A Mineralogical Study of Ni Distribution in an Atypical Pyrrhotite-rich, Cu-Ni Footwall Deposit, Norman Township, Ontario

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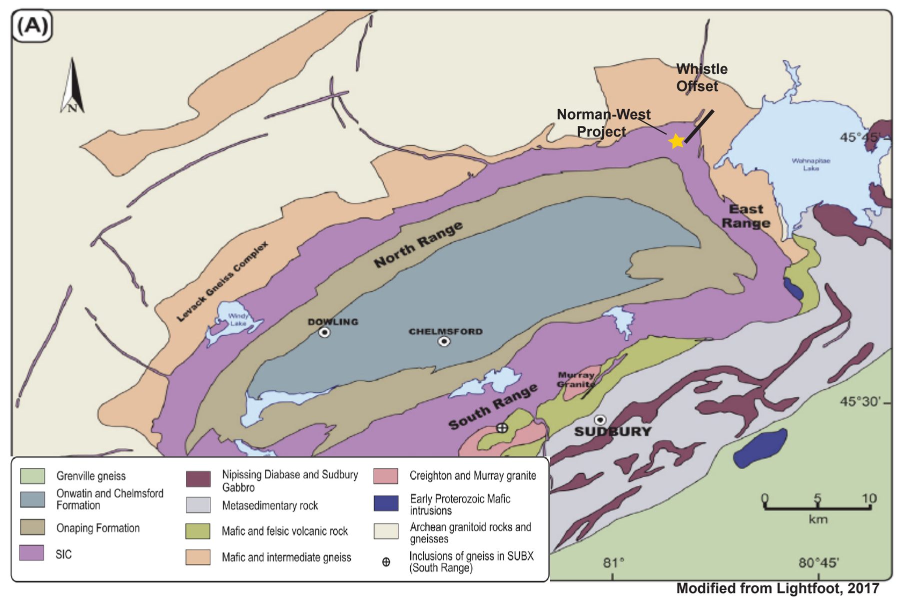
INTRODUCTION

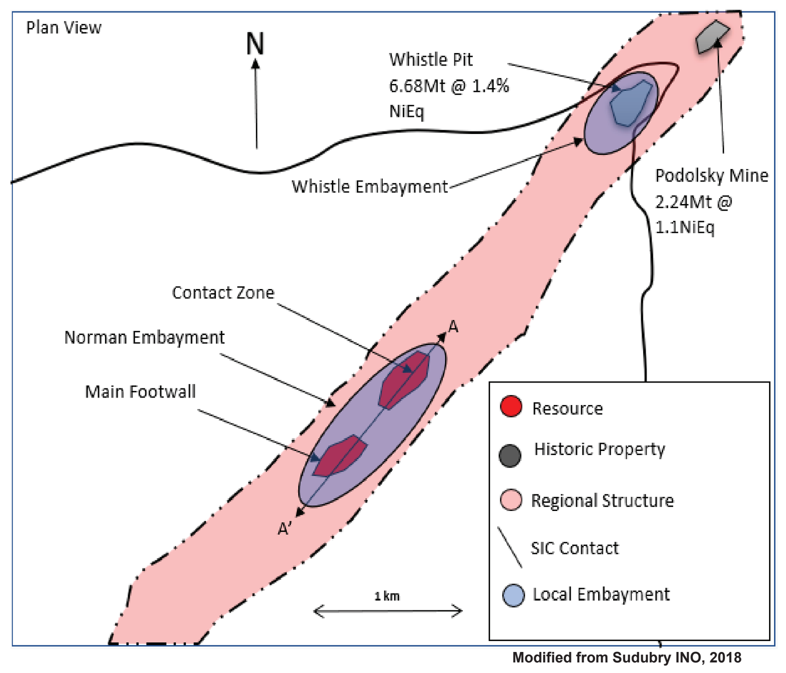
The Norman-West Project is an advanced stage exploration opportunity for a multi-lens, Ni-Cu-PGE contact-footwall environment located along a radial structure in the North-East corner of the Sudbury basin within the Norman township. Mineralization in the main footwall zone exhibits an unusual intergrowth texture of chalcopyrite and pyrrhotite. The project area is approximately 40 km North-East of Sudbury, and is owned by Sudbury Integrated Nickel Operations. The focus of this project is to:

- Characterize the dominant Ni-bearing sulphide phases (pyrrhotite, pentlandite, magnetite) present
- Determine distribution of Ni within the dominant phase(s)
- Establish whether there is a relationship between Ni content and observed textures of Ni-bearing sulphides

GEOLOGICAL SETTING, STUDY AREA, SAMPLE SELECTION

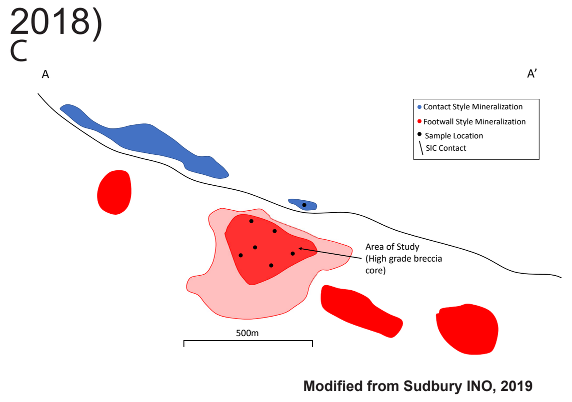
The Sudbury Igneous Complex (SIC) is a differentiated magmatic body, composed of noritic, gabbroic, and granophyric rocks with associated breccia units, thought to be the result of an impact event 1.85 Ga. Since discovery of the SIC in 1857, over 11.1Mt of Ni,10.8Mt Cu as well as Au, Ag, Co, and PGEs have been produced (Lightfoot, 2017).





The Norman West Project is located within the Norman embayment, a physical depression within the footwall along strike with the Whistle embayment. Both the embayments are along a regional structure, striking N45E. Associated with this regional structure are two historically producing properties. The Norman West project is composed of two main zones: contact zone and footwall zone.(Fig.1b). The contact zone is hosted within the Sublayer (SLN) and Late Granite Breccia, (LGBX) while the footwall zones are hosted within Sudbury Breccia (SDBX) (Sudbury INO 2018)

For this project, seven drillholes were selected across high grade breccia domain within the main footwall zone. From each drillhole, three to five samples were taken based on spatial relationship within the ore body, as well as textural varition obseved (Fig 1D-i to iii). 22 samples were selected in total, with 21 samples from the main footwall, and 1 sample from the contact zone to use as a comparison for contact mineralization.



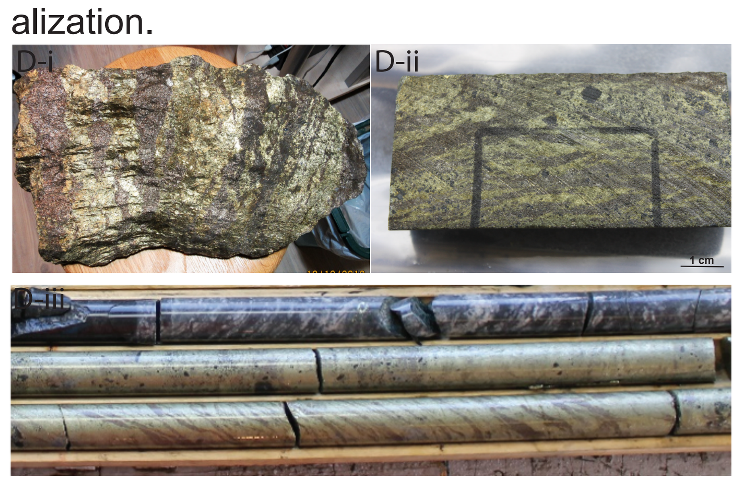


Fig.1 (A) Geology of the SIC and surrounding country rocks (Modifed from Lightfoot, 2017). **(B)** Plan view of the Norman West Project (Modified from SINO, 2018). **(C)** Long section (A - A') of Norman West Project, (Modified from SINO, 2018). **(D-i)** Sample of similar Ccp - Po texture from Creighton Mine. **(D-ii & iii)** Textural variations observed in NQ core.

