Bedrock Mapping at Northern Indian Lake, Manitoba (part of NTS 64H3, 5, 6)

T. Martins, P.D. Kremer, and R. Hiebert* *(*University of Manitoba)*

Manitoba

Introduction

Northern Indian Lake is located approximately 170 km north of Thompson along the lower Churchill River (**Figure 1**). The area has seen little to no exploration activity in the past several decades and the most recent mapping at Northern Indian Lake (1:100 000 scale) was conducted in the early 1980s (Corkery and Lenton, 1990). Water levels along the lower Churchill River are regulated by the Manitoba Hydro's Missi Falls control structure and are highly variable. At low water levels, the area is characterized by extensive and lichen-free outcrop exposed along much of the shoreline. Recent results from mapping and sampling elsewhere in the Southern Indian domain (Kremer et al., 2009a, b; Martins and Kremer, 2013) yielded anomalous values of base and precious metals, often associated with plutonic rocks which intrude the supracrustal assemblages. In the summer of 2014, the Manitoba Geological Survey initiated a 4 week, 1:50 000 scale mapping program designed to:

- update the bedrock geology of the Northern Indian Lake area,
- document the nature of the boundary between the Southern Indian and Chipewyan domains,
- further assess the distribution and genetic associations of base and precious metal occurrences,
- obtain a well-constrained sample suite of Paleoproterozoic supracrustal and plutonic rocks to evaluate the nature and extent of Archean crustal contamination, and provide constraints on the underlying crustal architecture in the northeastern THO in Manitoba.

Regional setting

The Southern Indian domain is one of three major tectonostratigrphic terranes that form the northern flank of the THO in Manitoba (**Figure 1**). It is comprised dominantly of variably migmatitic metasedimentary rocks, with rare belts dominated by metavolcanic rocks which have been historically assigned to the Wasekwan and Sickle groups (e.g., Frohlinger, 1972; Cranstone, 1972). The Southern Indian domain is bounded to the south by the volcanic-dominated Lynn Lake – Leaf Rapids domain, and intruded to the north by the voluminous ca. 1.86-1.85 Ga Chipewyan/Wathaman batholith, which stitches the northern flank of the THO to the southern margin of the Hearne craton.

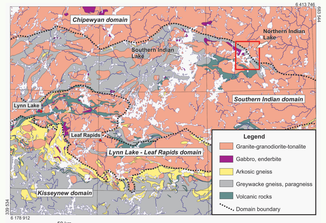
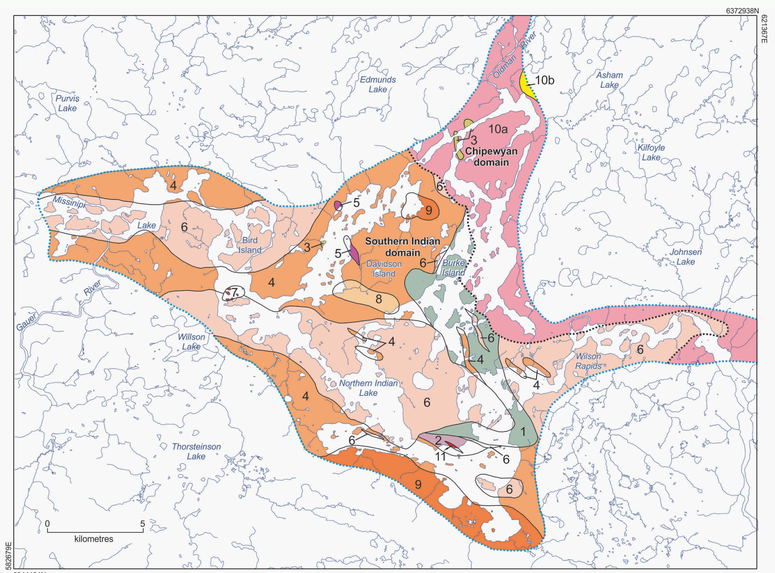


Figure 1: Regional geological setting of the Southern Indian and the Chipewyan domain. Norther Indian Lake is marked by the red square.

Based on recent mapping, lithogeochemical and geochronological data (Rayner and Corrigan, 2004; Kremer, 2008a, b; Kremer et al., 2009 a, b), supracrustal rocks of the Southern Indian domain have been further subdivided into several distinct lithotectonic assemblages. Massive to pillowed juvenile basaltic rocks and associated basinal sedimentary rocks comprise the Pukatawakan Bay assemblage (Kremer, 2008). In northeastern Southern Indian Lake, the Pukatawakan Bay assemblage is intruded by the ca. 1890 Ma Turtle Island intrusive complex, which provides a minimum age of deposition. The Turtle Island complex is coeval with bimodal, continental arc volcanic and volcaniclastic rocks comprising the Partridge Breast Lake assemblage. Both the Pukatawakan Bay and Partridge Breast Lake assemblages are intruded by several generations of plutonic rocks ranging in age from ca. 1880-1830 Ma, and are unconformably overlain by fluvial-alluvial clastic sedimentary rocks with maximum age constraints ranging from ca. 1860 Ma and 1830 Ma.

