Structural controls on Nickel Sulfide Mineralization at Sudbury, Thompson, and Voisey's Bay

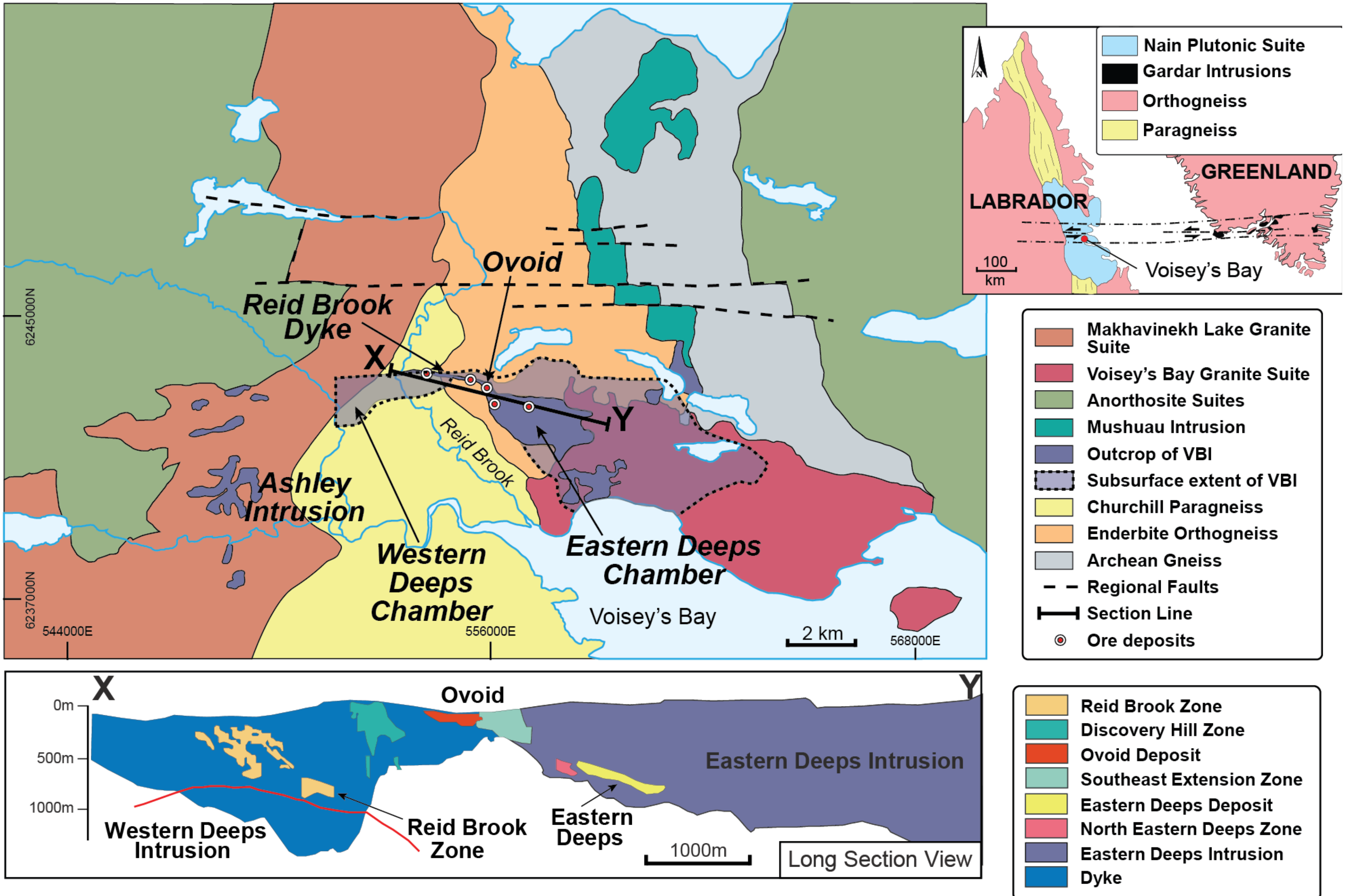
Peter C. Lightfoot

PDAC (2015)

Key points to take away

- ❑ A spectrum of structural controls:
  - ✓Primary morphology of the “ore containers”
  - ✓Syn-magmatic tectonic readjustments
  - ✓Post-magmatic dislocation/deformation
- ❑ Voisey’s Bay:
  - ❖Primary magma channel-ways localize sulfide in magma
  - ❖Syn-magmatic deformation localizes ores in country rocks
- ❑ Sudbury:
  - ❖ Primary impact topography controls magmatic sulfide
  - ❖ Crater re-adjustment – fractionated footwall sulfide
  - ❖ Post-impact deformation – translocation of sulfide
- ❑ Thompson:
  - ❖Primary magmatic chonoliths obscured
  - ❖Sulfide kinesis; four phases of deformation

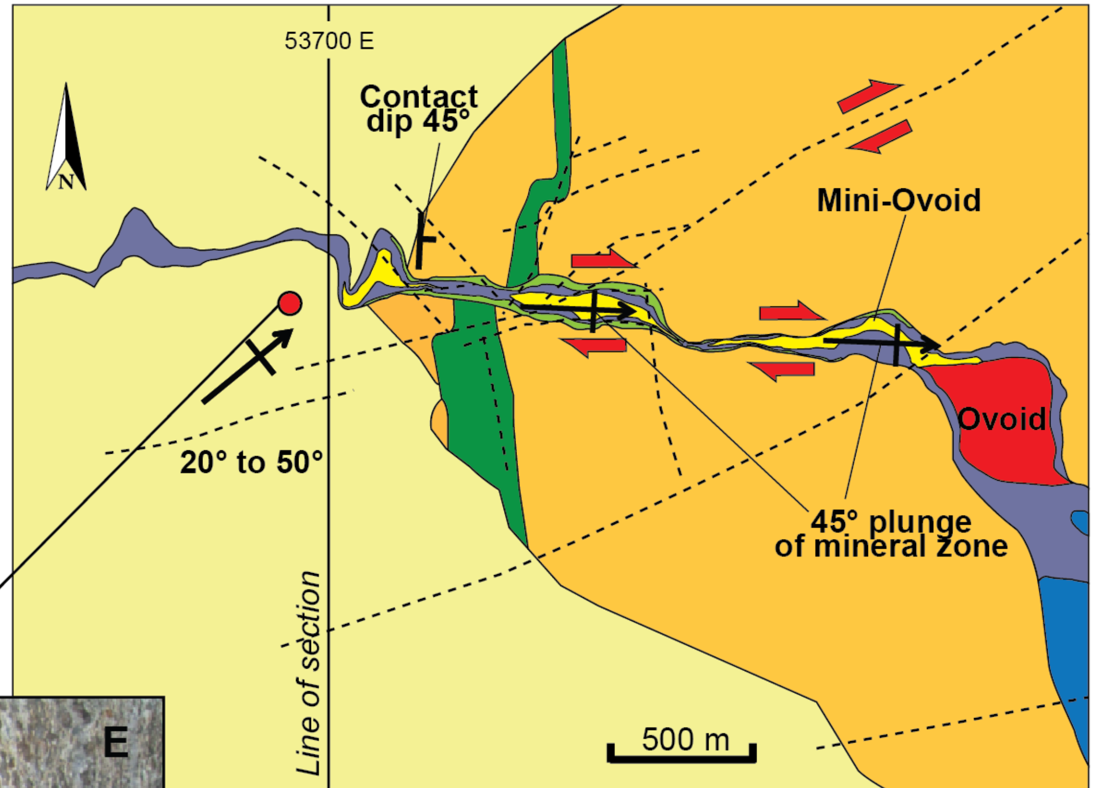
Geology of the Voisey's Bay Deposit

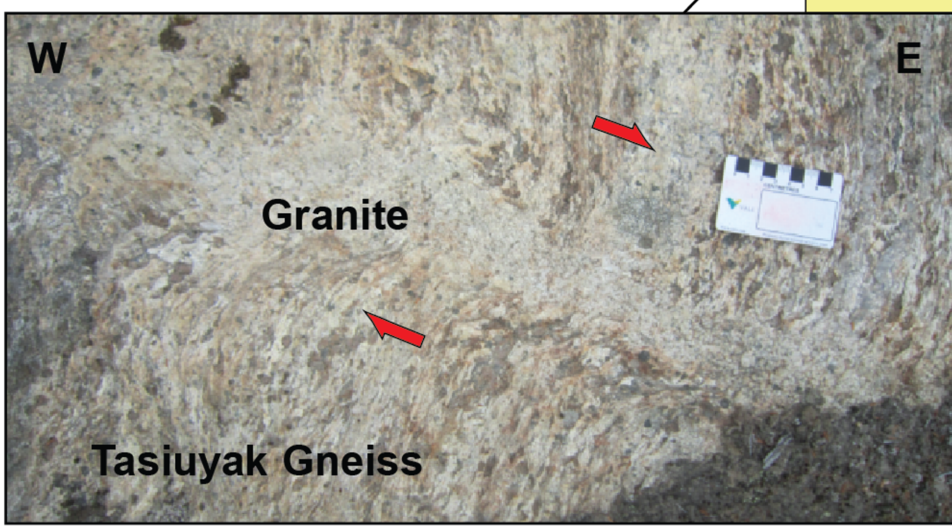


From Lightfoot & Evans Lamswood (2012)

Geology of the Reid Brook Zone

- Massive sulfide
- Leopard troctolite
- Variable troctolite with heavy disseminated sulfide
- Troctolite
- Ferrogabbro
- Churchill paragneiss
- Felsic Enderbite
- Mafic Enderbite
- Faults
- Plunge of mineral zone

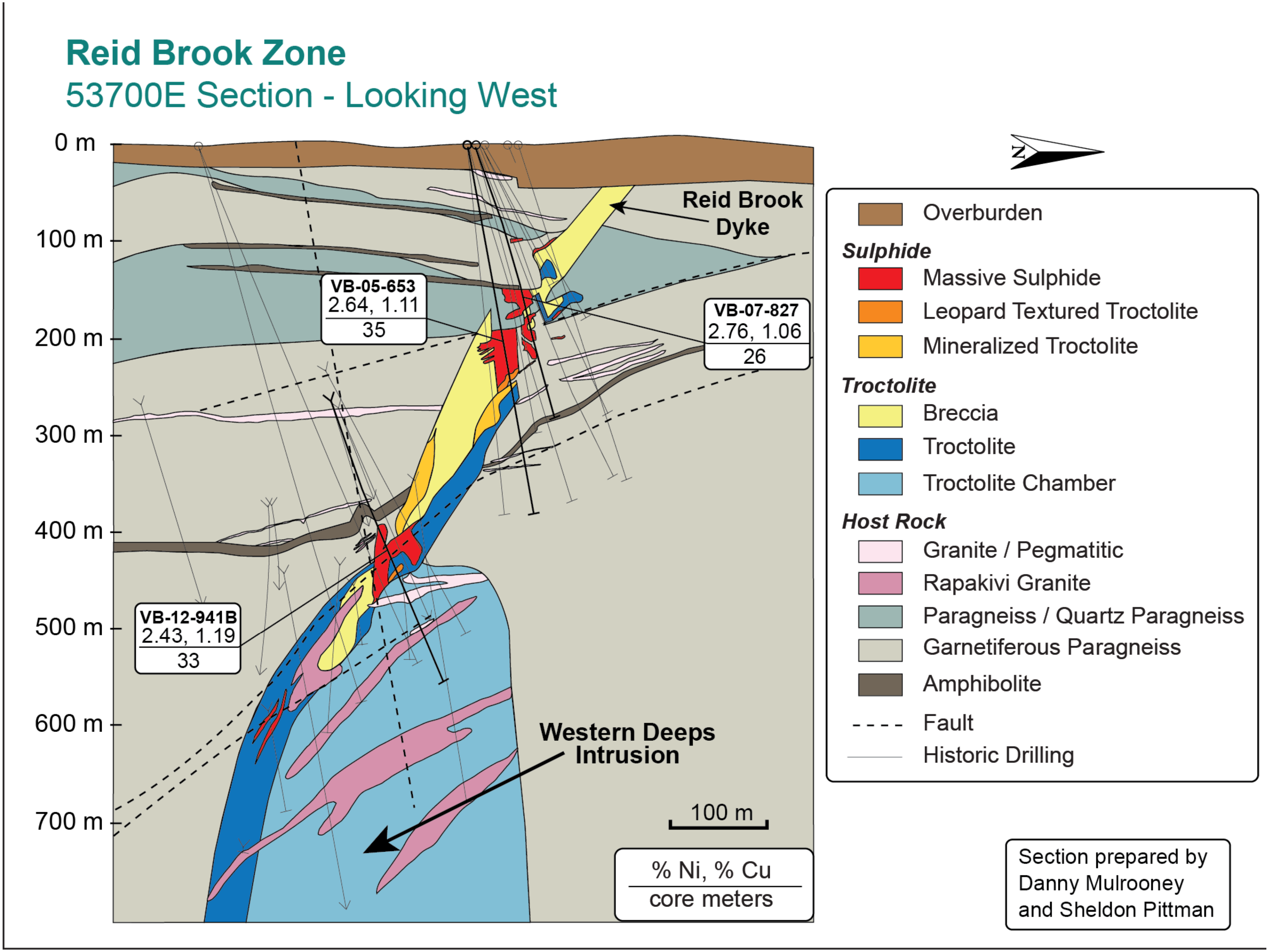




From Lightfoot & Evans Lamswood (2012)

Evidence for syn-magmatic dextral transtension

1. Displaced contacts
2. Magnetic fabric
3. Morphology of intrusion
4. Shear zones with granite
5. Fabric of gneiss rotated into north wall of Eastern Deeps