MINERALOGY AND MINERAL CHEMISTRY

Petrography of 22 polished thin section (PTS) samples provided an average distribution of sulphide phases: Pyrrhotite - 45%, Chalcopyrite - 35%, Pentlandite - 11%, and Magnetite - 9%. With the use of a scanning electron microscope (SEM) the following observations were made.

Pyrrhotite (Po) - $Fe_{(1-x)}S$

Two populations of Po was observed, Po and High Ni Po. This detemination was based on Fe vs Ni (Fig. 2A) and metal (Fe + Ni):S ratios (Fig. 2B).

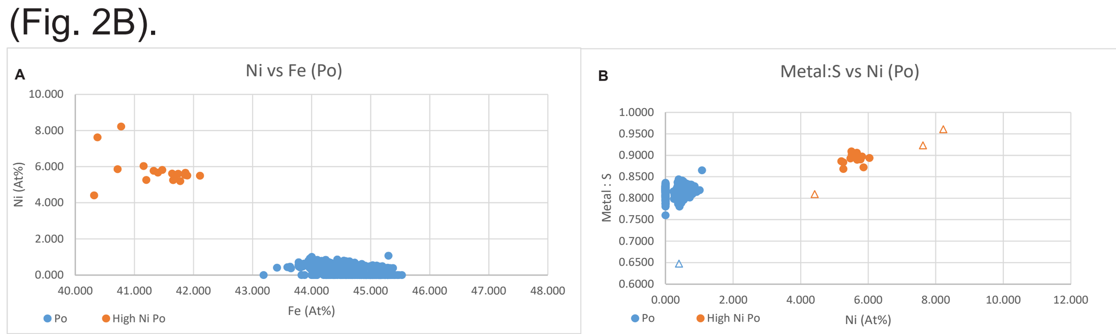


Fig 2: (A) Binary plot featuring Fe (At%) vs. Ni (At%), showing two populations of Po. **(B)** Binary plot featuring Fe + Ni:S vs Ni, again showing two populations of Po, and indicating the Po population is metal depleted.

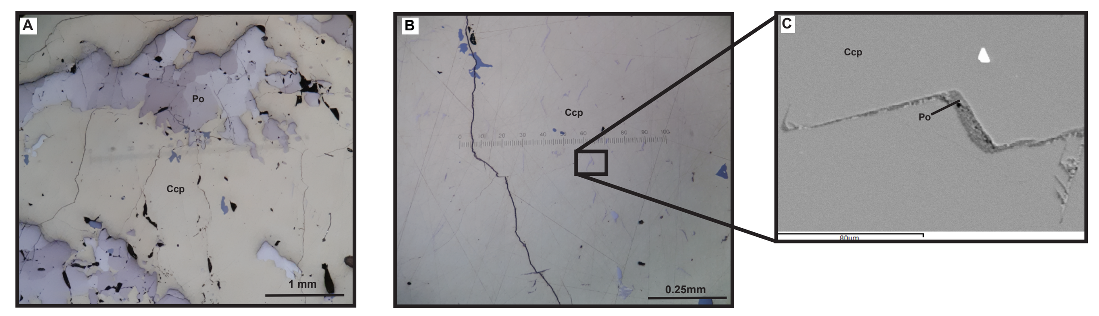


Fig.3: (A) Irregular, fragmented boundaries of Po. Reflected light image under XPL, 5x magnification. **(B)** High Ni Po as lamellae in Ccp. Reflected light image, 10x magnification. **(C)** High Ni Po lamellae in Ccp. SEM image, 700x magnification.

Pentlandite (Pn) - $(Fe,Ni)_9S_8$

Observations indicate three textural populations (eyes, flames and Ag-Pn exsolutions). Geochemical results indicate two chemical populations of Pn; Pn1, and Pn2 This determination was based on Ni vs. Fe values (Fig. 3A), as well as Ag vs. Ni (Fig. 3B). Pn1 is defined by Ag = 0, while the Pn2 is defined by Ag > 0. Data suggests there is a relationship between the texture and the Ni content. Coarse eyes and flames are typically Pn1 (Fig.4C & 4D), while fine exsolutions of Pn2 are typically observed along the Ccp - Po boundary (Fig. 4E).

