Microanalytical geochemical analysis of texturally variable pyrite associated with mineralization and surrounding host rocks in the Howard's Pass District, Selwyn Basin, Yukon

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Rationale and Purpose

This study aims at improving the current understanding of the controls on metal enrichment and distribution in the Zn-Pb sedimentary exhalative (SEDEX) deposits comprising the Howard's Pass district (HPD; fig. 1). The trends and variations observed in the geochemical and mineral textural data will be used to identify horizons at which mineralizing events occurred, and to vector along those horizons towards concealed sedex deposits. The first part of this study is to characterize the trace and minor element geochemistry of pyrite.

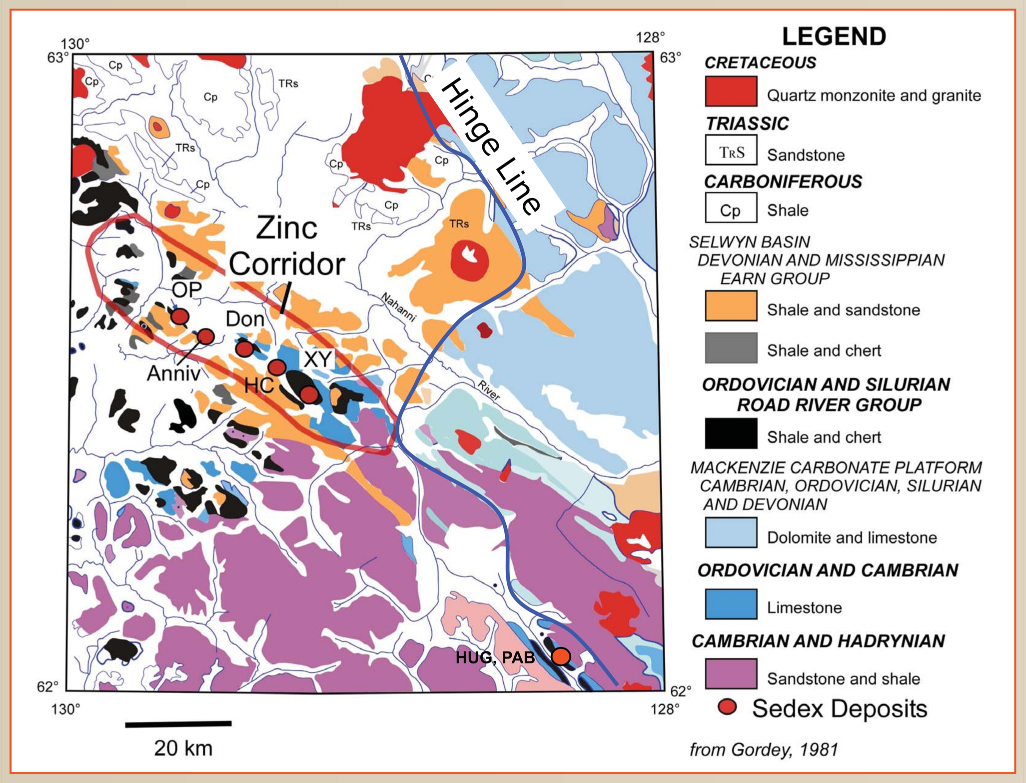

Fig. 1: Geological map showing significant sedex deposits in the 'Zinc Corridor' (the broad area within which Zn mineralization occurs; modified from Goodfellow, 2004).

Regional Geology

The HPD is located in the Selwyn Basin, an Upper Proterozoic to Paleozoic continental margin basin filled by thick successions of fine-grained siliciclastic and calcareous sedimentary rocks (Goodfellow, 2004). The Selwyn Basin is a prolific metallogenic province that is primarily known for its world-class Zn-Pb (±Ag±Ba) SEDEX deposits. The HPD hosts 14 SEDEX Zn-Pb-Ag deposits along a 40km trend near the eastern margin of the Selwyn Basin astide the Yukon/NWT border (SCML press release, 2010).