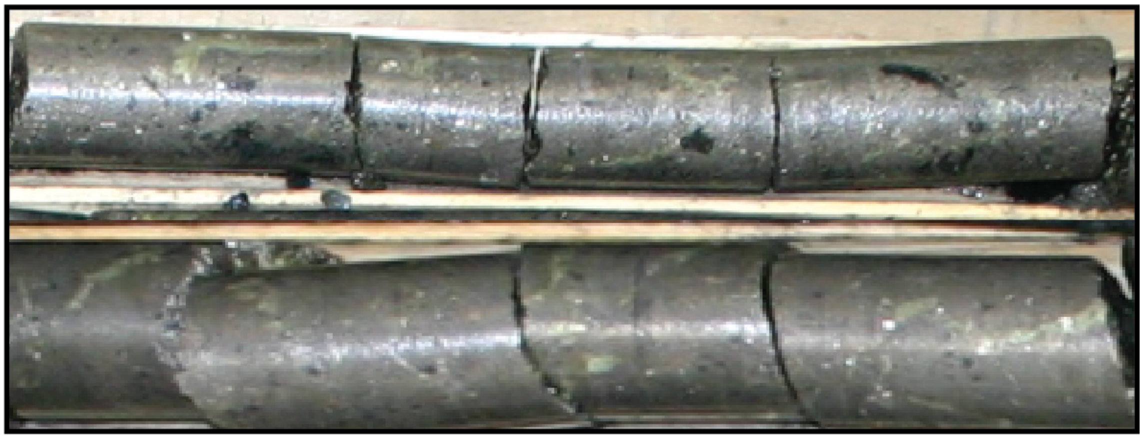


Reid Brook Zone
53700E Section - Looking West
0 m
100 m
200 m
300 m
400 m
500 m
600 m
700 m
N
Reid Brook
Dyke
VB-05-653
2.64, 1.11
35
VB-07-827
2.76, 1.06
26
VB-12-941B
2.43, 1.19
33
Western Deeps
Intrusion
100 m
% Ni, % Cu
core meters
Overburden
Sulphide
Massive Sulphide
Leopard Textured Troctolite
Mineralized Troctolite
Troctolite
Breccia
Troctolite
Troctolite Chamber
Host Rock
Granite / Pegmatitic
Rapakivi Granite
Paragneiss / Quartz Paragneiss
Garnetiferous Paragneiss
Amphibolite
Fault
Historic Drilling
Section prepared by
Danny Mulrooney
and Sheldon Pittman

Geological model of the Reid Brook Zone

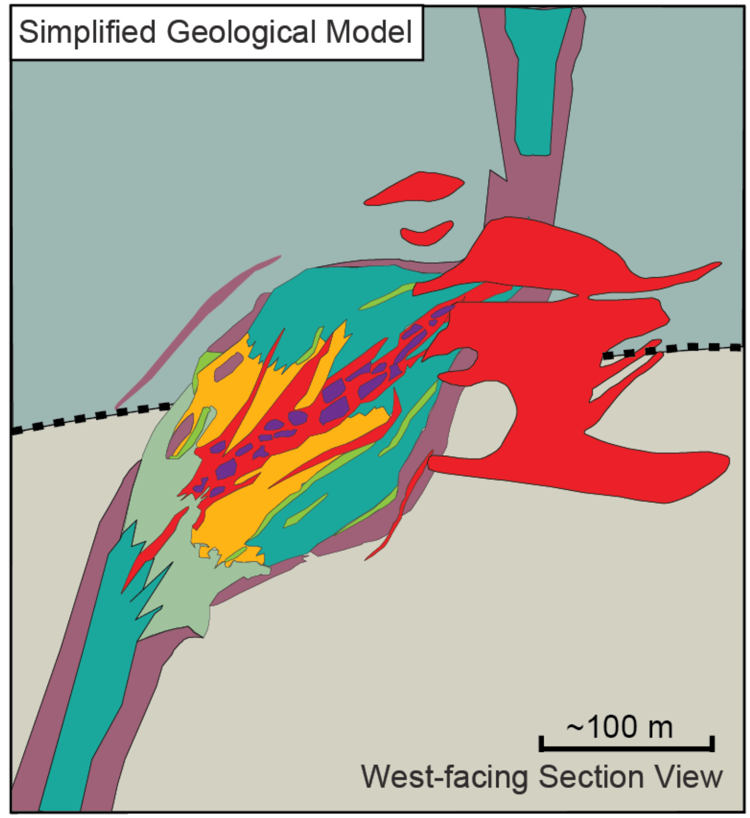
Faulted contact of quartzofeldspathic paragneiss with garnet paragneiss: epidote-chlorite-carbonate alteration.

Massive sulphide: pyrrhotite surrounded by loops of chalcopyrite with pentlandite eyes.



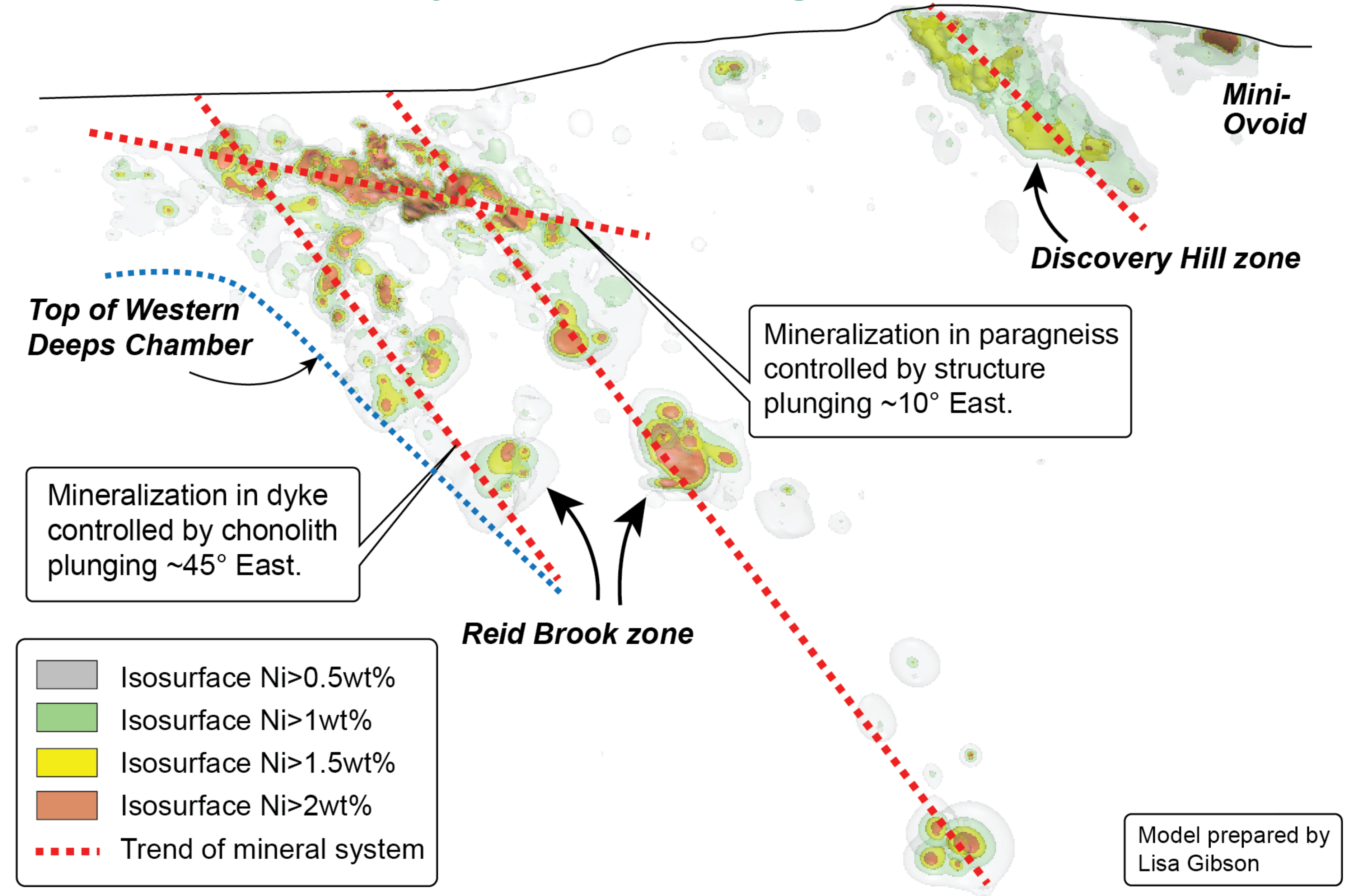
Tasiuyak quartzofeldspathic paragneiss with gneissic fabric.

- Variable troctolite with <10% fragments and <10% sulfide
- Massive sulphide
- Mafic to ultramafic fragments
- Zone of aligned gneiss fragments
- Leopard-textured troctolite
- Variable troctolite
- Ferrodiorite and biotite Ferrogabbronorite
- Paragneiss / Quartz Paragneiss
- Garnetiferous Paragneiss

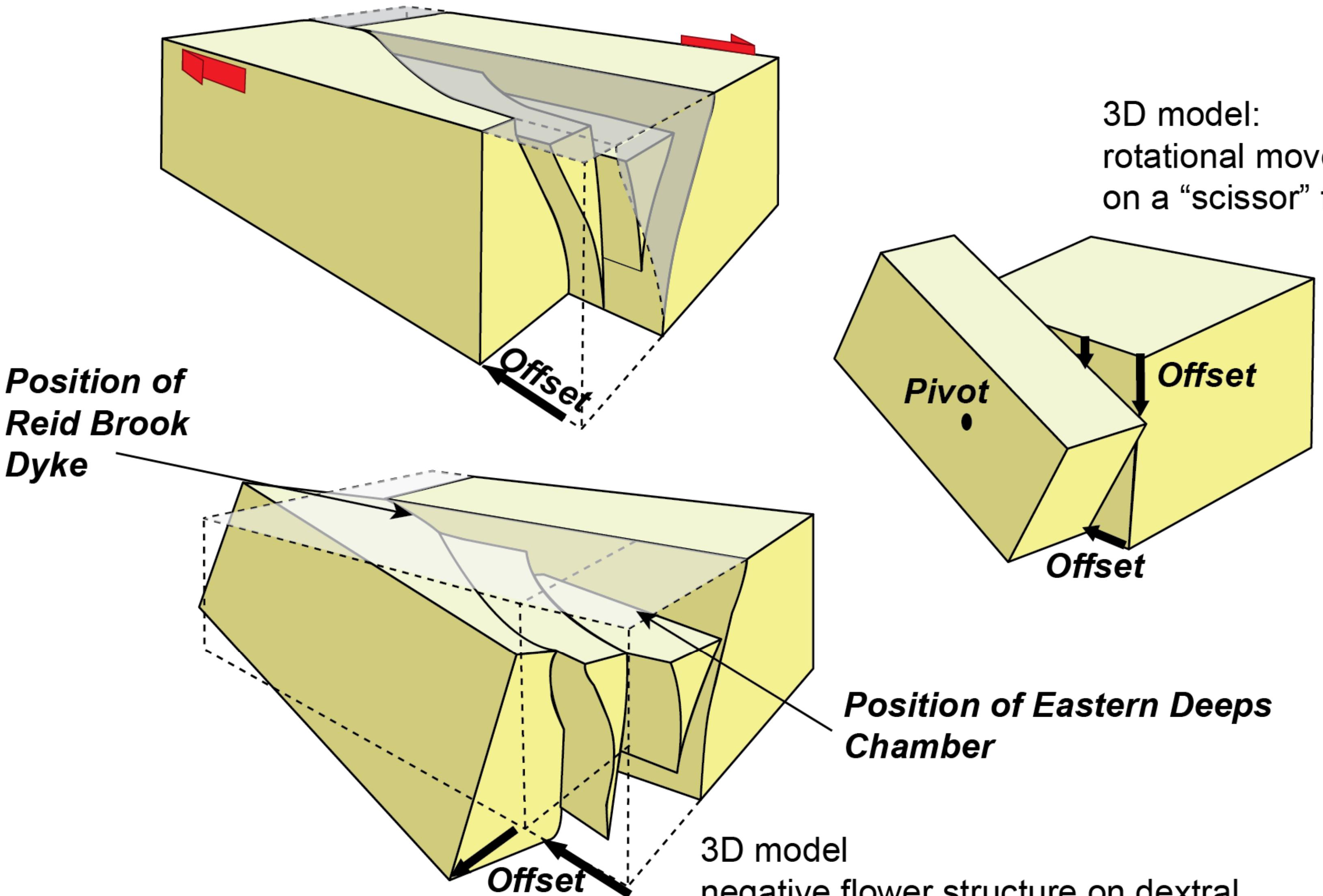


After Lightfoot & Evans Lamswood (2012)

Leapfrog model showing Ni grade distribution in the Reid Brook Zone projected onto W-E long section



Kinematics: Summary for Voisey's Bay

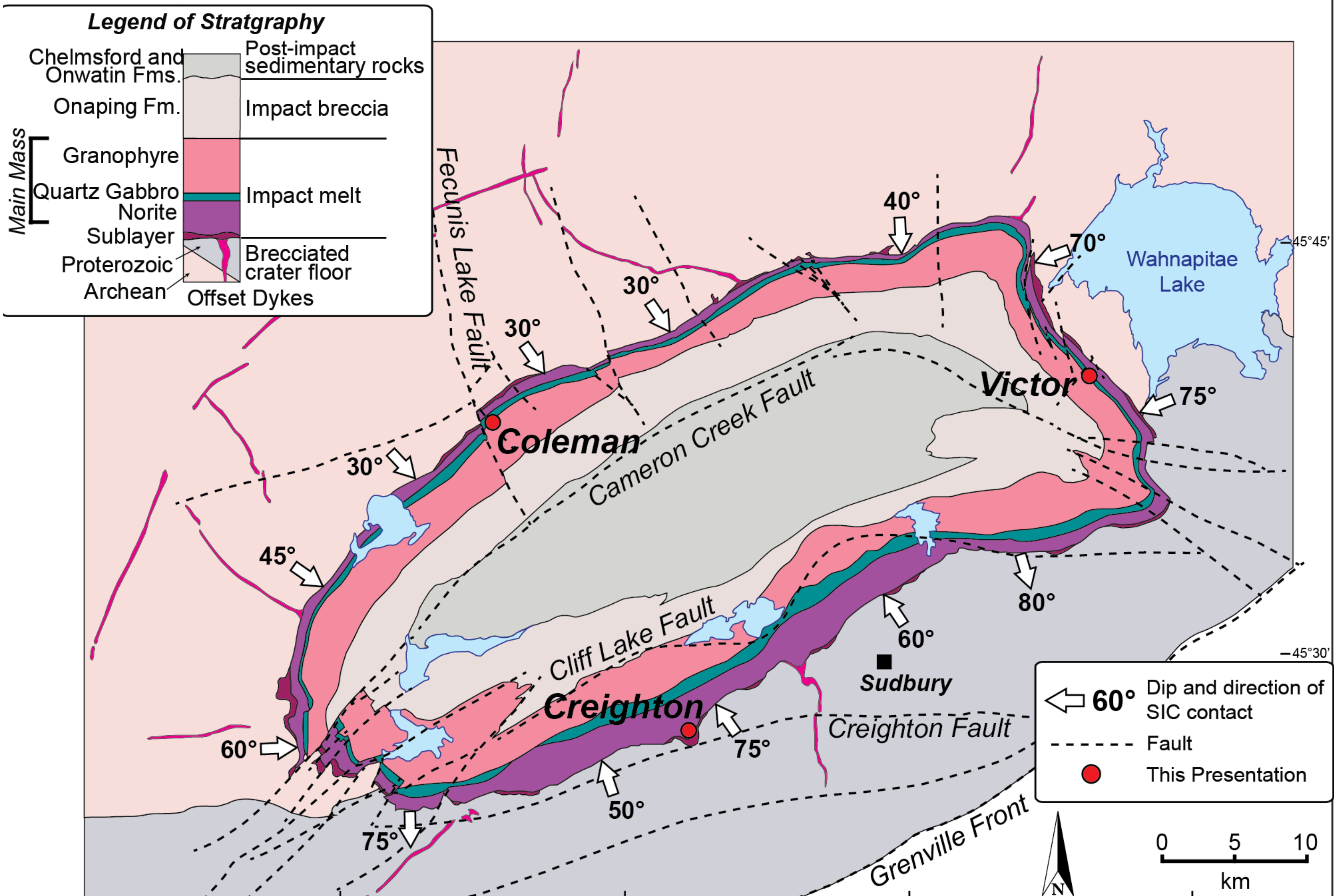


3D model:
rotational movement
on a "scissor" fault

3D model
negative flower structure on dextral
strike-slip fault with rotational movement
to create space for Eastern Deeps chamber

