KML
2	MMSIM CPY	count		35	0		18	0	0 1 2	23	KML
3	MMSIM GH	count		35	0		1	0	0 0 0	1	KML



Z	Till	HMC separation (ODM standard)	ODM MMSIM count - HMC 1.0-2.0 mm fraction	Mineral grain separation	None	[]
8	Till	HMC separation (ODM standard)	ODM KIM count - HMC 1.0-2.0 mm fraction	Mineral grain separation	None	[]
9	Esker	HMC separation (ODM standard)	ODM IM grain separation	Mineral grain separation	None	[]

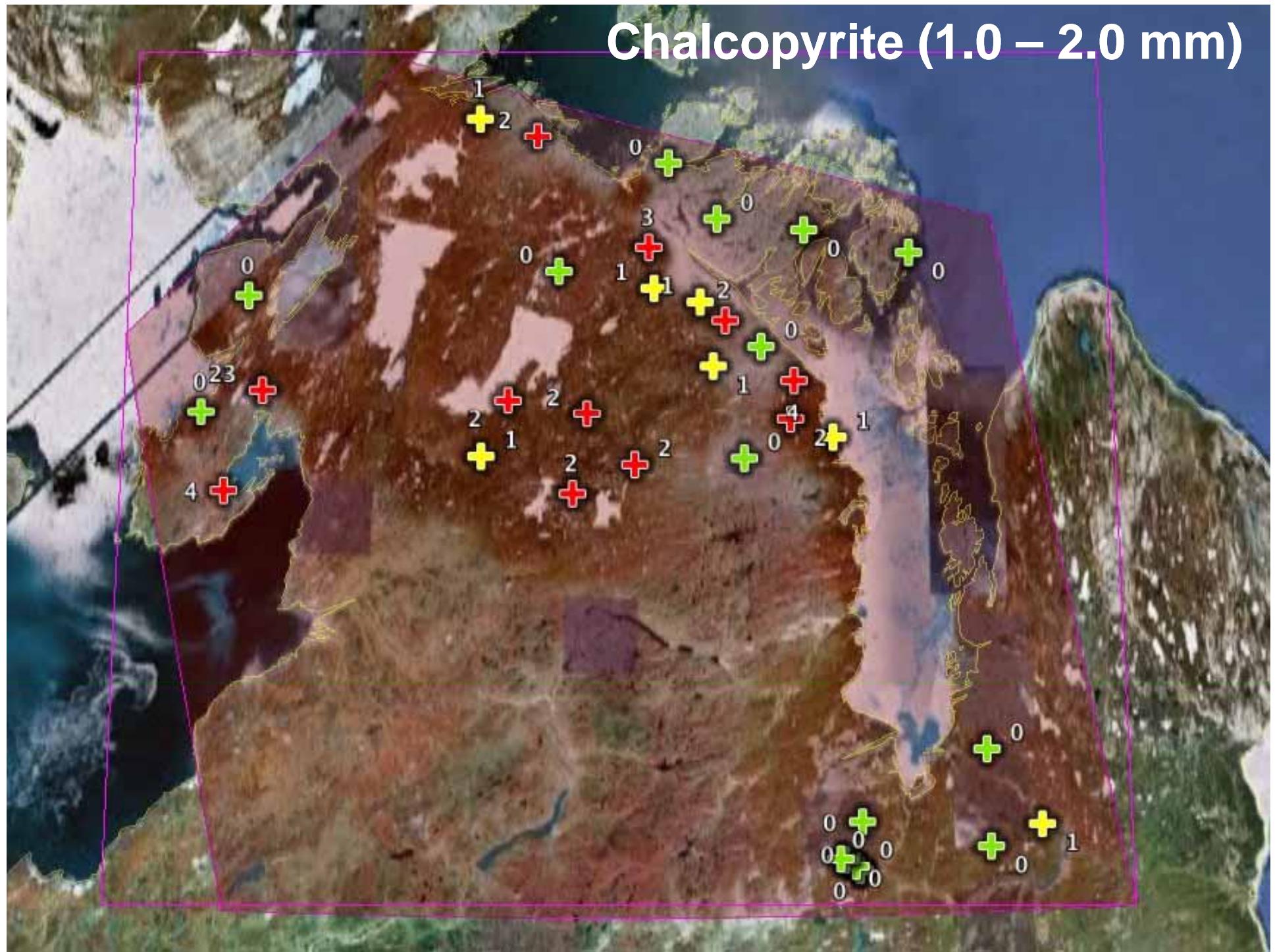


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Chalcopyrite (1.0 – 2.0 mm)