SEDEX mineralization in the HPD is hosted in the Duo Lake Formation, a succession of Llandoverian carbonaceous calcareous to siliceous mudstones and limestones (Gordey and Anderson, 1993). The strata in the Duo Lake formation that contain SEDEX mineralization are collectively referred to as the Active Member (ACTM; Morganti, 1979).

Zn-Pb mineralization within the ACTM is predominantly sphalerite and galena. Sphalerite occurs as fine laminae (<1mm), interlaminated with galena and framboidal pyrite. Non-laminated sphalerite occurs less commonly as light brown crystalline blebs. Galena occurs predominantly within laminae associated with sphalerite; however, high-grade galena mineralization occurs as cleavage controlled stringers. The ACTM has three mineralized sub-units: 1) finely laminated dark grey to brown mudstone, 2) calcareous white to grey Zn-Pb-rich mudstone and 3) silicic white to grey Zn-Pb-rich mudstone. SEDEX mineralization has been interpreted to be the product of venting of hydrothermal fluids and precipitation of fine-grained sulphide minerals near the seafloor, where the laminae were rhythmically deposited (Goodfellow, 1984, 2004).

Methods

Petrographic analyses of pyrite has shown:

1) Growth zoning and morphological variability are present in pyrite and imply a dynamic and protracted growth history.

2) Microscopic sphalerite, galena and chalcopyrite inclusions that are common to all forms of pyrite throughout the HPD stratigraphic succession.

Preliminary electron-probe micro-analysis (EPMA) and laser ablation inductively coupled plasma-mass spectrometry (LA ICP-MS) data reveal elemental zoning in pyrite from the Duo Lake and Steel formations. Elemental zonation imitates textural zonation, suggesting metalliferous fluids persisted after the mineralization event responsible for the Zn-Pb SEDEX deposits that define the HPD.

Pyrite Morphology and Geochemistry

Pyrite is a minor but ubiquitous component of the ore mineralogy (i.e., dominantly composed of sphalerite and galena) and host carbonaceous mudstones at HPD. Pyrite occurs as framboids, bedding-parallel wispy to well-formed bands, nodules and porphyroblasts (fig. 2). Two stages of overgrowth are common in pyrite crystals present throughout the HPD stratigraphic succession (fig. 2, 3D).

Framboids are interpreted to be the earliest form of pyrite (py 1) and they occur as discrete framboids or as polyframboidal masses in laminae. Individual framboids are commonly <5μm, but can be up to 50μm in diameter (fig. 3A). Bedding-parallel pyrite bands and nodules are diagenetic pyrite forms. Bands (py 2a) comprise subhedral to euhedral pyrite crystals and are <0.1mm to several mm thick (fig. 3B). Bands are interpreted as overprinting laminated py 1. Pyrite nodules (py 2b) comprise intergrown subhedral pyrite crystals with radial growth patterns. Nodules range in size from 0.5cm to 1.5cm and are commonly enveloped by quartz+calcite±mica strain shadows parallel to the regional cleavage (fig. 3C). Nodules are interpreted as overprinting polyframboidal masses (py1). Porphyroblastic pyrite is the latest stage of pyrite growth (py 3). Porphyroblasts form subhedral and euhedral crystals oriented parallel to the regional cleavage and range in size from 0.1mm to 500mm (fig. 3D).