From Lightfoot & Evans Lamswood (2012)

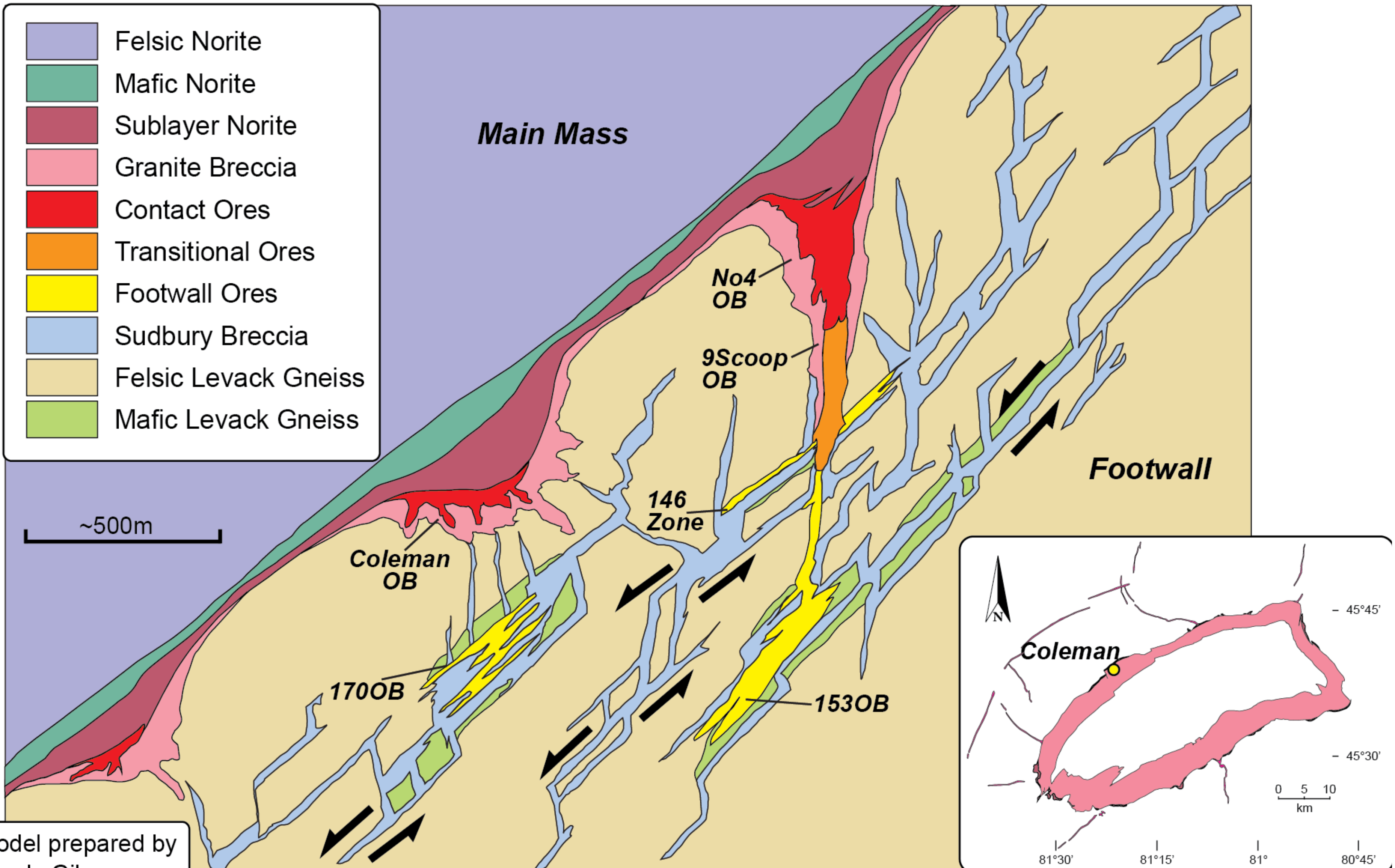
Geological Map of the Sudbury Igneous Complex



Modified Afler Ames (2005)

Coleman Mine

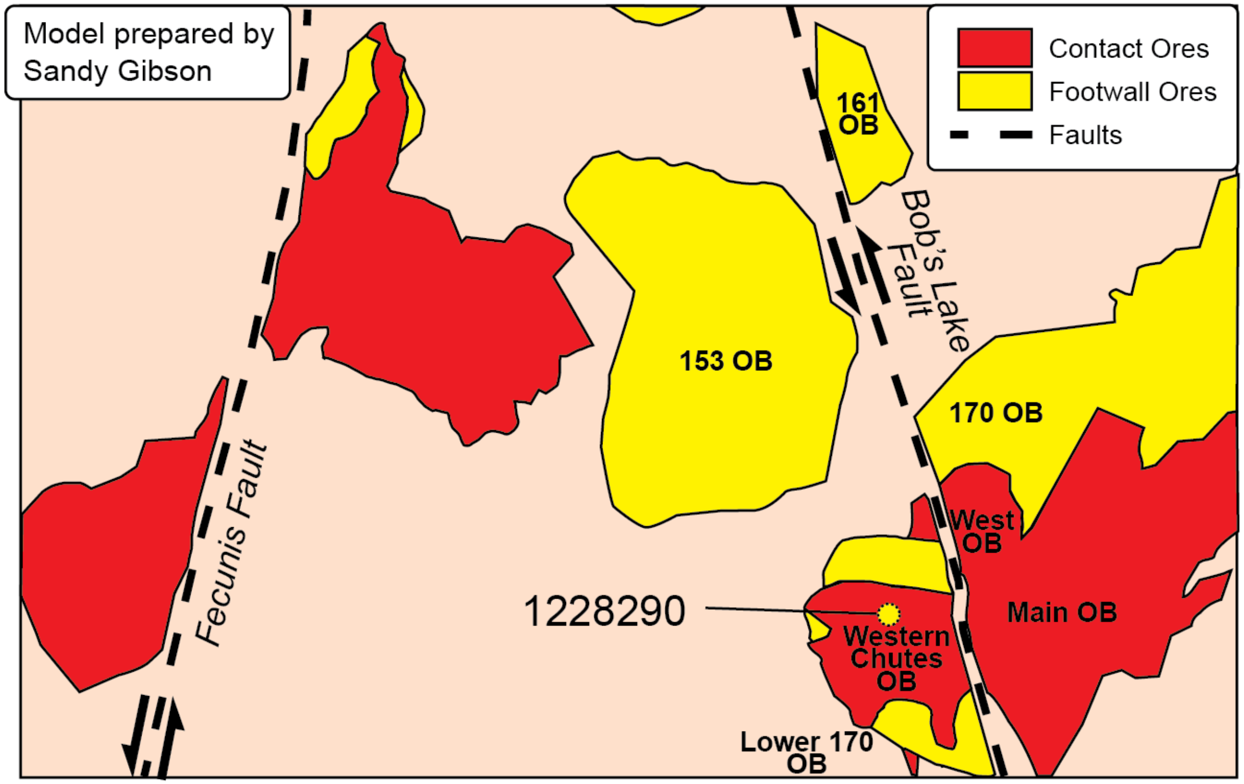
Geological Model - Section View Facing WSW

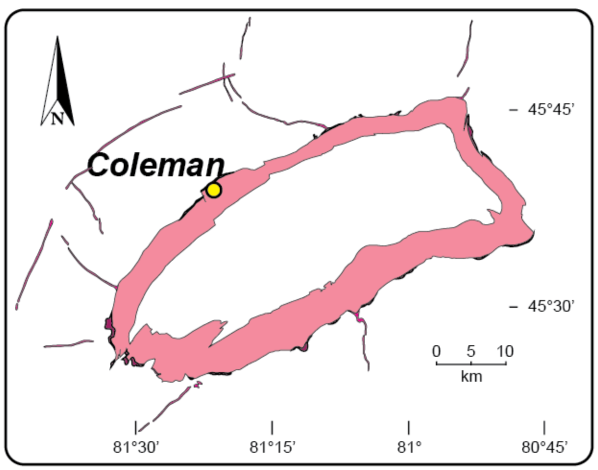


Model prepared by
Sandy Gibson

Coleman Mine

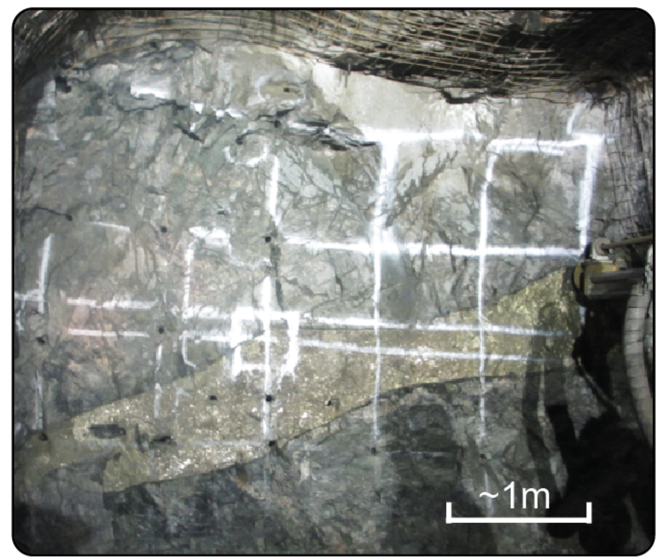
Geological Plan on the Lower SIC Contact



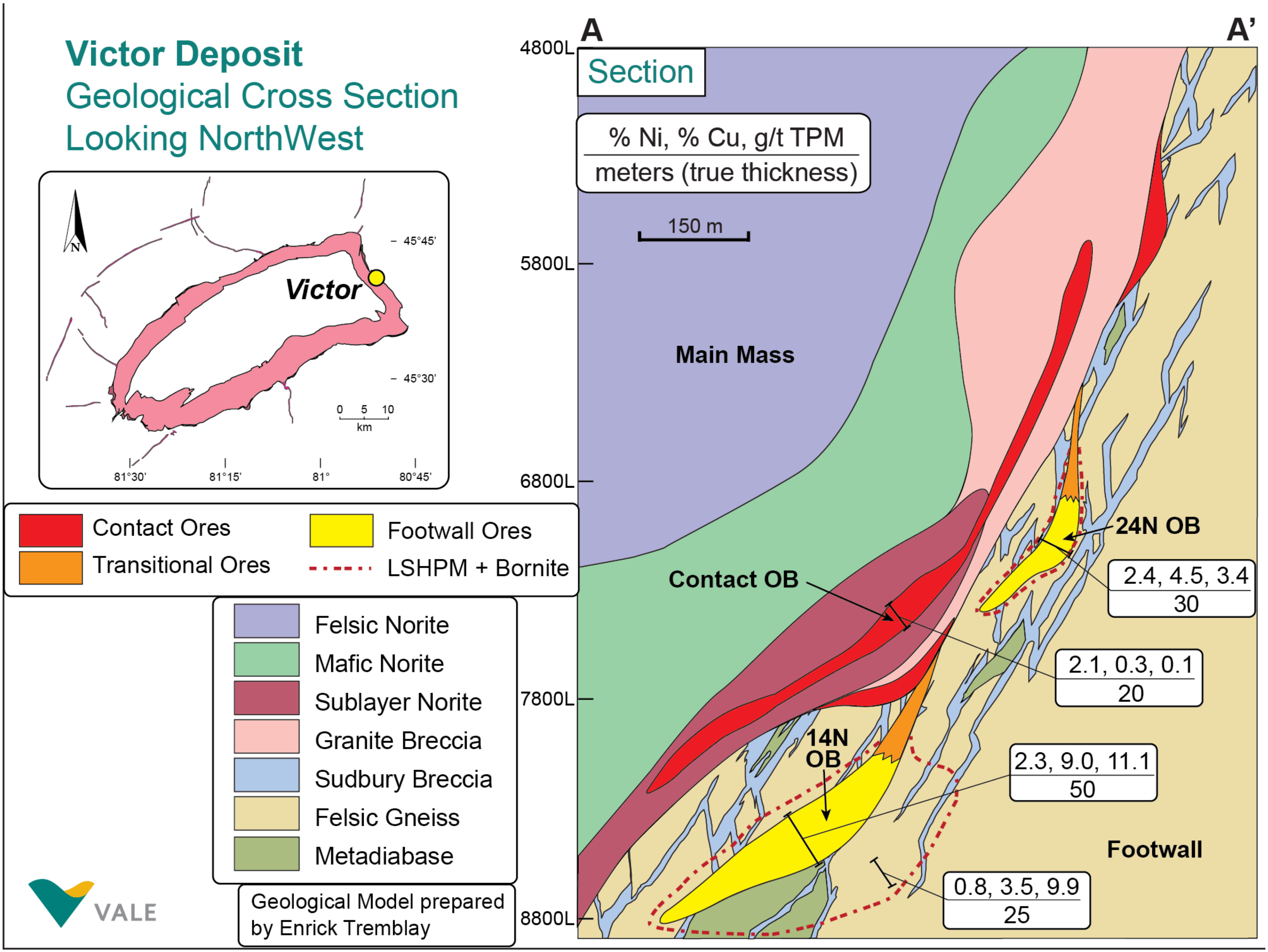


1228290
1.13%Ni, 30.15%Cu, 42.38g/t TPM
10.7m True Thickness
10.8%Ni, 16.1%Cu, 49.21g/t TPM
0.6m True Thickness