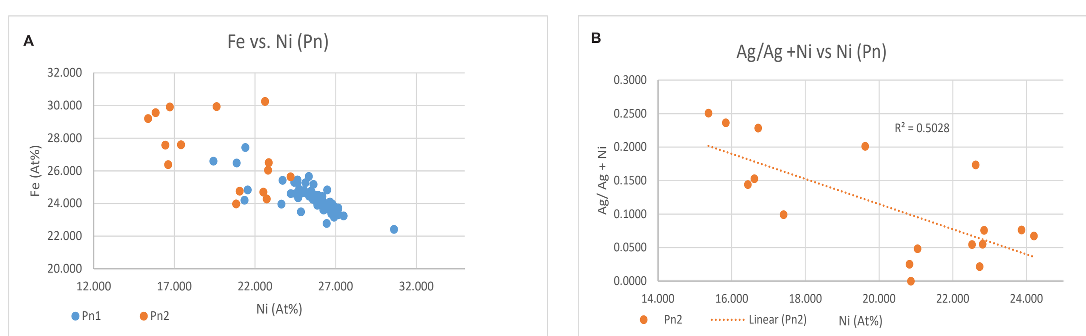


Fig 3. (A) Binary plot featuring Fe (At%) vs. Ni (At%), showing the relationship between the Pn1 and Pn2. **(B)** Binary plot featuring Ag vs. Ni (At%), with observed values of Ag similar to that observed in argentian-pentlandite (Kontny et al, 1994).

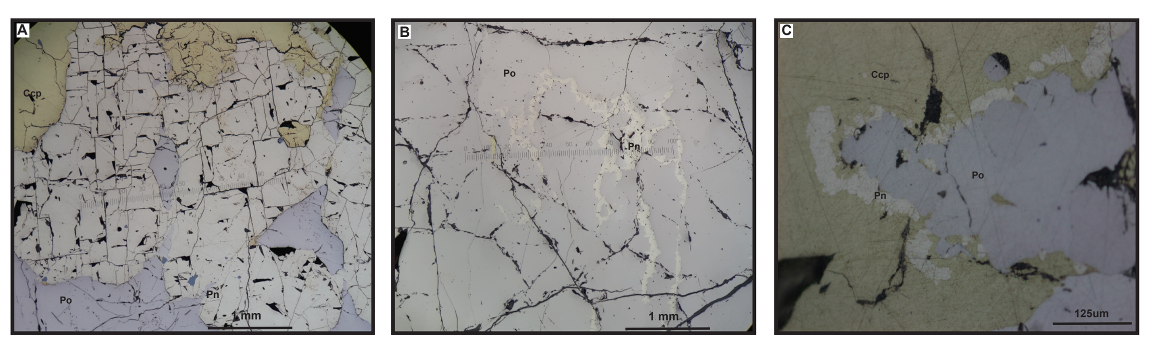


Fig.4: (A) Coarse grain Pn1 eyes with Po intergrowth. Reflected light image, 5x magnification. **(B)** Coarse Pn1 exsolution flames within Po. Reflected light image, 5x magnification. **(C)** Pn2 mantling the boundary between Ccp - Po. Reflected light image, 20x magnification.

Magnetite (Mag) - Fe_3O_4

Magnetite grains across all samples are subhedral and variable in size (0.25-2.0mm), occuring as individual rounded and/or elongated grains (Fig. 5A), in addition to amalgamations of grains (Fig. 5B). Relationship between Ni bearing Mag and location of sample was obvsered (n=4) Similar relationship was observed with Ti + Mn in a seperate location. (n=19)