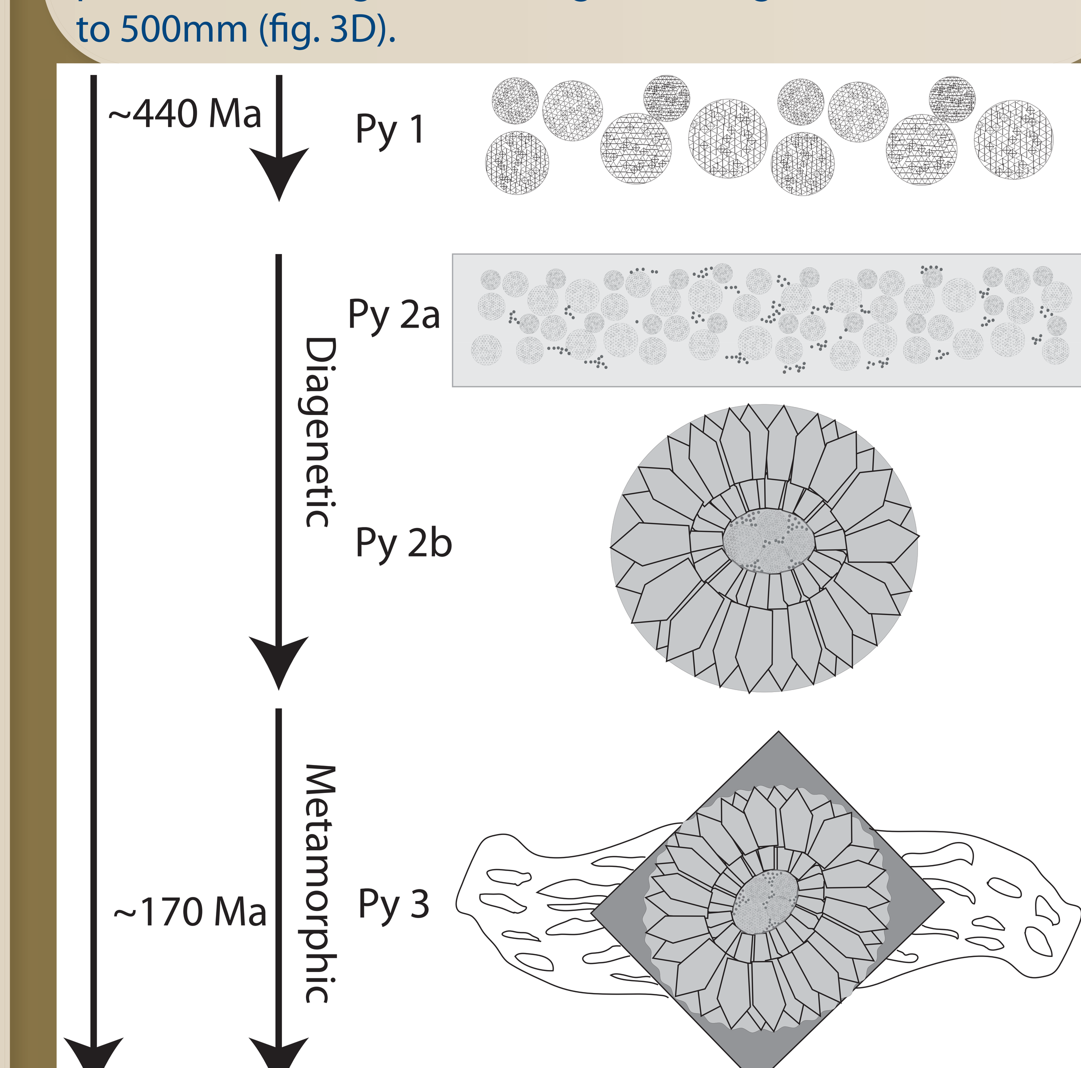

Figure 2: Idealized paragenetic diagram of pyrite growth stages. Py 1 consists of syngenetic to early diagenetic framboidal pyrite. Py 2a consists of diagenetic pyrite that overprints and recrystallizes laminated py 1. Py 2b consists of diagenetic nodular pyrite that overprints and recrystallizes py 1. Py 3 consists of late metamorphic pyrite that overgrows all preceding generations of pyrite.

