CHAPTER 1 EXECUTIVE SUMMARY

1.1 Objectives

The overall objectives of this project were to: 1) define the geology, stratigraphy, petrogenesis, and metallogenesis of the ores and host rocks in the Thompson Nickel Belt (TNB), 2) refine geological and geochemical exploration tools applicable to the TNB and other terranes, 3) refine regional tectonic and metallogenetic models for the TNB, 4) aid in the identification of new exploration targets, and 5) identify areas for further research.

Specific goals of the Geology Subproject were to:

1) Produce updated stratigraphic columns for the northern, central, and southern parts of the TNB, particularly the various lithofacies of the Ospwagan Group and the occurrences of ultramafic rocks within that sequence
2) Define the detrital zircon age characteristics of the metasedimentary units of the TNB and link them to precise U-Pb ages for a) mafic and ultramafic magmatism in the TNB,
   b) magmatism and/or metamorphism in the adjacent Superior Province basement, and/or c) magmatism in the adjacent Reindeer Zone of the Trans-Hudson Orogen
3) Undertake detailed structural analysis of the TNB in the exposed shield and beneath the Phanerozoic cover using field, drill core, seismic, magnetotelluric (MT), and potential field data
4) Design, implement and undertake analysis of an integrated digital geoscience knowledge base system (GIS) for the overall CAMIRO project
5) Generate a 3D model of subsurface structure from available geological, gravity, magnetic, seismic, rock property, and bore hole data using GIS and 3D software tools.

Specific goals of the Geochemistry Subproject were to:

1) Compile existing geological and geochemical data for the TNB and its southern extension
2) Investigate elemental behaviour in the ores and host rocks during magmatic, metamorphic and tectonic processes, as they relate to contamination, metasomatism and ore redistribution
3) Define geochemical and petrogenetic relationships between various types of ultramafic sills and mafic-ultramafic volcanic rocks
4) Develop geochemical tools to discriminate between mineralized and nonmineralized ultramafic bodies
5) Define stratigraphic relationships between various types of ultramafic sills and mafic-ultramafic volcanic rocks
6) Characterize the geochemistry of sedimentary country rocks.

1.2 Results

The principal results and interpretations of this project can be summarized as follows:

- **Stratigraphic Continuity**

  Observation: The stratigraphy of Ospwagan Group, as established by the TNB Geology Working Group[1], appears to be valid over the entire length of the TNB.

  Significance: Stratigraphy can be used to establish structural position and to guide mineral exploration (e.g., to locate Op target horizon).

- **Coherent TNB Stratigraphy**

  Observation: The stratigraphic sequences within major structures throughout the TNB are chronologically continuous and coherent.

  Significance: This is consistent with isoclinal, recumbent folding, but not with thrusting or nappe structures.

- **TNB Regional Structure**

  Observation: The structure of the TNB is characterized by a steeply-dipping NNE-SSW foliation associated with conjugate ductile shear zones at all scales. The overall pattern reflects principal sub-vertical stretching, intermediate along-strike stretching, and subhorizontal ESE-WNW shortening. The same strain field is observed from partial melting to greenschist facies conditions.

  Significance: This indicates progressive deformation associated with a westward-verging regional transpressional regime, not east-verging nappe emplacement (which would require parts of the sequence to be beheaded).

- **Duration of Transpression**

  Observation: The bulk kinematics (i.e., transpressive strain patterns) remained the same for at least 100 Ma (~1850 Ma to ~1750 Ma).

  Significance: The transpressive event was a major, protracted event, not a minor, late event, as previously thought.

- **Diachronous Deformation**

  Observation: Deformation stopped at ~1800 Ma in the easternmost part of the TNB, ~1770 Ma at Thompson, and ~1750 Ma at Pipe.

  Significance: The westward-verging deformation appears to have been diachronous.

- **Ore Localization**

  Observation: Most of the ore deposits appear to be located in zones where deformation lasted until ~1770-1750 Ma. This may reflect the greater susceptibility of sulfides to accommodate deformation at lower temperatures (greenschist facies).