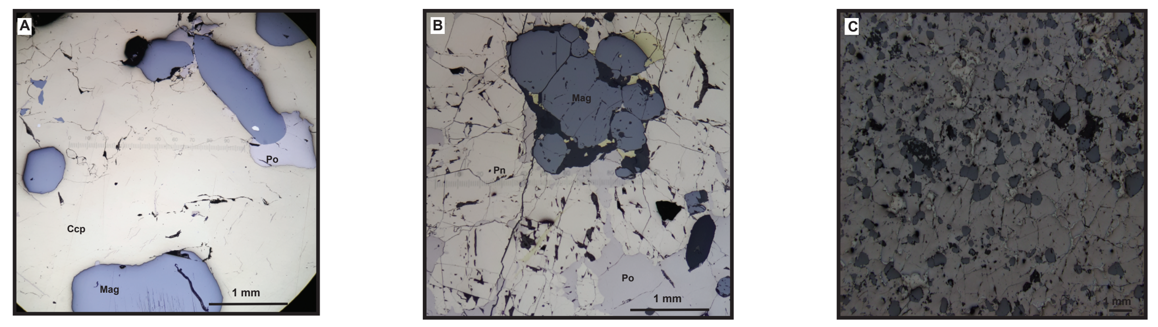


Fig. 5: (A) Subhedral and elongated isolated grains of Mag. Reflected light image, 5x magnification. **(B)** Subhedral grain amalgamations. Reflected light image, 5x magnificaion. **(C)** Contact style mineralization, isolated Mag. Reflected light image, 1.5x magnification.

Chalcopyrite (Ccp) - $CuFeS_2$

Chalcopyrite was dominantly observed as a late phase, containing inclusions of both Po populations, Pn eyes and fragments, Mt and PGE mineral phases. Average composition of Ccp across the samples is 37 wt% Fe, 30 wt% S, and 33 wt% Cu. (n = 74)

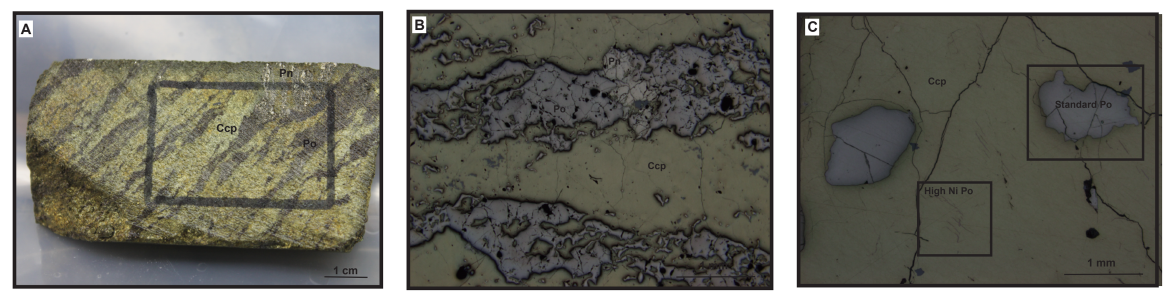


Fig. 6: (A) Ccp - Po intergrowth on cut NQ core. **(B)** Ccp - Po intergrowths as seen in A. Reflected light image, 1.5x magnification **(C)** High Ni and standard Po populations. Reflected light image, 5x magnification.

Platinum Group Mineral- (PGM)

SEM observations determined Michnerite was the dominant PGE mineral found in the samples with average composition 27.6% Te, 45.8% Bi, 21.7% Pd, and 3.5% Pt. (n = 5)