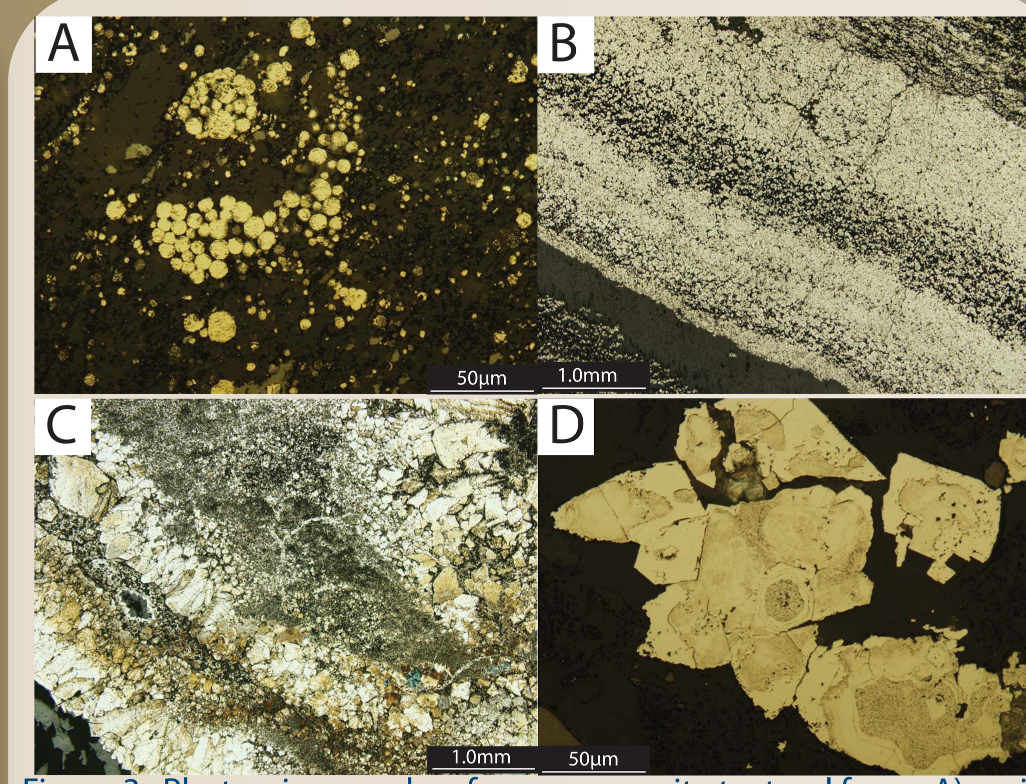

Figure 3 : Photomicrographs of common pyrite textural forms A) pyrite framboids (py 1); B) diagenetic, bedding parallel bands (py 2a); C) growth-zone diagenetic nodular pyrite (py 2b); and D) growth zoned euhedra within strain shadows (py 3).

Preliminary EPMA-WDS and LA ICP-MS data reveal spatial control of trace and minor elements in the various textural forms of pyrite in the HPD:

1) Ni, Cu and As display zonation in porphyroblastic pyrite from the upper Duo Lake Formation (fig. 4, table 1). Interior pyrite growth zones are characterized by moderate to high Ni and Cu contents, and As contents below the analytical detection limit. Cores of the interior growth zones have high Ni and lower Cu contents (1170ppm and 340ppm, respectively). The Ni content decreases away from the cores and the Cu content increases (380ppm and 600ppm, respectively). Clear pyrite rims are characterized by low Cu contents (150ppm) and high Ni and As contents (4500ppm and 990ppm, respectively). Chalcopyrite commonly forms at the margin between the inner and outer growth zones, and also forms at the exterior margin of pyrite crystals.