Base Metal Indicator Minerals



Summary

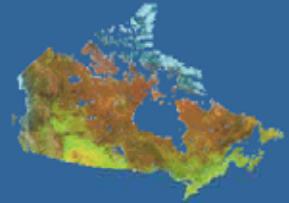
- Website updates:
 - Indicator mineral metadata online in 2010
 - Additional GSC survey data online early 2011
- Steve Adcock, Geological Survey of Canada
adcock@nrcan.gc.ca
- Roger Paulen, Geological Survey of Canada
Roger.Paulen@NRCan-RNCan.gc.ca
- Beth McClenaghan, Geological Survey of Canada
bmccclena@nrcan.gc.ca



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Wanted: Indicator Mineral Data From Industry

- Permanent archive of indicator mineral data
- Accessible via the internet in office or field
- Currently accepting donations of indicator mineral data for the database
- Properly documented sample information
(i.e., sample type, location, weight, size fraction, etc.)
- Properly documented sample processing methodology
- Also accepting donated concentrates and other media. Priority areas (e.g., GEM Project areas) may undergo re-picking of heavy mineral concentrates



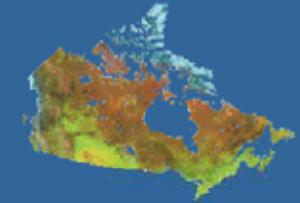
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Base Metal Indicator Minerals



Future Indicator Mineral Research - TGI4

- Rare metals
- Magmatic Ni-Cu-PGE
- VMS
- Intrusion hosted deposits
 - porphyry Cu-Au
 - Sn-W-Mo



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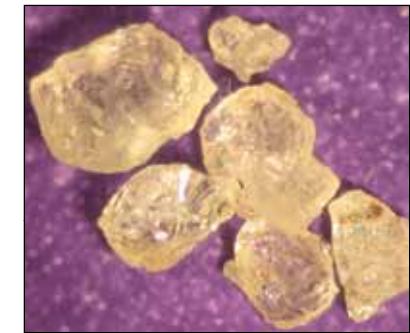


INDICATOR MINERALS COMMONLY RECOVERED

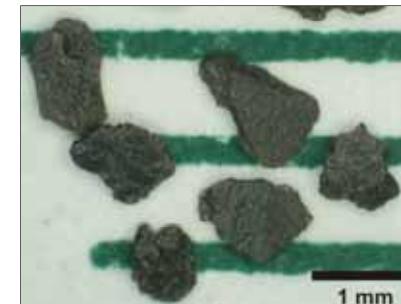
- Gold grains (Au)
- Native copper (Cu)
- Kimberlite indicator minerals
- Platinum Group minerals (PGM)
- Sulphide minerals
- Metamorphosed massive sulphide minerals- e.g. gahnite
- Magmatic Ni-Cu-PGE minerals
- Scheelite (W)
- Cassiterite (Sn)
- Cinnabar (Hg)
- Fluorite, topaz (F)
- Uranium minerals
- Rare earth element (REE) minerals



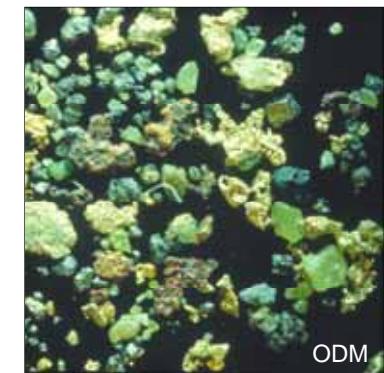
Kimberlite indicator minerals



Topaz



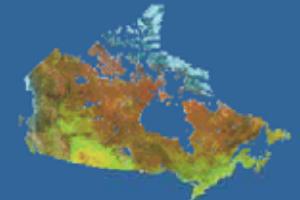
Sphalerite



ODM

Gold, native Cu,
pyromorphiteNatural Resources
CanadaRessources naturelles
Canada

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GEM

Base Metal Indicator Minerals



Conference Workshop:

25th International Applied Geochemistry Symposium

August 22-26, 2011 Rovaniemi, Finland

'Indicator Mineral Methods in Mineral Exploration'

Conveners: Beth McClenaghan and Vesa Peuraniemi

<http://www.iags2011.fi/>



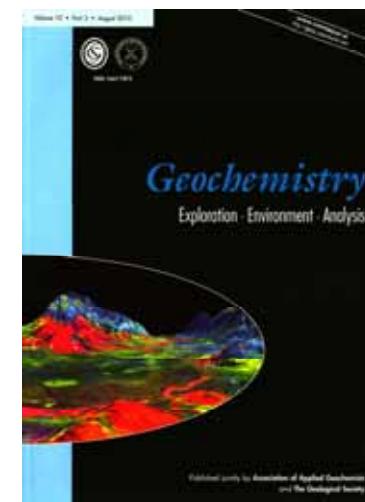
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Editors: Beth McClenaghan and Gwenda Hall



Natural Resources
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