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[1] The Thompson Nickel Belt Geology *Working Group* is based at the Manitoba Geological Survey and during the course of this project included J. Macek, T. Corkery, P. Lenton, M. Pacey, D. Peck, P. Theyer, and H. Zwanzig.

Significance: Shear zones represent a regional scale exploration target and may be recognizable on the basis of distinctive structural fabrics and/or retrograde mineral assemblages.

- **Lithophile Element Mobility**

  Observation: Many elements were mobile in the ultramafic host rocks during metamorphism and deformation, but Th, Nb, Ta, Zr, Hf, Ti, HREE, Al, and Cr appear to have been immobile in many cases.

  Significance: Th, Nb, Ta, Zr, Hf, Ti, HREE, Al, and Cr may be used to evaluate magma sources, petrogenesis, and contamination processes.

- **Bah Lake Assemblage Petrogenesis**

  Observation: Sampled volcanic rocks of the Bah Lake assemblage are depleted in highly incompatible lithophile elements (HILE) and undepleted in highly chalcophile elements (HCE), whereas the ultramafic sills within the Ospwagan Group are enriched in HILE and enriched in HCE.

  Significance: The sampled Bah Lake volcanic rocks are not petrogenetically related to the ultramafic sills. The volcanic products of the sills have not been identified, but should have had a volume at least 4x greater than that of the sills.

- **Ore Genesis**

  Observation: The abundances of Ni and platinum-group elements (PGEs) in mill feed from the Birchtree and Thompson mines (representing the best estimate of bulk ore composition) are consistent with equilibration with a komatiitic magma and show no evidence of metal fractionation (magmatic, metamorphic, or hydrothermal) on the scale of the mined ore zones.

  Significance: The ores did not fractionally crystallize Fe-Ni-(Cu) monosulfide solid solution (MSS) during cooling. Ni and PGEs were not lost from the ore zones during deformation and metamorphism.

- **Metal Mobilization**

  Observation: Massive and semi-massive ores from Birchtree and Thompson are depleted in Au, Pt, and Cu relative to the compositions expected from magmatic processes. Mill feed from the same mines is essentially undepleted in Pt and only slightly depleted in Au and Cu. Disseminated ores from Birchtree are not depleted in any metals relative to the compositions expected from magmatic processes.

  Significance: Pt appears to have been mobile in massive ores during deformation and/or metamorphism on a scale smaller than mining widths, but greater than that of hand samples, whereas Au and Cu appear to have been mobile on a scale larger than mining widths.

- **Magmatic Ore Chemistry**

  Observation: Thompson "magmatic" massive and semi-massive ores have slightly fractionated chalcophile element abundances (except Pt) consistent with equilibration with a komatiitic magma at relatively low magma:sulfide ratios (R factors). Birchtree and Pipe "magmatic" massive and semi-massive have lower Pd/Ir ratios that cannot be produced via differences in R factor. Birchtree and Pipe are located in Op1, whereas Thompson is located in Op2.

Significance: Birchtree and Pipe magmatic ores were derived from a different magma than those that produced the Thompson magmatic ores and/or contain different contributions from assimilated country rocks.

- **Sedimentary Ore Chemistry**

  Observation: Barren massive sedimentary sulfides are strongly depleted in Ni-IPGE relative to PPGE-Cu. Thompson massive and semi-massive sedimentary ores are moderately to slightly depleted in IPGE relative to PPGE-Cu, but are anomalously enriched in Ni (as previously reported by W. Bleeker).

  Significance: Thompson massive and semi-massive sedimentary ores formed via a process that involved greater enrichment in Ni than IPGE. The relative roles of physical mobilization, solid-state diffusion, and hydrothermal mobilization are not known.