170 OB: Cpy-mill vein



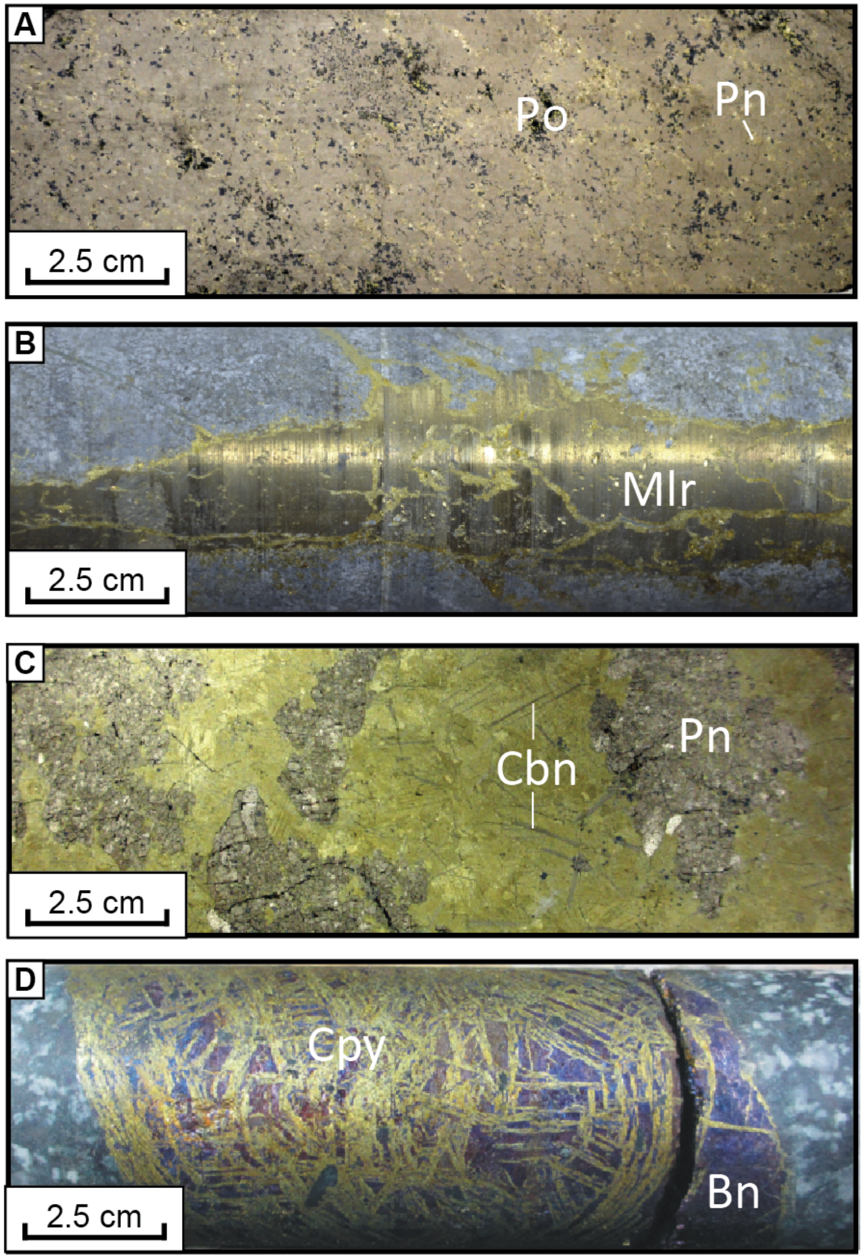
170 OB: Pn-mill vein

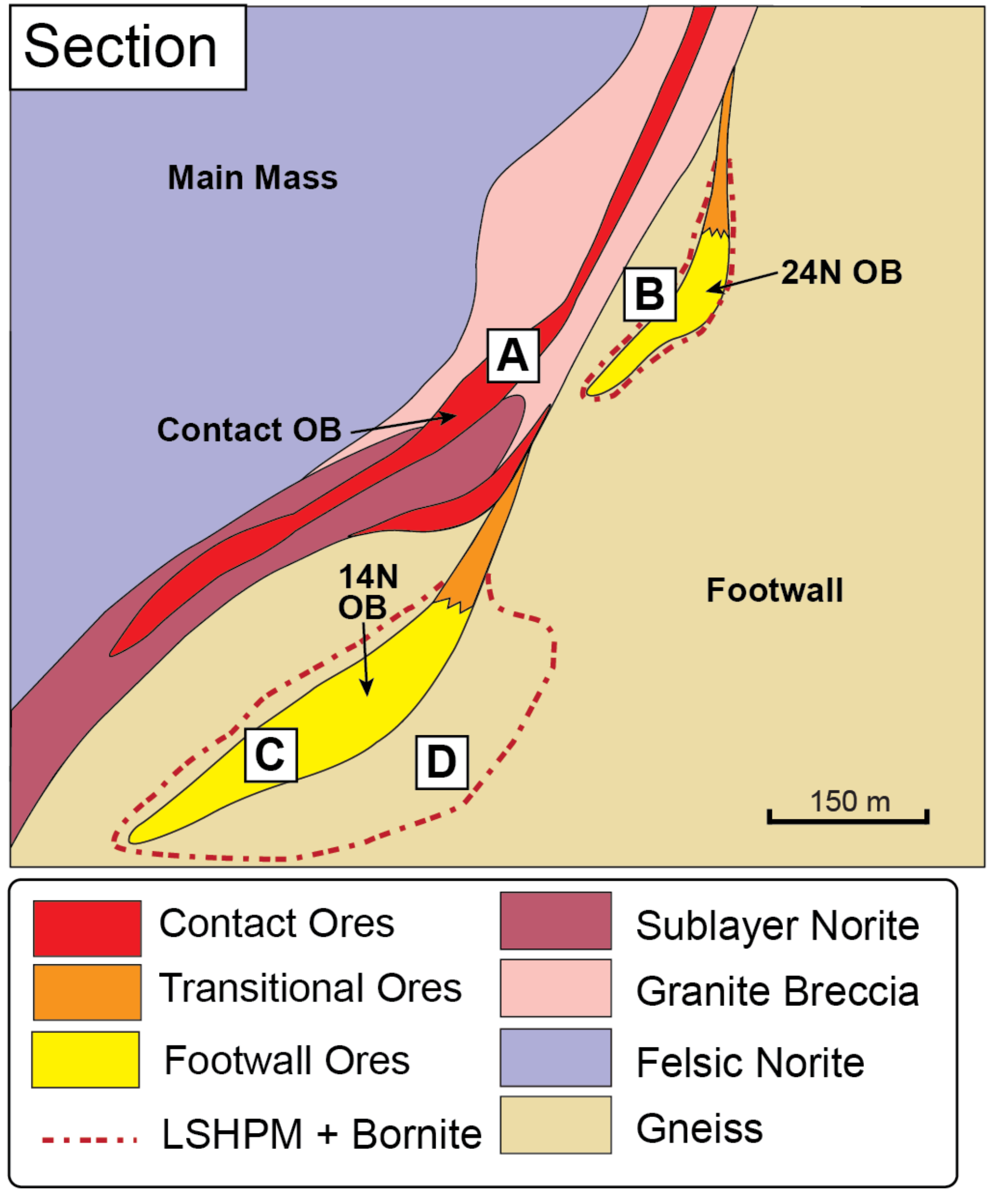


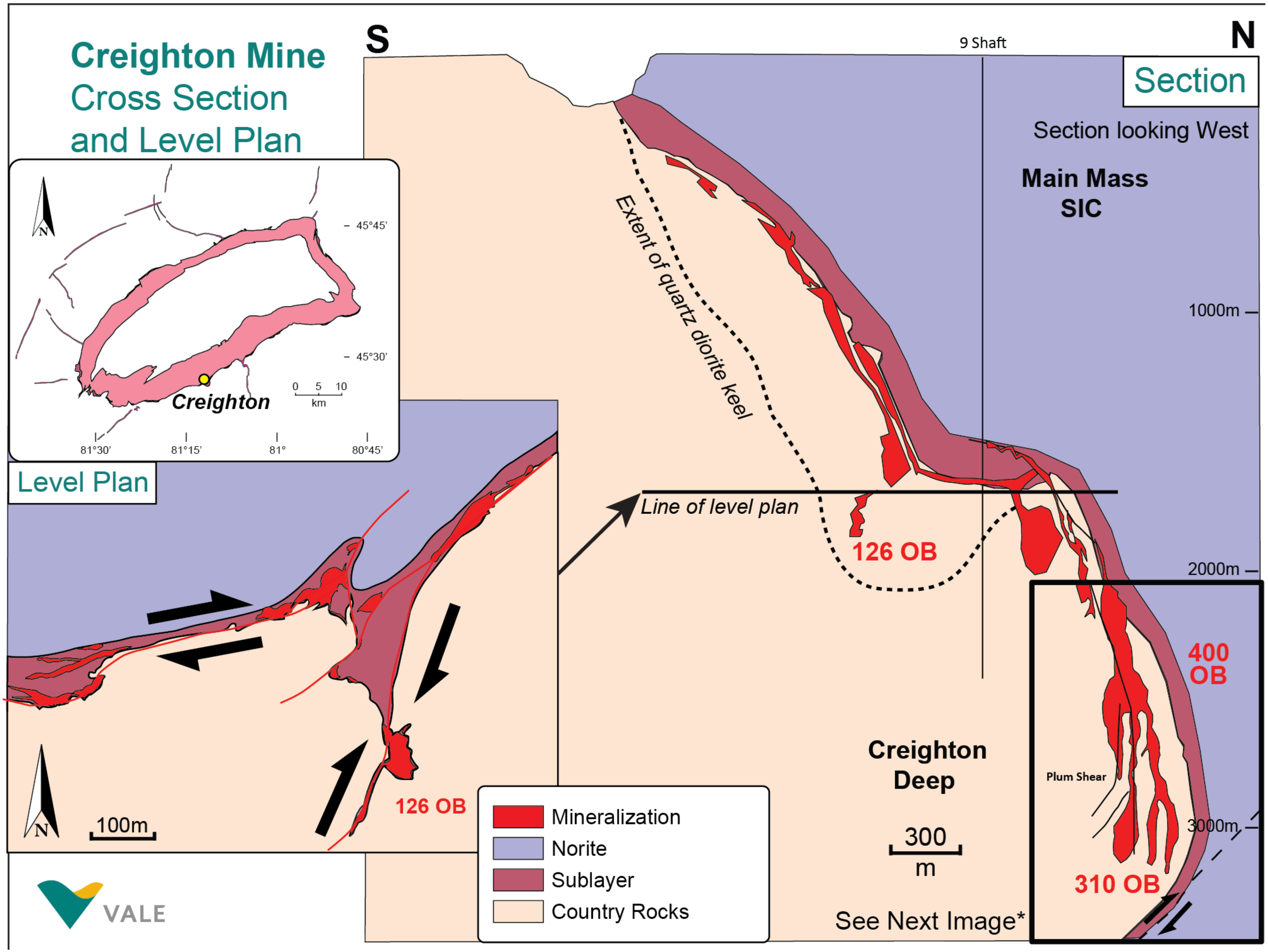
Victor Deposit
Geological Cross Section
Looking NorthWest
Victor
45°45'
45°30'
0 5 10
km
81°30'
81°15'
81°
80°45'
N
Contact Ores
Transitional Ores
Footwall Ores
LSHPM + Bornite
Felsic Norite
Mafic Norite
Sublayer Norite
Granite Breccia
Sudbury Breccia
Felsic Gneiss
Metadiabase
VALE
Geological Model prepared
by Enrick Tremblay
A
A'
4800L
5800L
6800L
7800L
8800L
Section
% Ni, % Cu, g/t TPM
meters (true thickness)
150 m
Main Mass
Contact OB
24N OB
14N
OB
Footwall
2.4, 4.5, 3.4
30
2.1, 0.3, 0.1
20
2.3, 9.0, 11.1
50
0.8, 3.5, 9.9
25