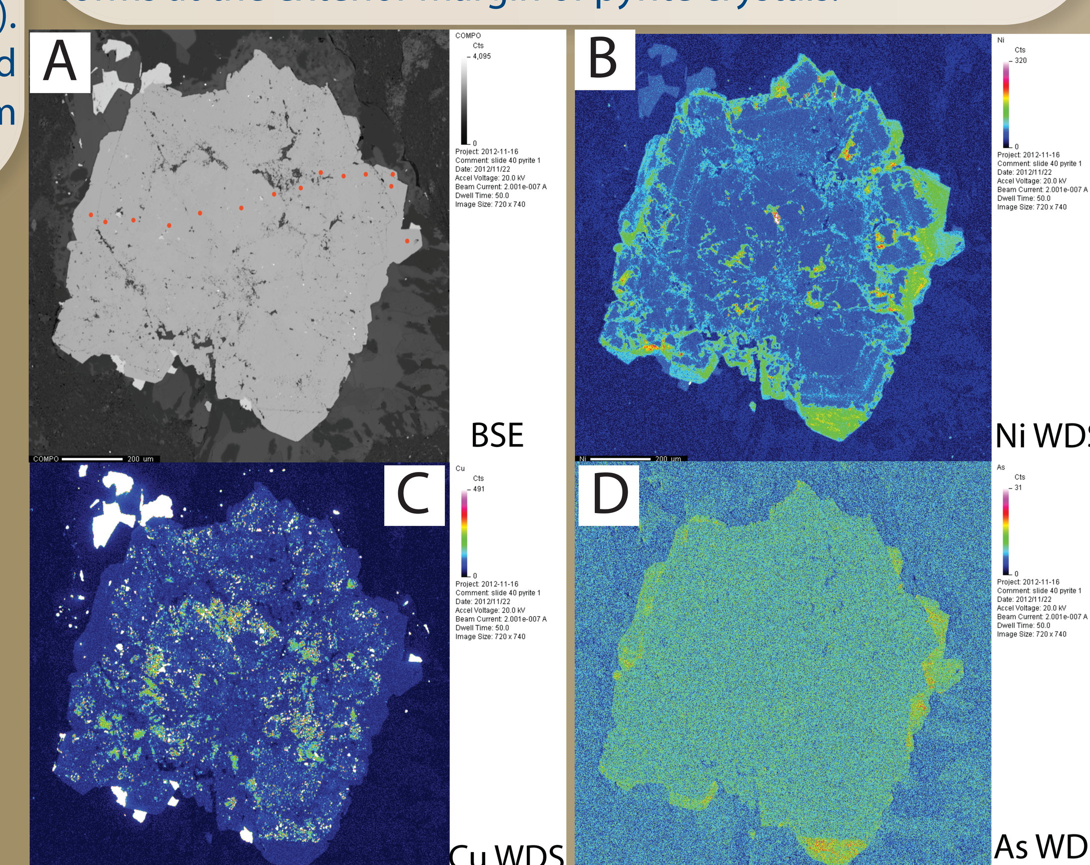

Figure 4: A) EPMA-WDS BSE raster element maps of a pyrite porphyroblast with B) Ni, C) Cu and D) As. Colour ramps for intensities are in counts per second.

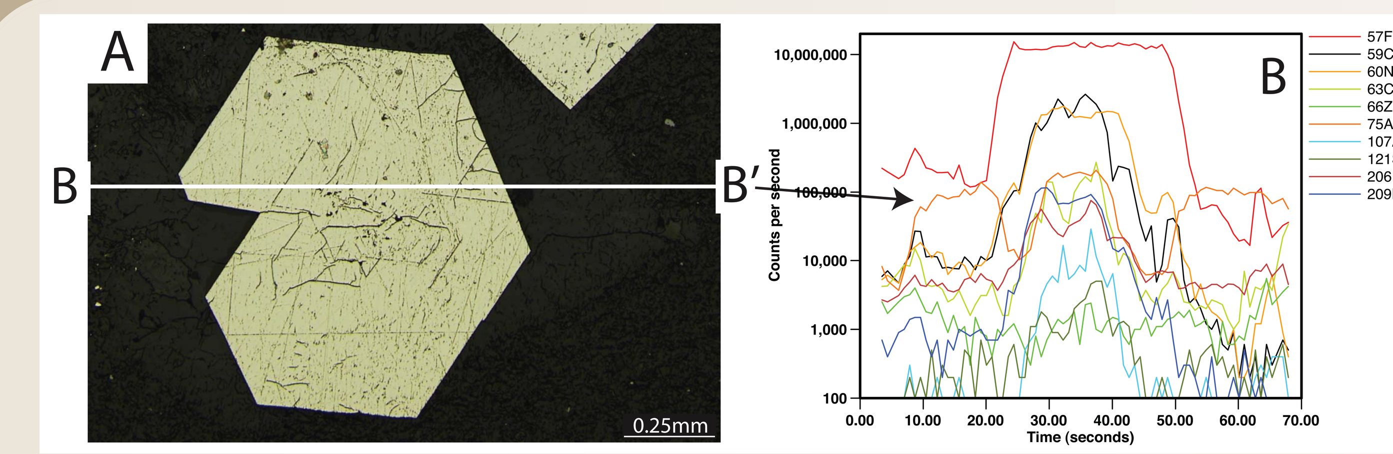

Figure 5: A) Photomicrograph of porphyroblastic pyrite with laser ablation line traverse B-B'; B) Laser ablation ICP-MS trace element profile across traverse B-B'.