1.3 Exploration Guides in TNB

1) The work by the TNB Geology Working Group and the results of this project have enhanced the view that mineralized ultramafic bodies are restricted to the Op1 and Op2 members of the Pipe Formation, which contain abundant sulfide-facies iron-formation. This is consistent with the interpretation that an external source of S is required to generate magmatic Ni-Cu-(PGE) sulfide deposits.
2) The localization of the ores in the TNB within or near ultramafic boudins and the compositions of the ores suggest that the ores are magmatic and related to the ultramafic rocks. This is consistent with the interpretation that these bodies represent a source of heat (for melting sedimentary S) and the principal source of metals for the ores. Although often tectonically-disrupted from the ores, these bodies still represent an important exploration target.
3) Although many TNB ores have relatively low Ni contents (~5% Ni in 100% sulfides), the magmas had the capacity to generate more metal-rich ores (up to ~15% Ni). Recognising that the rocks in the ultramafic sills formed after the original stratiform massive ores, exploration should focus on more dynamic, longer-lived (more magnesian, less differentiated) systems that would be characterized by higher R factors and therefore higher metal tenors.
4) Late (retrograded) shear zones containing ultramafic boudins with talc-carbonate altered margins and associated ductile massive Fe-Ni-Cu sulfides may have focussed late-stage deformation. They may be recognisable on the basis of distinctive structural fabrics and greenschist-facies mineral assemblages.
5) The metals in TNB ores appear to have been mobilized in the order Au > Cu >> Pt >> Ni >> Pd-Rh-Ru-Co-Ir >> Cr. Because this appears to have occurred during deformation and metamorphism and because the principal stretching direction is subvertical, this raises the possibility that Au, Cu, and Pt may be dispersed upwards along shear zones defining halos that may be used to vector toward mineralization.

1.4 Work Not Completed and Follow-Up Work

The following work was planned, specifically or indirectly, but was not completed for logistical reasons or time constraints:

1) SIMS analyses of trace metals in the sulfide minerals were planned, but the instrument was down and the collaborator in charge of this work was on leave. These data would aid in interpreting the distributions of metals amongst the various minerals in the ores, which would help constrain interpretations regarding their mobility and which would aid in ore beneficiation.
2) We had hope to do structural mapping between Soab Lake and Joey Lake, but did not have time. This work is required to complete the structural analysis of the TNB.
3) We had planned to do more Sm-Nd work on mafic flows in the Ospwagan Lake and Setting Lake areas, but had problems in getting all of the samples and analyses that were required. This work would have provided better constraints on the degree of contamination of the magmas.
4) We had hoped to establish the contact relationships and age(s) of intrusion using enclaves and/or xenoliths within the ultramafic bodies and possible restite phases on their rinds and to use mass balance constraints to examine modal vs. non-modal (incongruent) melting processes. However, we were not able to obtain 3D access to any of the ultramafic bodies. It is possible that this work could be done at the Thompson Mine if sample locations could be identified.
5) We had hoped to examine whole-rock and mineral compositions of metasedimentary rocks adjacent to mineralization for metasomatic haloes (modal or cryptic), but were not able to obtain suitable samples. Elements of interest would include metals (e.g., Fe, Co, Ni, Cu, Zn, Pb, Au, Ag, PGE), semi-metals (e.g., As, Sb, Bi, Se, Te), and volatile metals (e.g., Hg, Cd).
6) We had hoped to model selected ultramafic bodies in 3D to establish their internal structure and magma dynamics (e.g., number of magma pulses, variation in contamination as a function of depth, metal depletion), but did not have time to do this work.
7) We had hoped to link the magma chemistry to the existing regional geochronological and geochemical database for mafic rocks to establish the time line for mafic-ultramafic magmatism/volcanism in the belt, but did not have time to do this.

The results of this study have also identified several areas of research that justify additional work:

1) A regional and mine-scale structural and metamorphic analysis of TNB focusing on shear zones to define their scale (crustal vs. local), rheology (brittle vs. ductile), and style (wet vs. dry) would aid in determining which types of shear zones are preferentially associated with mineralization and which are not
2) An integrated structural, mineralogical, and geochemical analysis of deformed ores in the TNB would aid in determining how metals fractionate in shear zones and whether metal ratios of more mobile metals can be used as vectors to mineralization.

3) A more thorough examination of the P-T-t history of the southern and central part of the exposed TNB would i) aid in the differentiation between potentially conflicting interpretations of the tectonic evolution of the belt and ii) aid in the identification of the high-strain, steeply-dipping, substantially retrogressed, younger deformation zones that appear to host most of the economic mineralization in the TNB.