Victor Deposit

Mineralogy of contact, transitional, and footwall sulfides



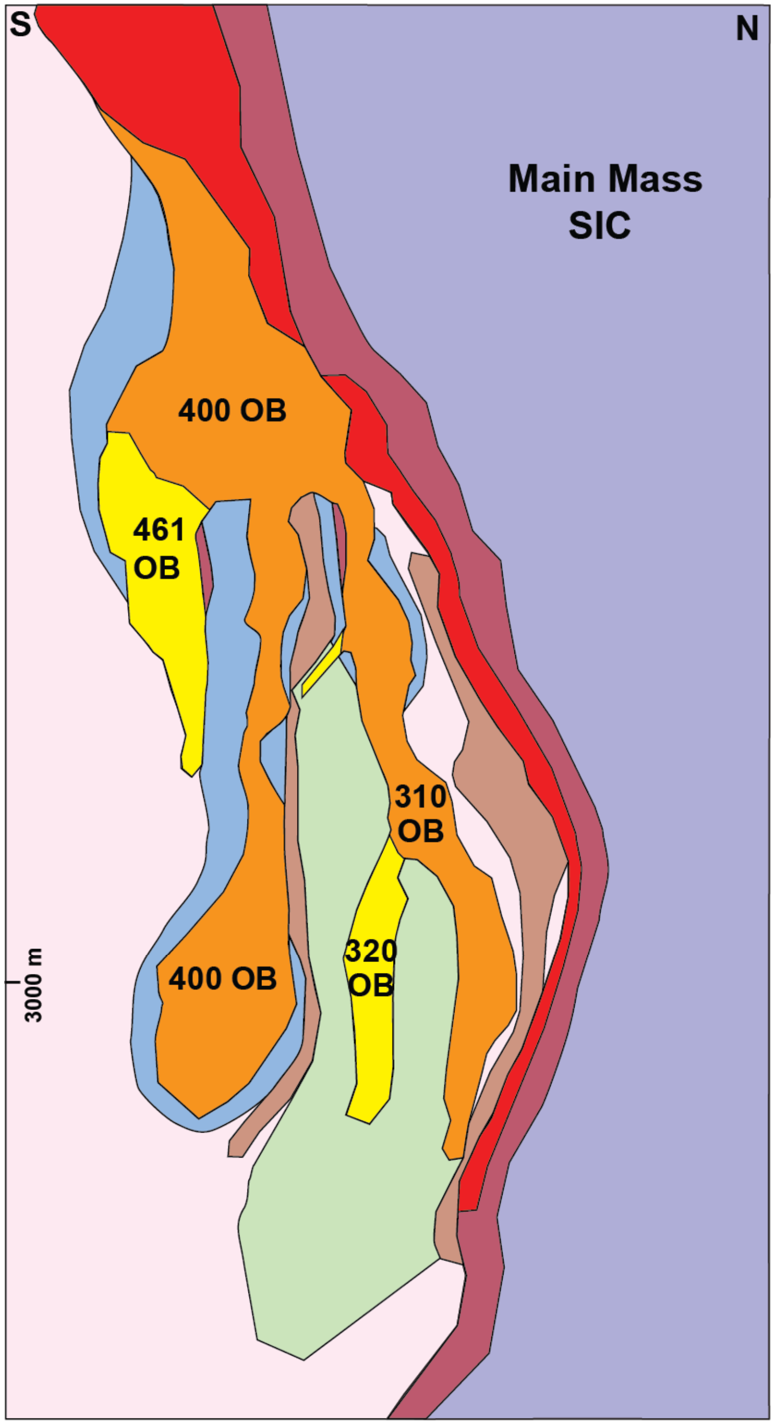




Creighton Mine
Cross Section
and Level Plan
S
N
9 Shaft
Section
Section looking West
Main Mass
SIC
45°45'
45°30'
Creighton
0 5 10
km
81°30'
81°15'
81°
80°45'
Level Plan
Extent of quartz diorite keel
1000m
Line of level plan
126 OB
2000m
400
OB
Creighton
Deep
Plum Shear
3000m
300
m
310 OB
126 OB
100m
Mineralization
Norite
Sublayer
Country Rocks
See Next Image*
VALE

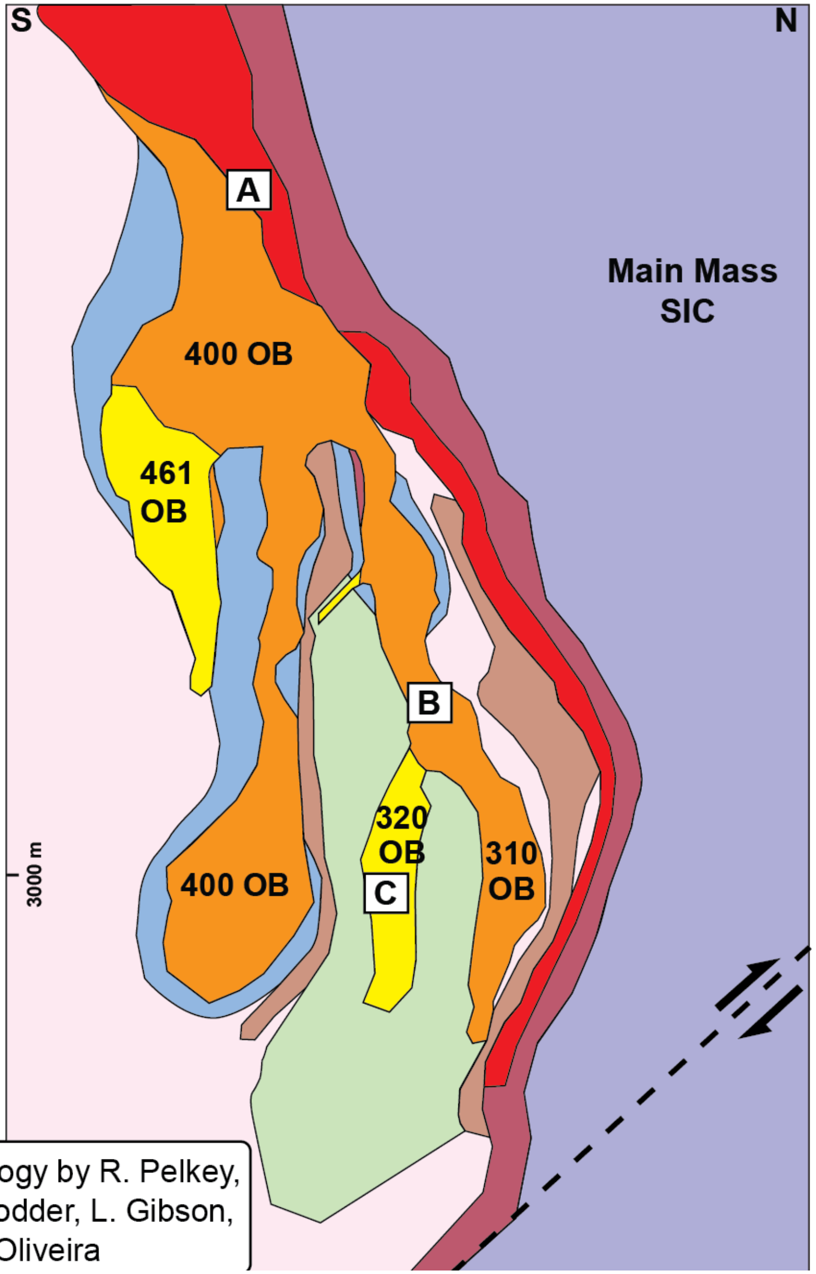
Geological model of Creighton Deep looking west showing orebodies and shear zones and kinematics

- Contact Sulfide
- Transitional Sulfide
- Footwall Sulfide
- Norite
- Sublayer Norite
- Sudbury Breccia
- Black Granite Porphyry
- Creighton Pluton
- Huronian



Geology by R. Pelkey, D. Hodder, L. Gibson, J. D'Oliveira

Creighton Deep: Mineralogy of the Contact, Transition, and Footwall Sulfides



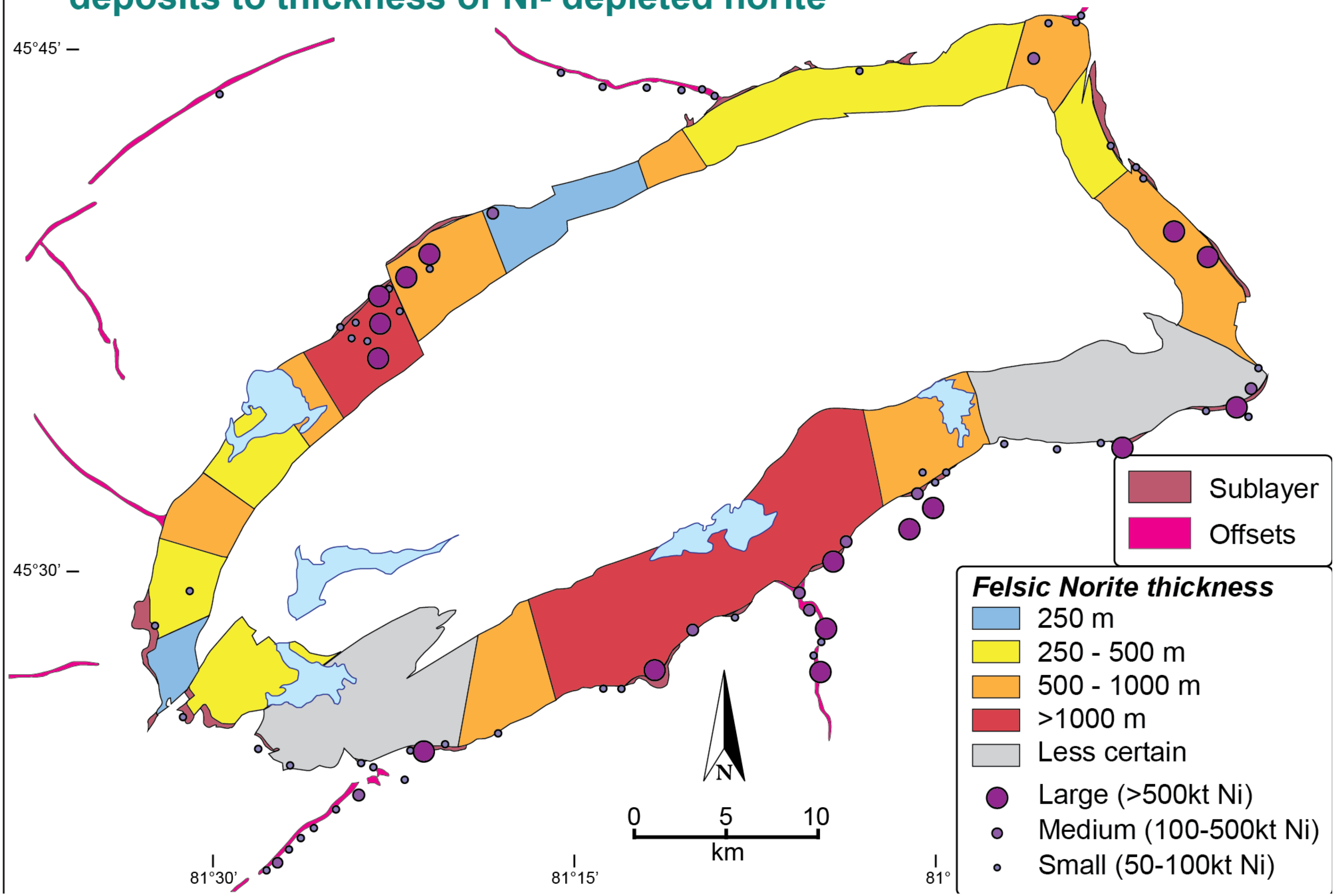
Geology by R. Pelkey, D. Hodder, L. Gibson, J. D'Oliveira

400 OB example: 5.7%Ni - 3.5%Cu - 1.1g/t over 35m true width.

310 OB example: 5.2%Ni - 2.7%Cu - 2.5g/t over 20m true width.

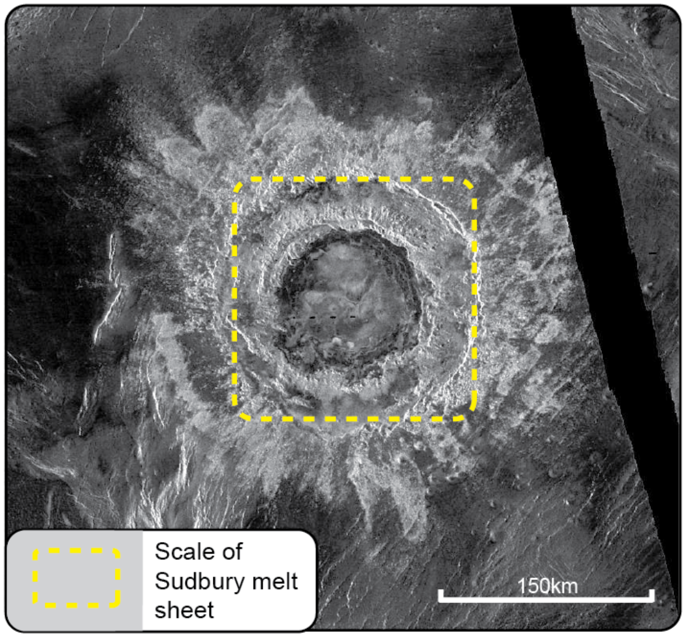
320 OB example: 2.6%Ni - 4.6%Cu - 4.8g/t over 10m true width.

Sudbury Igneous Complex relationship of main ore deposits to thickness of Ni- depleted norite