2) Trace element contents are higher in the interiors of porphyroblastic pyrites from the Steel Formation (fig. 5). The pyrite interior is enriched in Co, Ni, Cu, As, Se, Ag, Sb, Pb and Bi contents to a relatively trace element-free exterior (fig. 5B, table 1). Zinc is weakly present with no distinct zonation (fig. 5B).

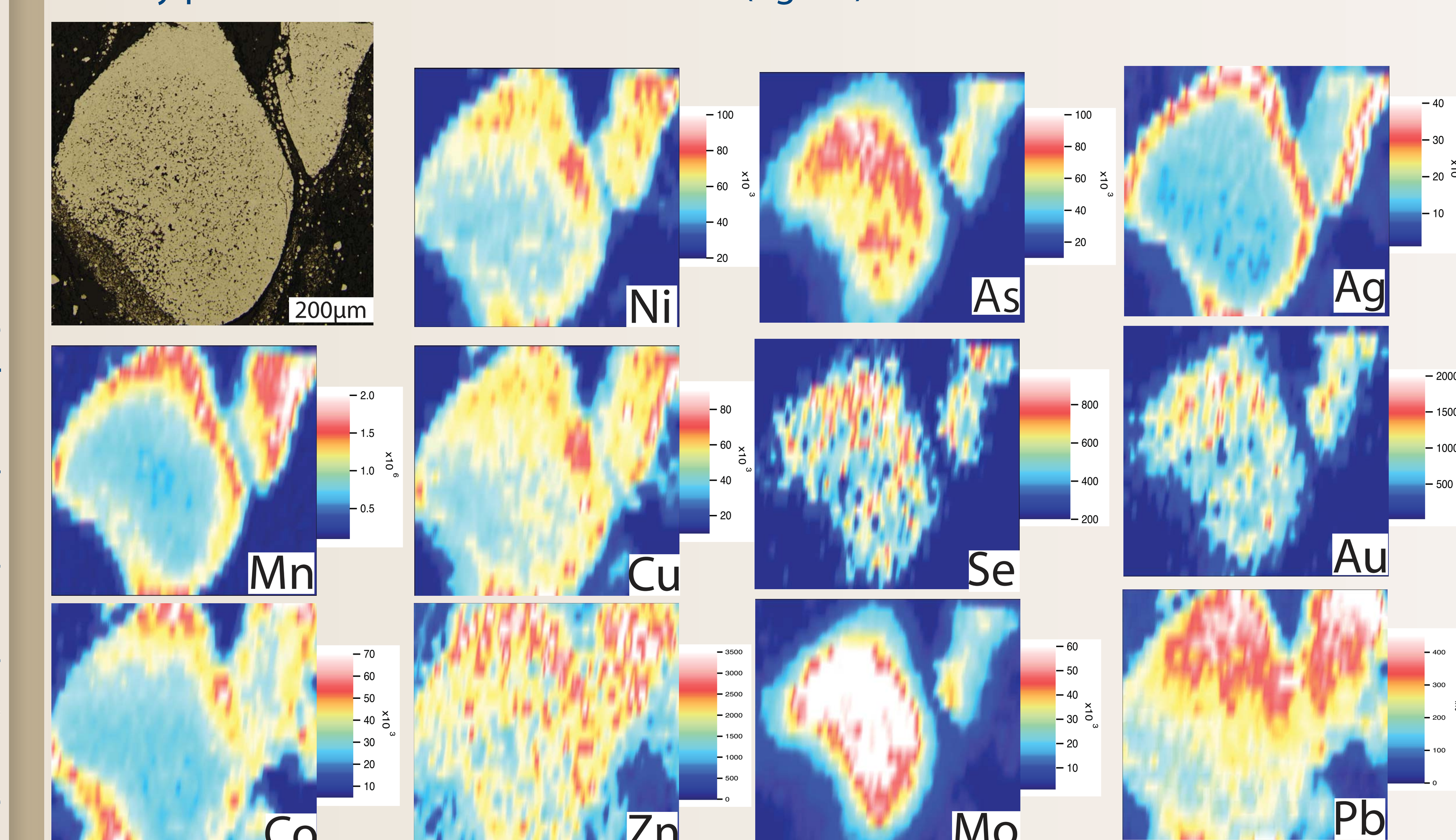

Figure 6: LA ICP-MS images of sooty nodular pyrite from the Steel Formation. Colour ramps for intensities are in counts per second.