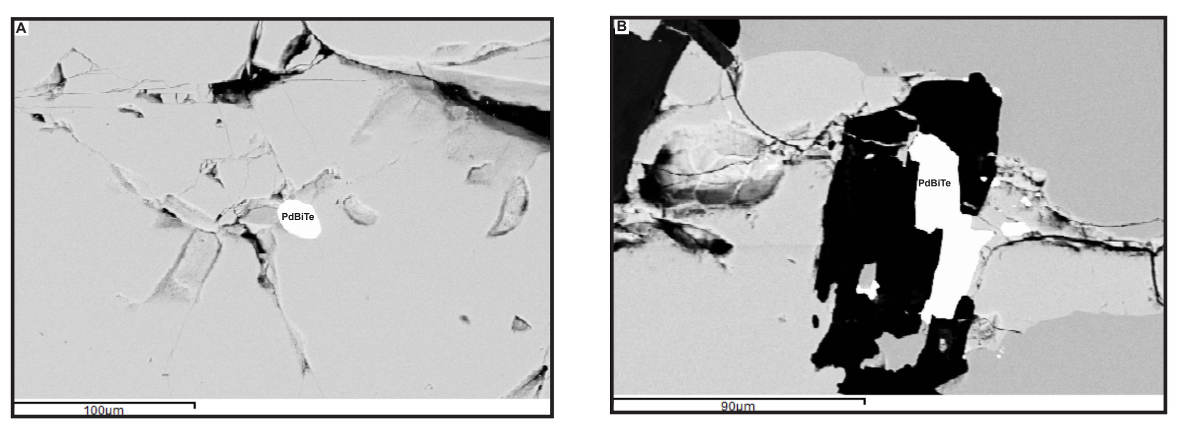
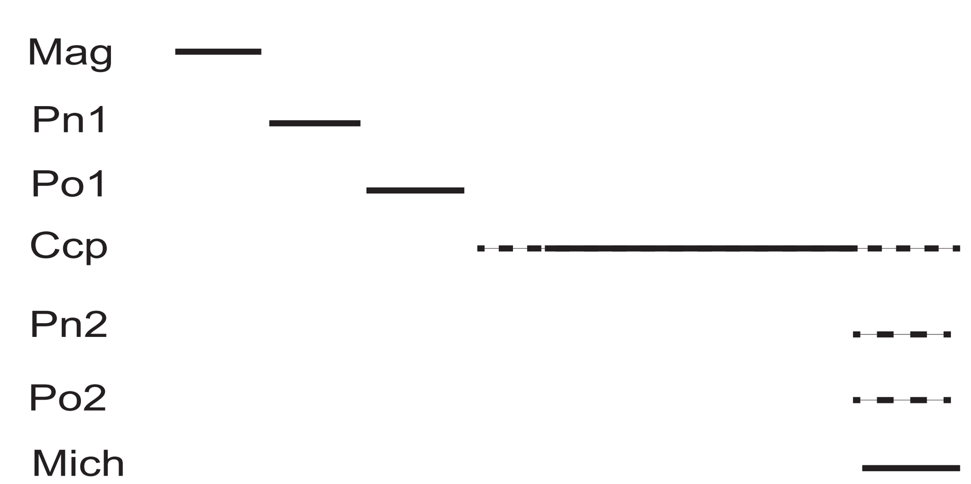


Fig 7: (A) Subhedral Michnerite grain in Ccp. SEM image, 400x magnification. **(B)** Fractured Michnerite grain in void. SEM image, 600x magnification.