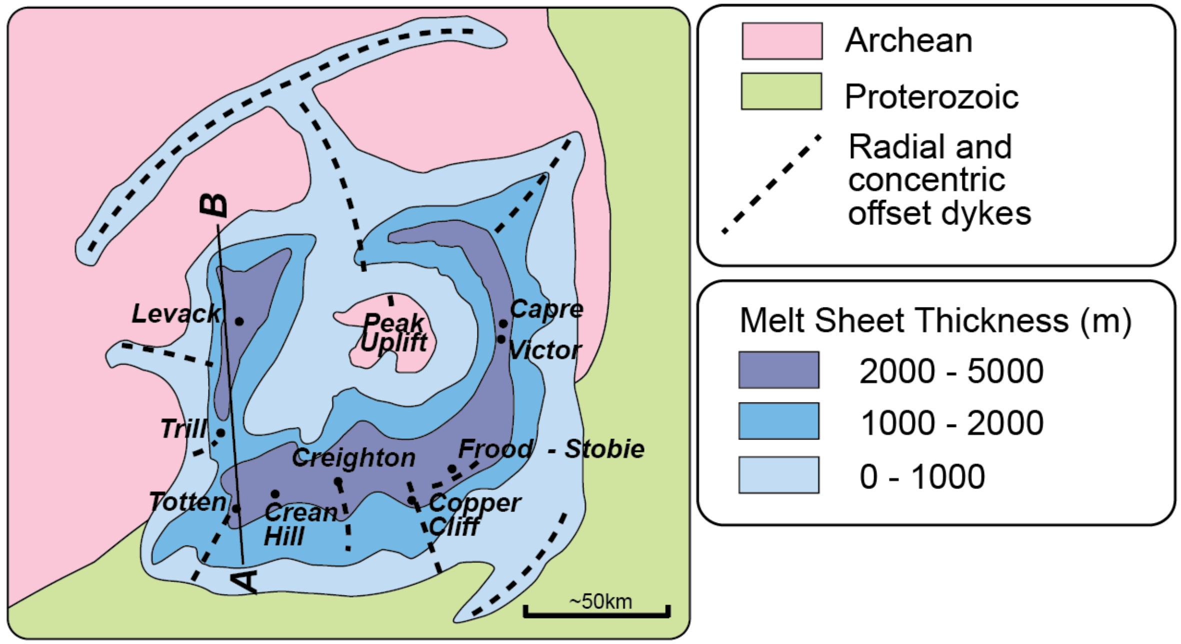


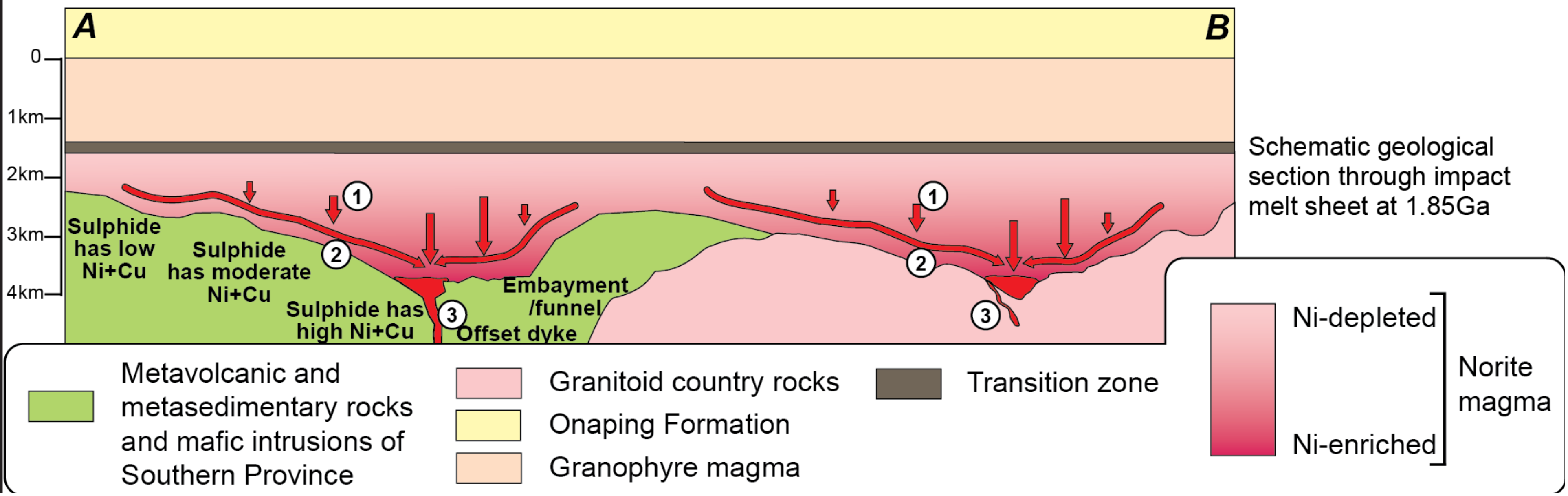
Sudbury impact crater: model for ore genesis

Photo mosaic of Meitner impact crater, Venus.



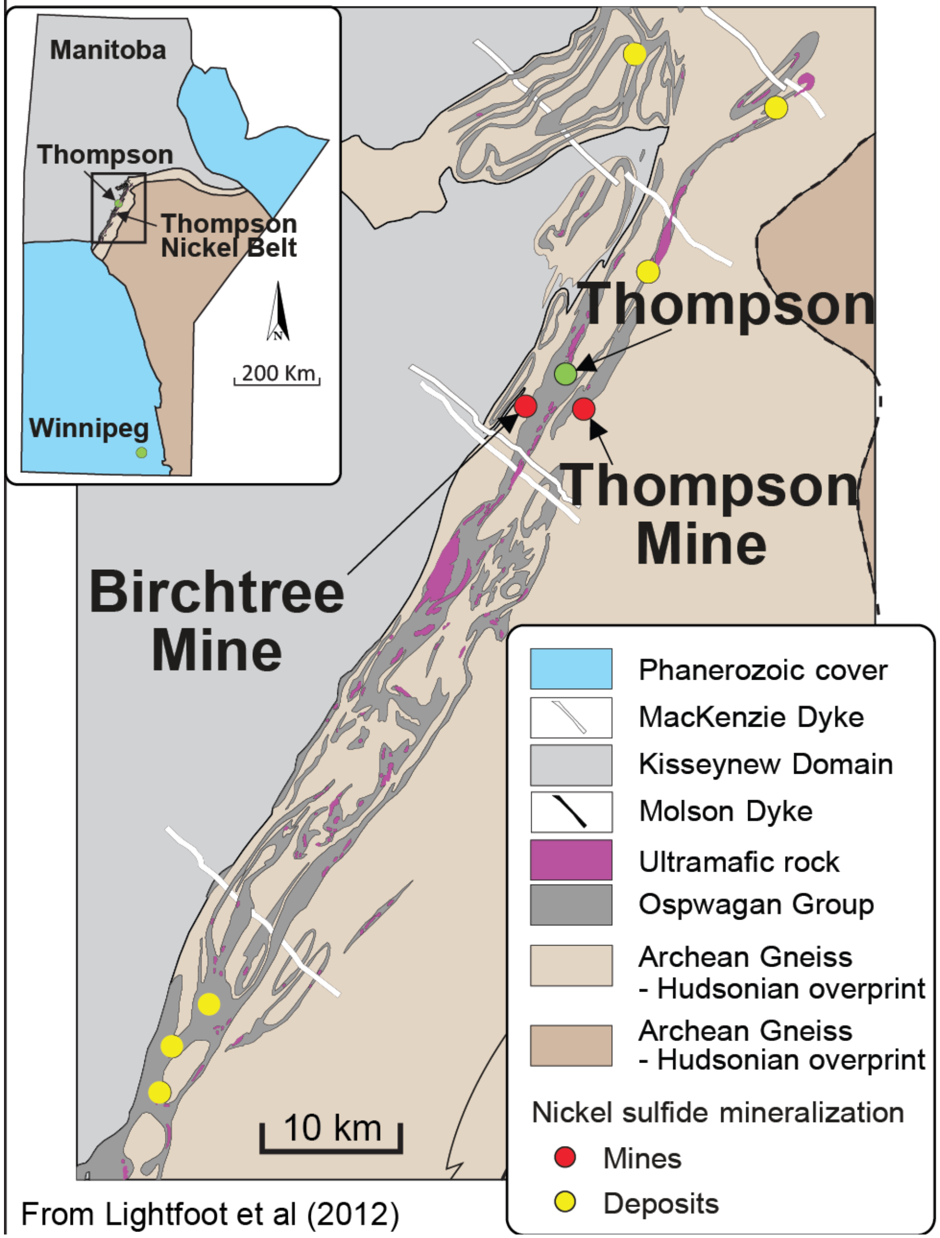
Schematic geology of the Sudbury impact melt sheet at 1.85Ga



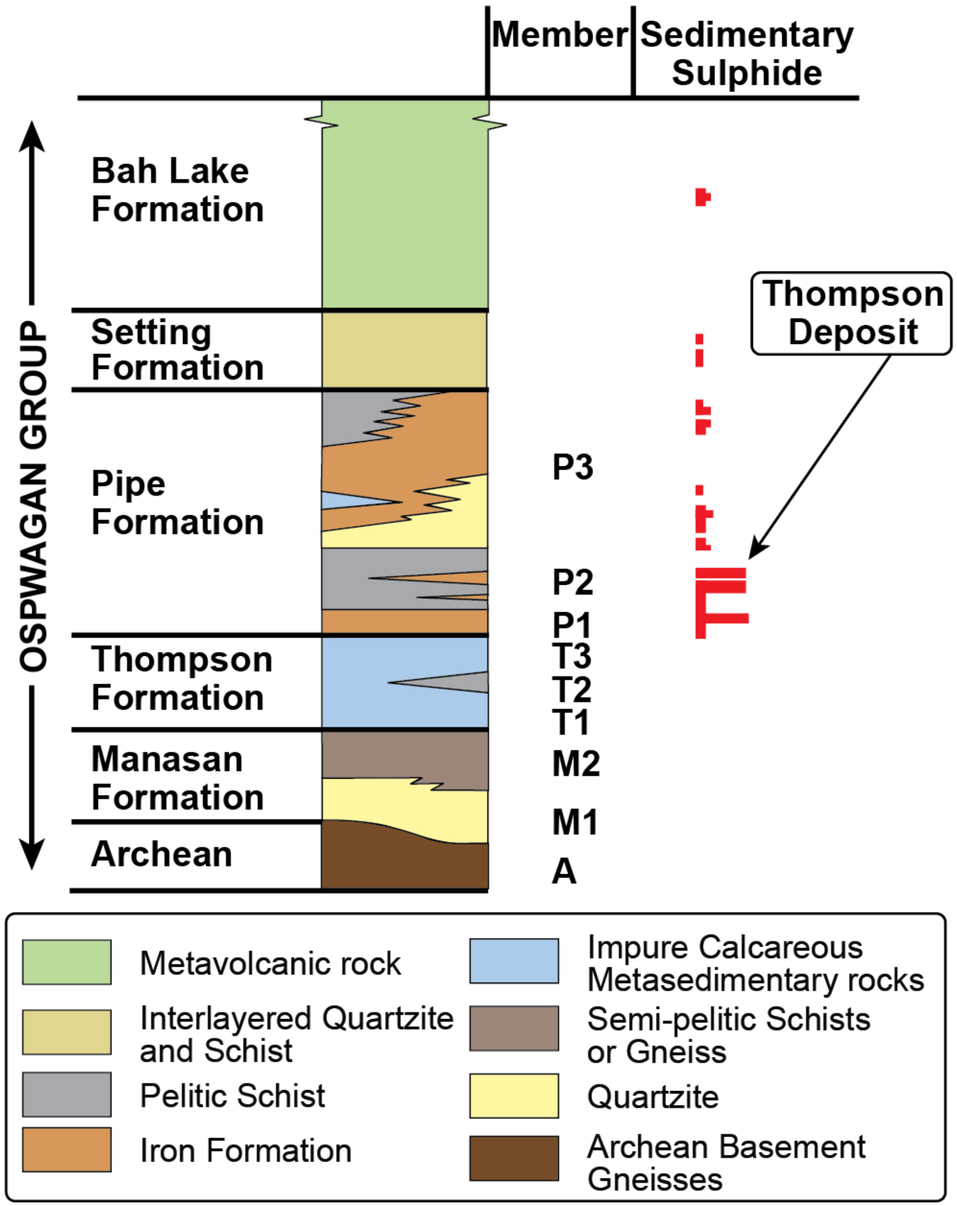


Schematic geological section through impact melt sheet at 1.85Ga

Thompson Nickel Belt
Geology and Stratigraphy

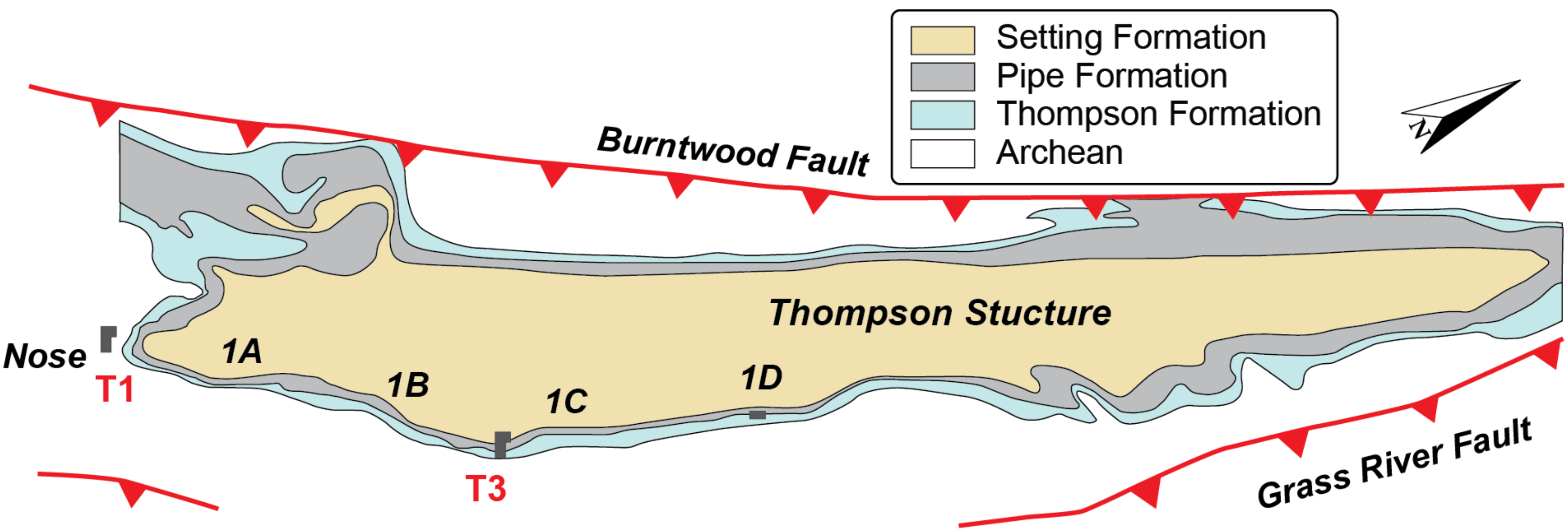


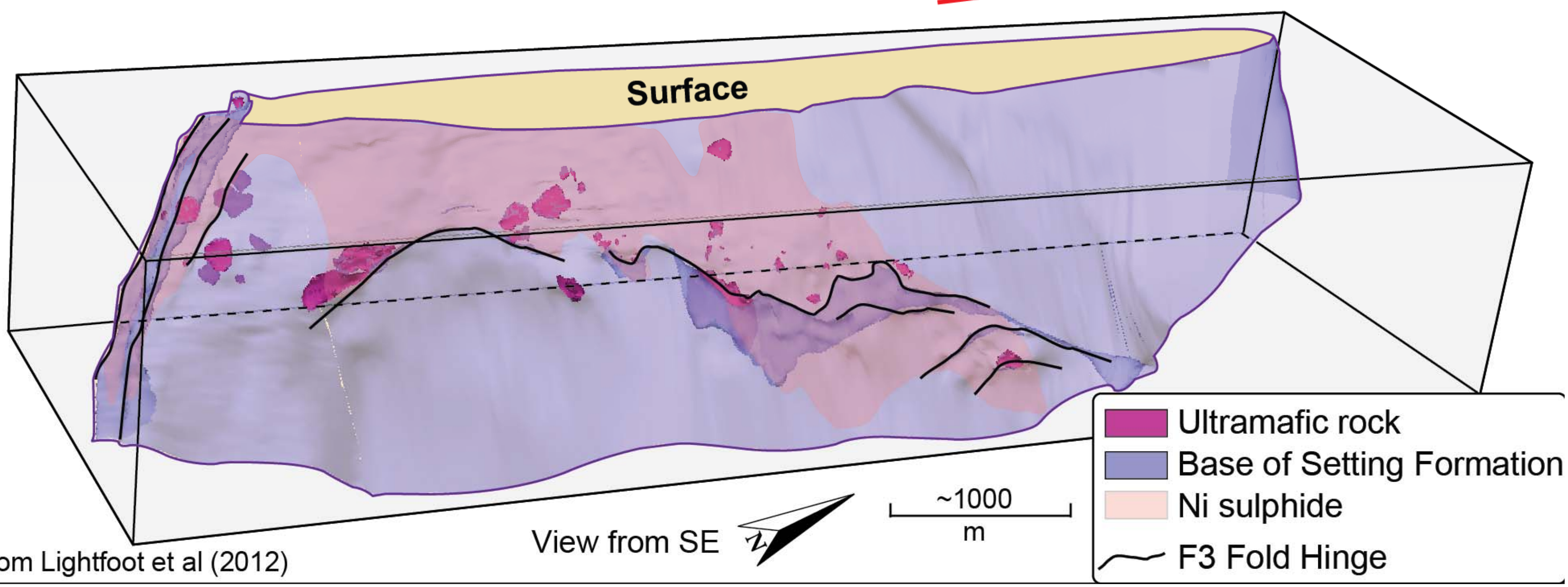
From Lightfoot et al (2012)



after Bleeker and Macek (1990)