3) Trace element distributions in sooty nodular pyrite (py 2b) display zonation (fig. 6). Arsenic, Se, Mo and Au are highest within silicate inclusion-rich pyrite cores. Manganese, Co, Ni, Cu, Zn and Ag are highest in silicate inclusion-poor outer growth zones.

Table 1: Quantitative trace element data for select elements determined using EPMA and LA ICP-MS

	Formation	Zn		Pb		Co		Ni		Cu		As	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Fig. 4	Duo Lake	LOD	35	LOD	1100	LOD	48	50	4510	90	600	LOD	990
Fig. 5	Steel	LOD	30	LOD	329	240	2400	341	4180	51	632	LOD	1145
Fig. 6	Steel	120	200	2000	6600	200	600	50	1910	60	620	LOD	1380

Conclusions

Pyrite morphologies and textural zoning imitate trace element geochemical zoning, supporting the interpretation that pyrite growth occurred in discrete stages. Assuming that framboidal pyrite formed during, or shortly after sedimentation and that overgrowths formed during diagenesis and (pre?)-Cordilleran compressional tectonism, a long fluid history is likely recorded in the geochemical trends in the pyrite of these rocks.

Select References

Goodfellow, W.D. (2004): Geology, Genesis and Exploration of Sedex Deposits, with Emphasis on the Selwyn Basin, Canada, in Deb, M., and Goodfellow, W.D., eds., Sediment-Hosted Lead-Zinc Sulphide Deposits: Attributes and Models of Some Major Deposits of India, Australia and Canada: Narosa Publishing House, Delhi, India, p. 24-99.

Jonasson, I.R. and Goodfellow, W.D. (1986): Sedimentary and diagenetic textures, and deformation structures within sulphide zone of Howards Pass (XY) Zn-Pb deposit, Yukon and Northwest Territories, in Morin, J.A., ed., Mineral Deposits of the Northern Cordillera: Canadian Institute of Mining and Metallurgy, Special Volume 37, p. 51-70.

Gordey, S.P. (1981): Geology of the Nahanni map-area, Yukon Territory and District of Mackenzie, Geological Survey of Canada, Open File 780.

Gordey, S.P. and Anderson, R.G. (1993): Evolution of the Northern Cordilleran Miogeocline, Nahnni Map Area (105I), Yukon and Nowthwest Territories. Geological Survey of Canada Memoir 428, 214 p.

Norford, B.S. and Orchard, M.J. (1985): Early Silurian Age of the Pb-Zn Mineralization at Howard's Pass, Yukon Territory and District of Mackenzie; Review of Local Biostratigraphy of Road River Formation and Earn Group. Geological Survey of Canada, Paper 83-18, 36 p.

Recommended citation
Gadd, M., Layton-Matthews, D., Paradis, S. and Peter, J., 2013. Microanalytical geochemical analysis of texturally variable pyrite associated with mineralization and surrounding host rocks in the Howard's Pass District, Selwyn Basin, Yukon; Geological Survey of Canada, Open File 7353. doi:10.4095/292483

doi:10.4095/292483

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Acknowledgements

This project is jointly funded by NSERC, CAMIRO and the TGI-4 program of the Geological Survey of Canada. We sincerely thank SEGCF for financial support and Jason Dunning, Gabe Xue, Wolfgang Schleiss and Jelle de Bruyckere of Selwyn Chihong Mining Ltd. for providing transportation, lodging, access to core, samples and technical information. We also greatly appreciate time spent in the field with Duncan Bain and Bob Hodder and for their insightful discussions with us on many aspects of Selwyn Basin geology and mineral deposit genesis.

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2013

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