Mineral Paragensis



POWDER X-RAY DIFFRACTION DATA

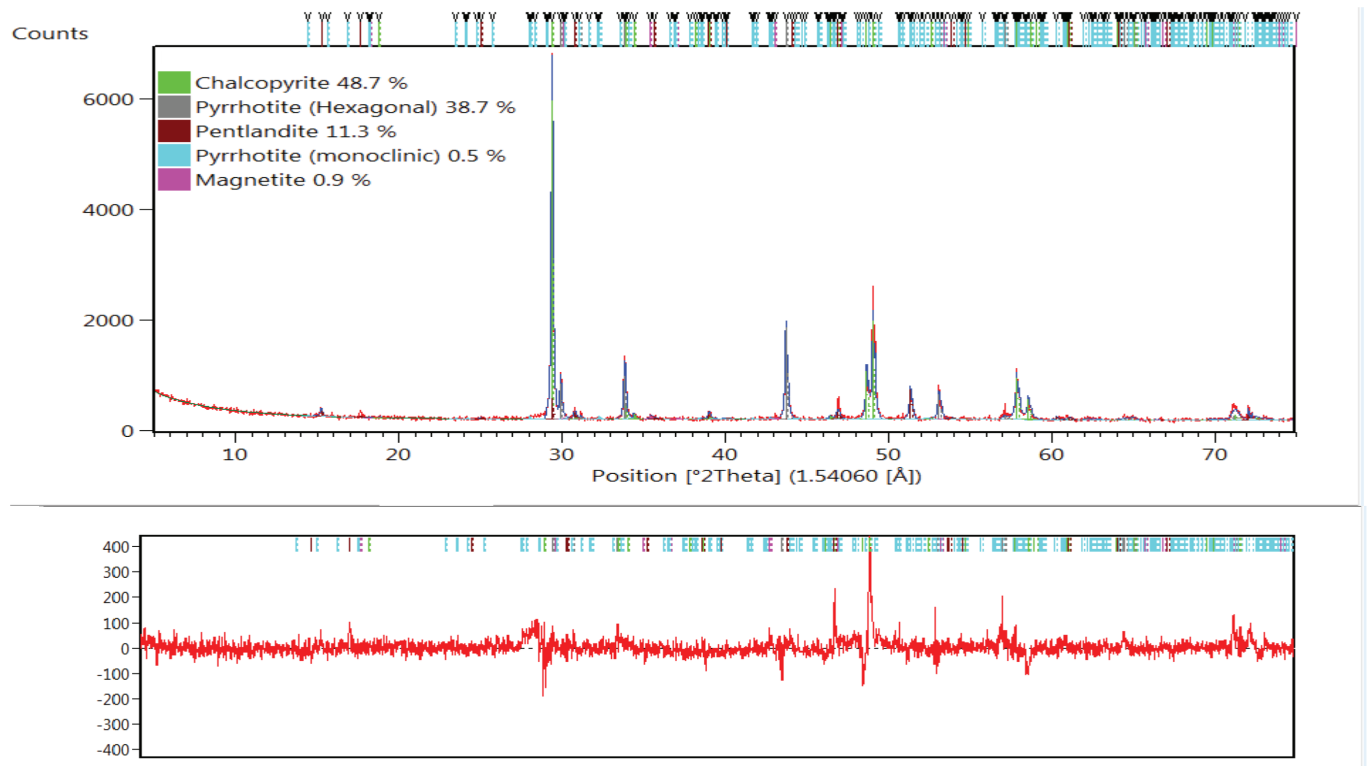


Fig 8. (A) Observed powder X-ray diffraction with Reitveld refinement, showing major sulphide phases, polytypes and quantative modal abundances. **(B)** Comparison of observed data to the generated model. Used as a metric of confidence for the model.

CONCLUSIONS

- Pyrrhotite (Po) is the marginally dominant sulphide phase, with two populations present. These population are defined by textural and chemical differences (Ni < 1.0 wt% and Ni >1.0wt%). The High Ni Po abundance is trace, <1% of the samples. X-ray diffraction data indicates hexagonal pyrrhotite is the dominant polytype compared to monoclinic pyrrhotite, with no observed relationship to depth.
- Pentlandite (Pn) is divided into three texturally different populations (eyes, flames, fine exsolutions), which have then been characerized as two chemically different populations (Pn, Ag = 0 wt%, and Low Ni Pn, Ag > 0 wt%). Eyes and flames fall into the Pn chemical population, while the fine exsolution fall into Low Ni Pn chemical population. The Low Ni Pn population is observed to contain up to 14 wt% Ag.
- Magnetite (Mag) was found to be consistent in chemistry and variable in size. SEM analysis constrained Ni-bearing Mag grains to one sample location, and Ti+Mn bearing Mag to second sample location.
- Chalcopyrite (Ccp) is observed as a late phase of mineralization, occuring along-fragmented Po and Pn grains. The observation of High Ni Po along grain boundaries of Ccp - Po indicate a lower temperature assemblage of mineral phases.
- Michnerite was the only PGM mineral observed in the samples, associated with the Ccp masses. Pd/Pd+Pt ratios average 0.866.
- Observations made during this study are consistent with the data observed in the previous unpublished research material from the same deposit, with additional insight gained on the Ag content of the Pn, and the identification of a second high Ni population of Po.
- The dominant polytype NC Po indicates the system formed at temperatures greater than 254°C and did not have time to sufficiently cool, as a transformation from NC - 4C Po would occur as the system cooled below 254°C.

References

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