Plan and 3D View of the Thompson Dome

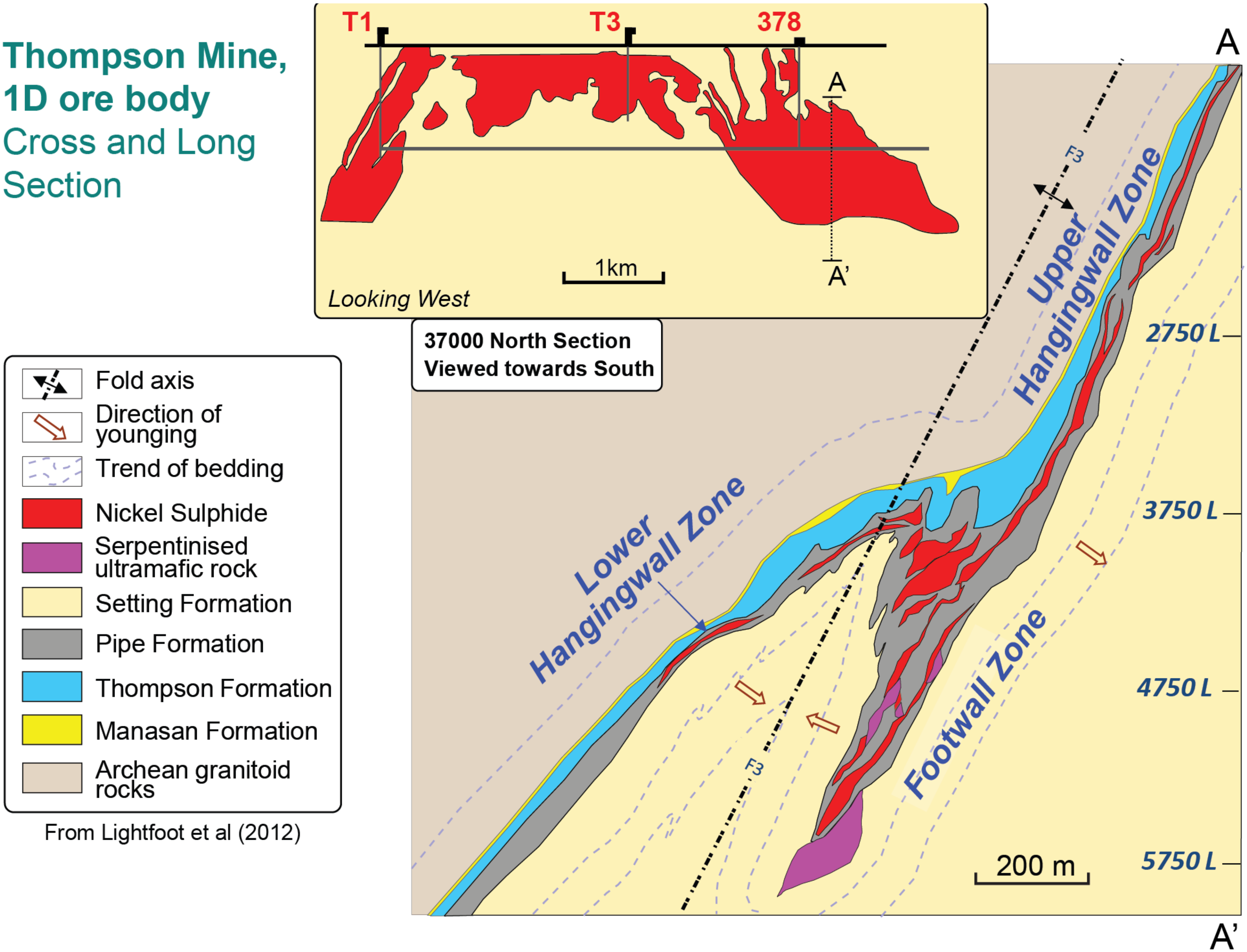




From Lightfoot et al (2012)

Thompson Mine, 1D ore body

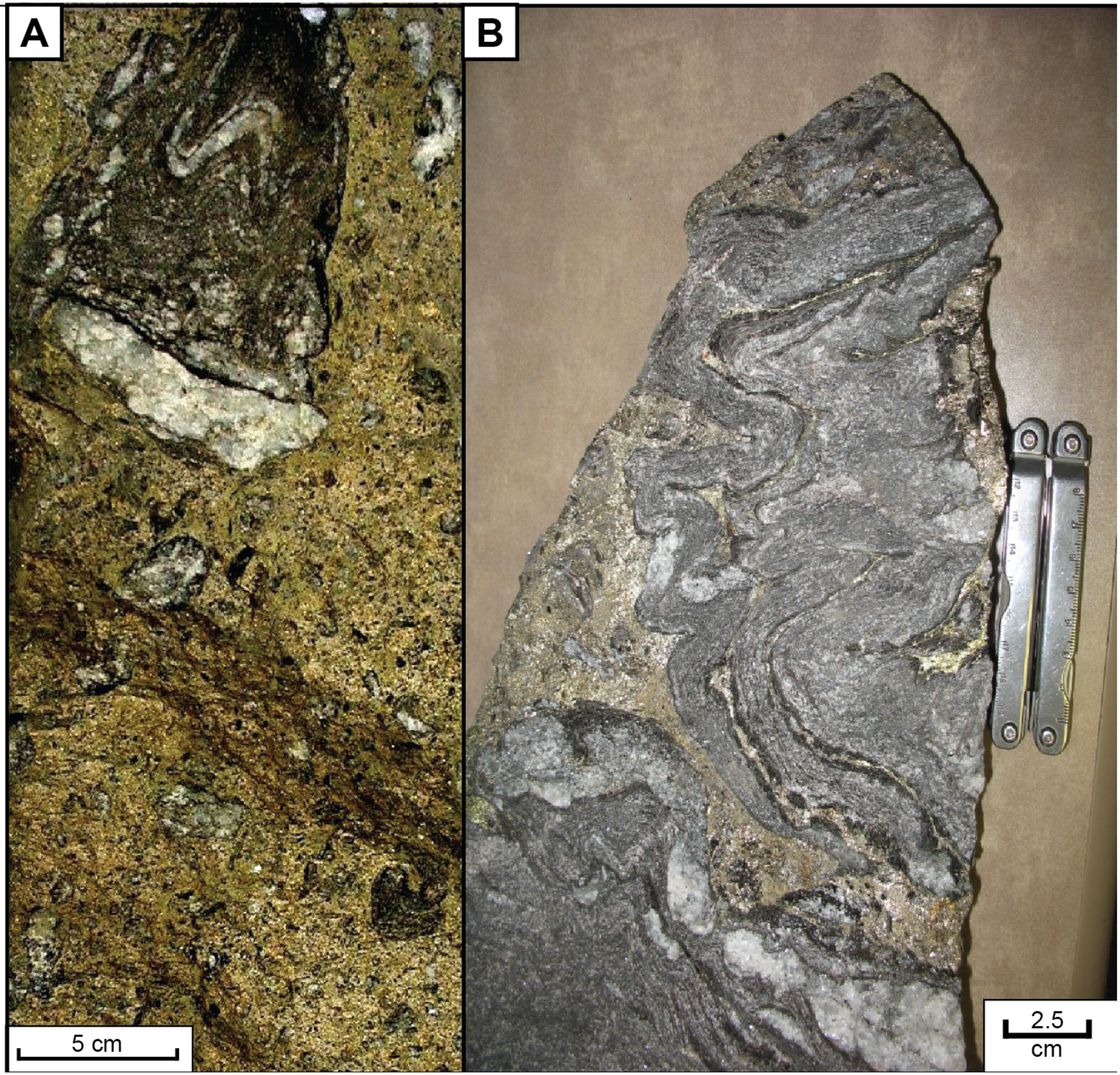
Cross and Long Section



From Lightfoot et al (2012)

Thompson Mine

1D Deposit
Typical ore and host rock

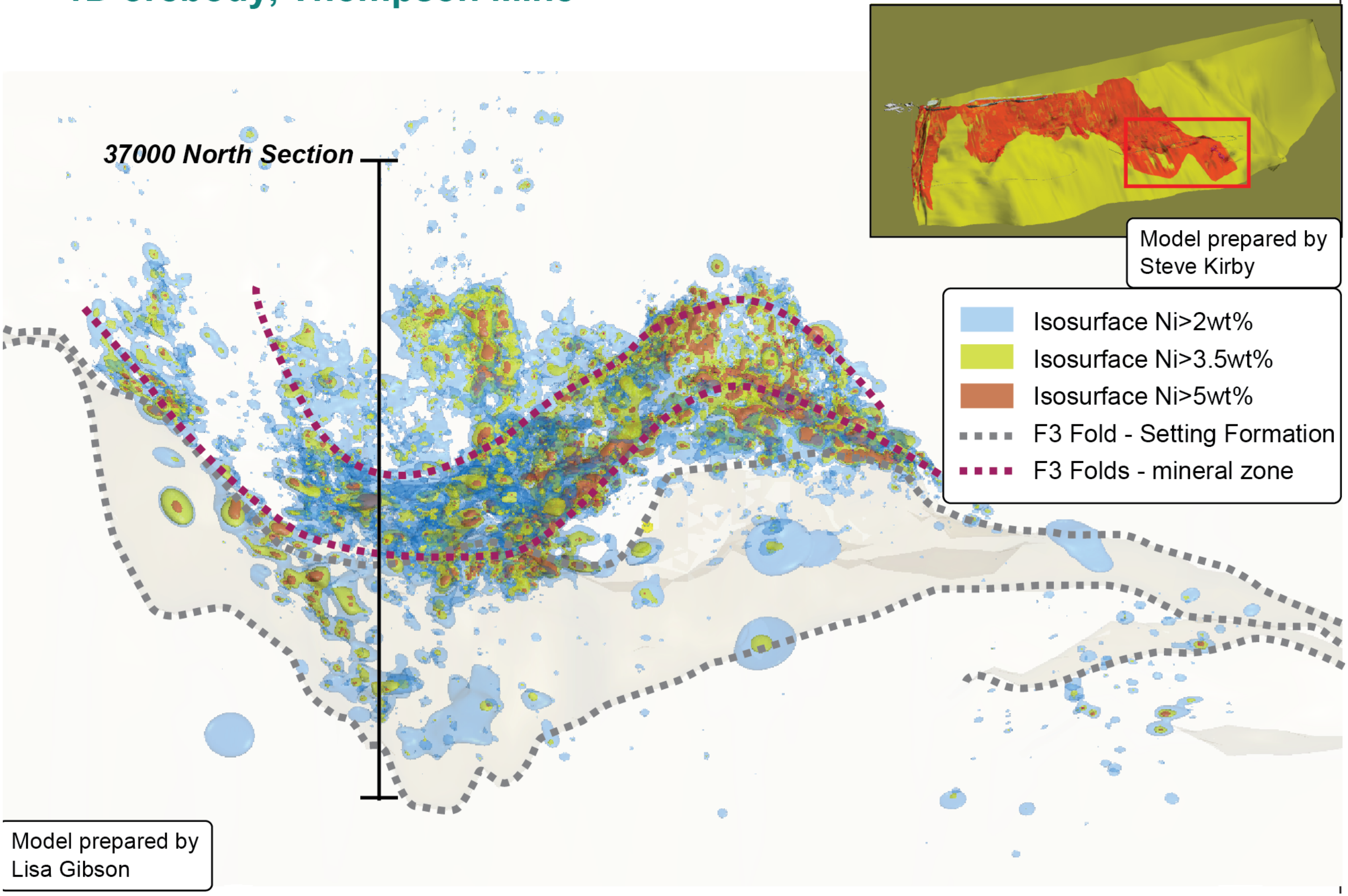


1D Deposit:

A. Inclusion Massive Sulfide

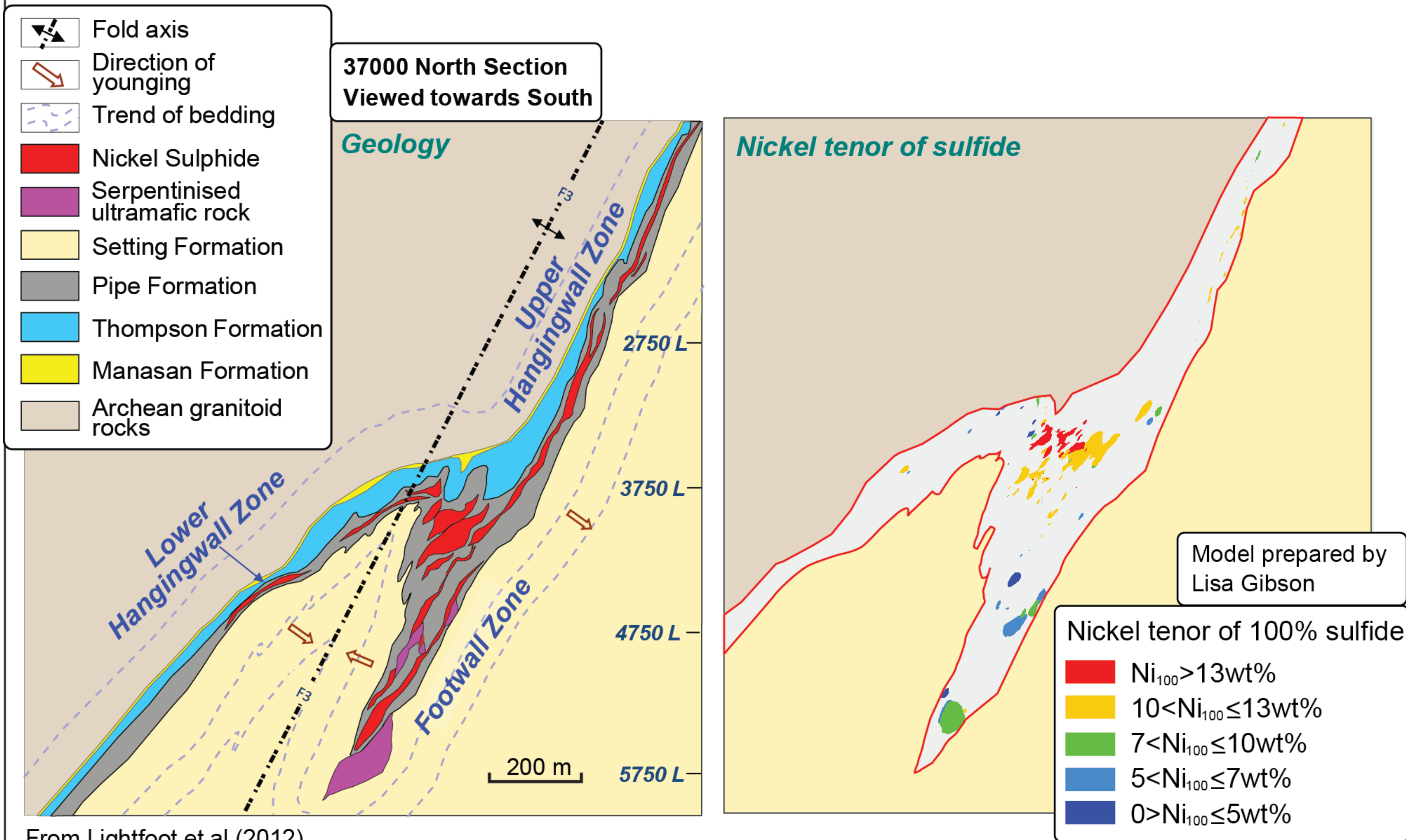
B. Pipe Formation with sulfide

Leapfrog model showing Ni grade distribution in the 1D orebody, Thompson Mine



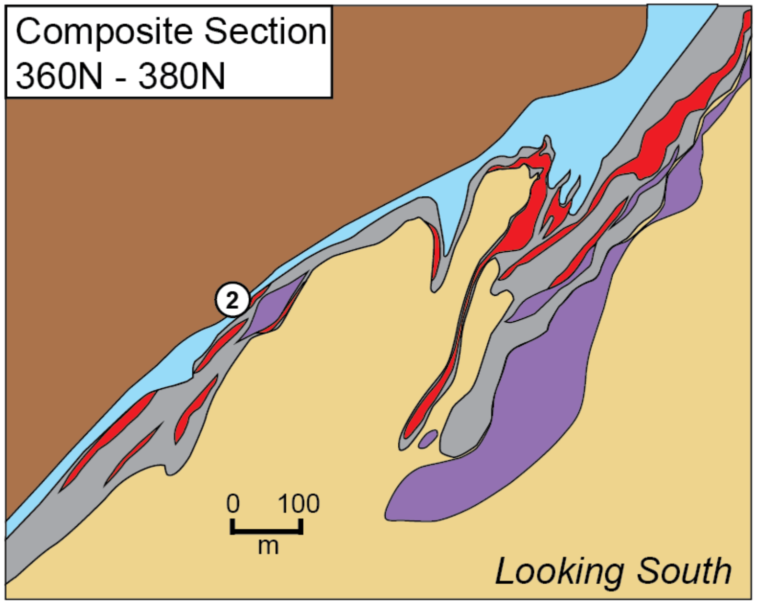
Leapfrog tenor shell model for Nickel in the 1D orebody, Thompson Mine

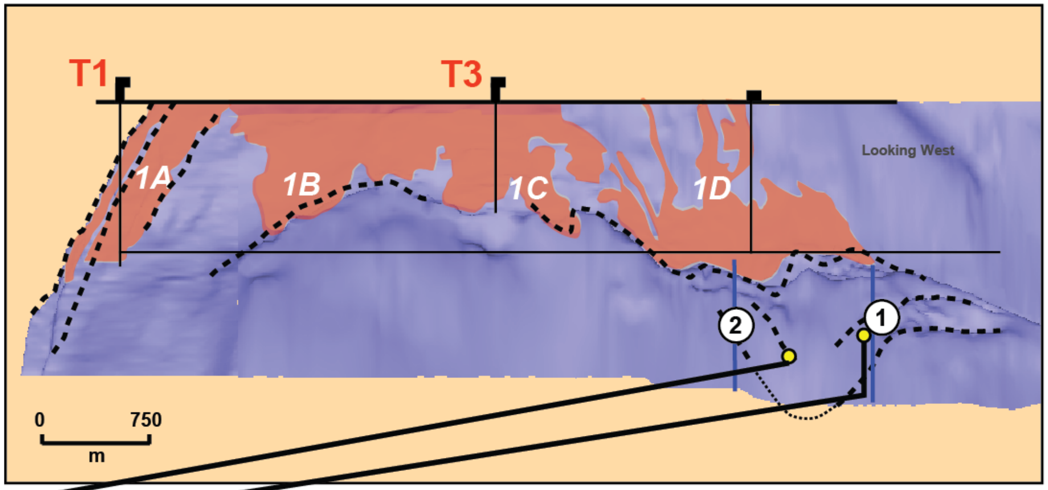
Cross Section



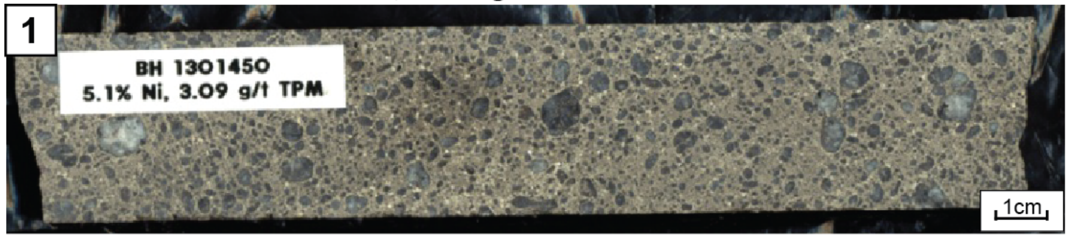
From Lightfoot et al (2012)

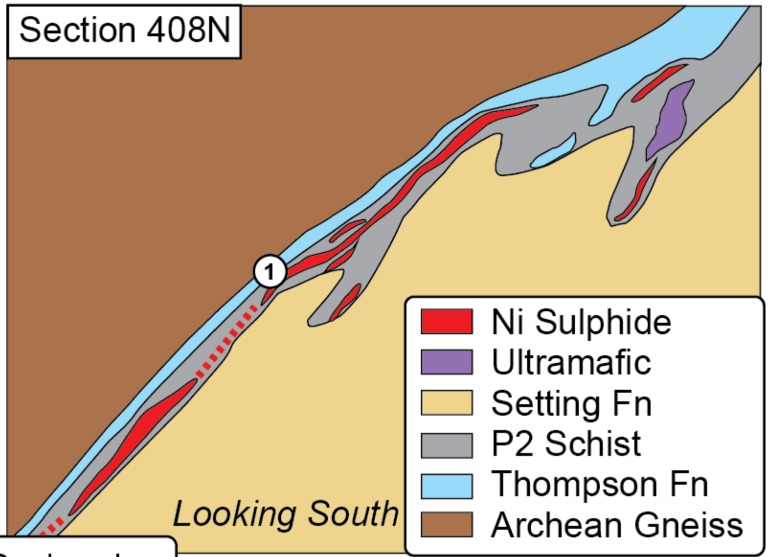
Structural controls on mineral zones in Thompson Extensions Zone



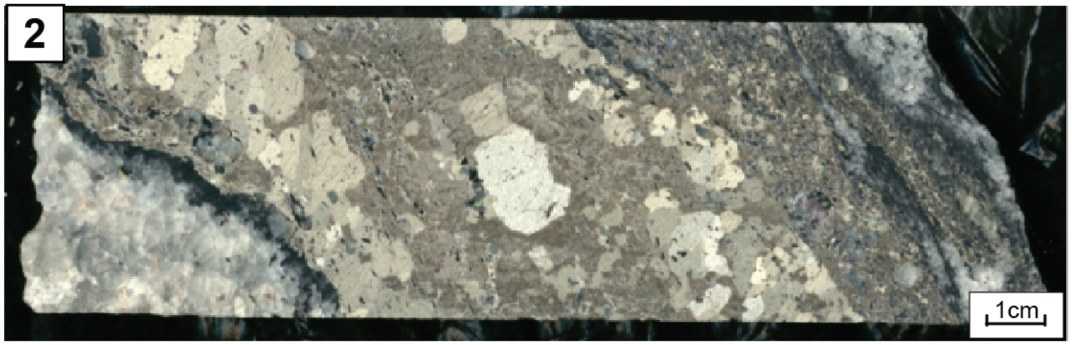


BH 1301450 4.75% Ni, 1.28 g/t TPM / 31.0m True



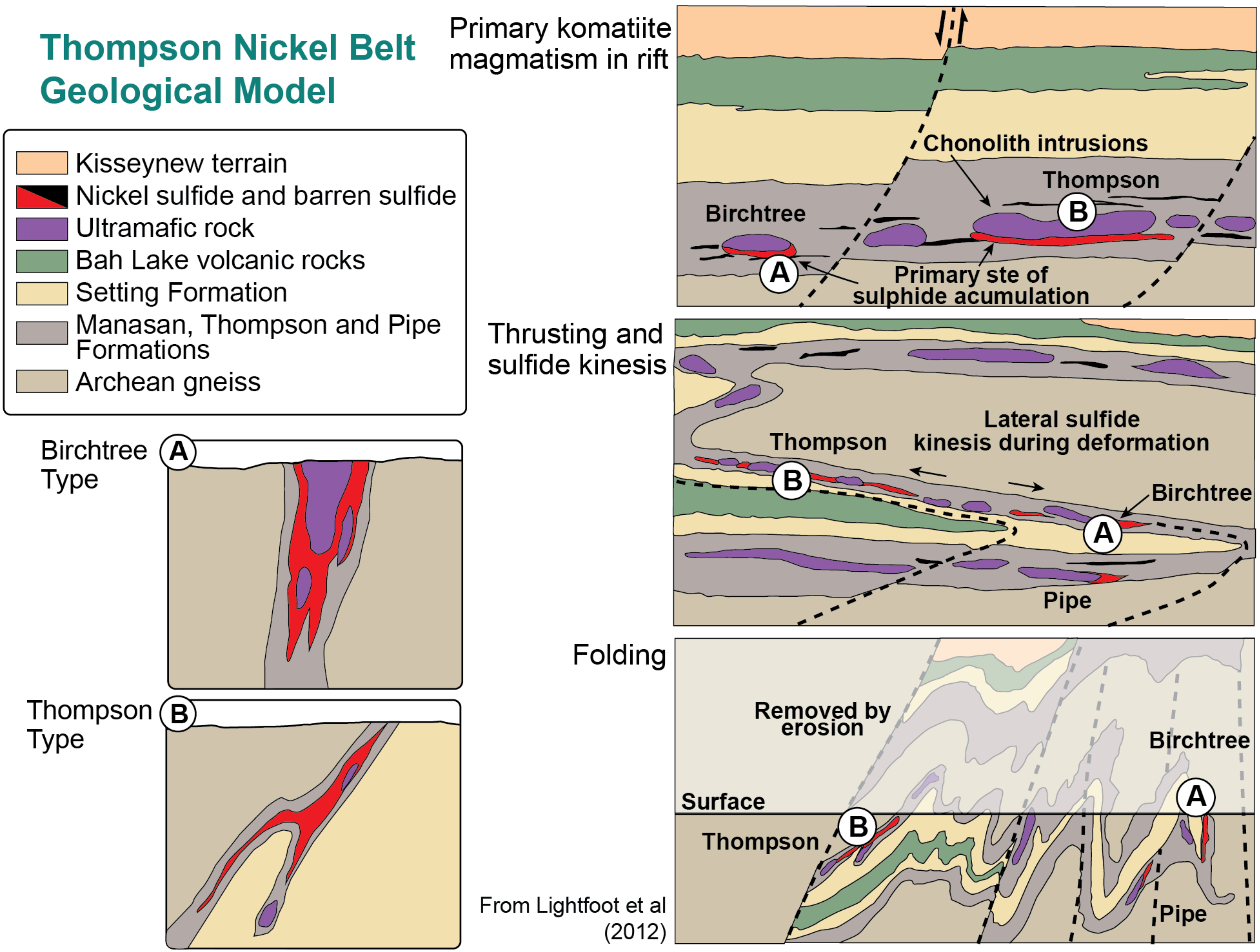


BH 1140690 2.04% Ni, 0.505 g/t TPM / 17.1m True



Geology by
Steve Kirby

Thompson Nickel Belt Geological Model



From Lightfoot et al (2012)

Summary

- A spectrum of structural controls:
  - Primary morphology of the "ore containers"
  - Syn-magmatic tectonic adjustments
  - Post-magmatic dislocation/deformation
- Voisey's Bay:
  - Steep plunge of primary chonolith in dyke
  - Syn-deformational flat structures modify geometry
- Sudbury:
  - Impact crater topography creates ore system
  - Re-adjustment space for footwall ores
  - Post-impact deformation displaces ores
- Thompson:
  - Magmatic sulfide models don't help much
  - Structural trends of ore bodies reflect four phases of deformation

Acknowledgements

- Brownfield Exploration team contributions to this presentation
  - Scott Mooney, Mars Napoli, Glenn McDowell, Clarence Pickett, Rob Pelkey,Darren Hodder Sandy Gibson, Enrick Tremblay, Rob Stewart, Graeme Gribbin, Steve Kirby, Dawn Evans-Lamswood, Danny Mulrooney, Sheldon Pittman, Joe D'Oliveira Lisa Gibson and Alex Gagnon
- Vale for permission to give this talk