The Pukatawakan Bay assemblage is in fault contact with latest Archean to earliest Paleoproterozoic orthogneiss (ca. 2520-2380 Ma) in west central Southern Indian Lake (Kremer et al., 2009a). Though exposure of this orthogneiss is limited to a group of small islands, zircons of that range from dominant and subdominant populations in detrital zircon spectra from all Paleoproterozoic assemblages in the area. Additionally, similar aged zircons are ubiquitous as inherited grains in Paleoproterozoic plutonic and volcanic rocks (Rayner and Corrigan, 2004; Kremer et al., 2009a). Late Archean to early Paleoproterozoic orthogneiss at Southern Indian Lake may represent a window of Hearne craton margin exposed in the internides of the THO. Alternatively, it form part of an exotic, microcontinental fragment, similar to the Sask craton.

Figure 2: Simplified geology of Northern Indian Lake, showing the main lithological units



1 Volcanic and sedimentary rocks
2 Gabbro
3 Quartz monzonite to quartz diorite
4 Granodiorite to tonalite
5 Melatonalite to quartz diorite
6 Granite to granodiorite
7 Granite
8 Leucogranite
9 Porphyritic granite

Chipewyan batholith

10a Megacrystic monzogranite
10b Syenogranite

11 Granitic pegmatite

Geological boundary
Limit of mapping
Domain boundary

Bedrock geology of the Northern Indian Lake

The lithological units identified in the Northern Indian Lake area are divided into two main groups: **Southern Indian domain** and **Chipewyan domain**. In this part of the Southern Indian domain, the metavolcanic and metasedimentary rocks are highly deformed and are preserved as large screens and xenoliths within several phases of younger felsic plutonic rocks (Kremer and Martins, 2014; **Figure 2**).

Southern Indian domain

Partridge Breast Lake assemblage

The exposed supracrustal succession at Northern Indian Lake consists of bimodal volcanic and volcaniclastic facies with sequences of epiclastic rocks. Volcanic rocks include massive to pillowed, amygdaloidal basalt which locally contains zones of epidosite alteration (**Figure 3a**). Intervening horizons of well-bedded felsic tuff up to 5 m thick occur interlayered with basalt (**Figure 3b**). Massive to moderately bedded feldspathic volcanic sandstone with subordinate volcanic conglomerate (**Figure 3c**) is the dominant lithofacies in the northern arm of the supracrustal rocks near Burke Island. Finer-grained sedimentary rocks with garnet and sillimanite porphyroblasts (**Figure 3d**) occur at one location. Based on similarities in lithofacies and preliminary analytical results, the supracrustal succession at Northern Indian Lake is tentatively correlated to the Partridge Breast Lake assemblage, which has trace and rare earth element abundances and tracer isotope signatures indicative of deposition in a continental arc setting (Kremer et al., 2009).

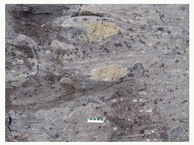


Figure 3a: Outcrop photograph of the Partridge Breast Lake assemblage showing dark grey amygdaloidal basalt, with sub-rounded to elongate epidosite nodules (unit 1a).

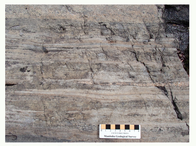


Figure 3b: Partridge Breast Lake assemblage at Northern Indian Lake evidencing well-bedded light beige to buff felsic tuff (unit 1a).

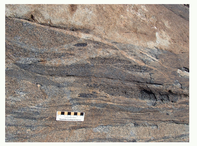


Figure 3c: Massive heterolithic conglomerate from the Partridge Breast Lake assemblage (unit 1b).

Figure 3d: Detail of garnet and sillimanite porphyroblasts in pelitic to semipelitic schist (unit 1d) from Partridge Breast Lake assemblage.

Undivided plutonic rocks

The supracrustal assemblage is intruded by abundant felsic to locally intermediate plutonic rocks (**Figures 4a** to **d**). Based on overprinting relationships observed in the field, several generations of intrusive rocks have been identified, including porphyritic quartz monzonite (**Figure 4a**), medium to coarse grained (biotite + hornblende) tonalite-granodiorite (**Figure 4b**), medium-grained equigranular to weakly porphyritic (biotite +/- hornblende) granite-granodiorite (**Figure 4c**), and K-feldspar porphyritic medium to coarse grained granite (**Figure 4d**). Despite the clear petrographic and temporal variations of the felsic plutonic rocks, preliminary geochemistry indicates that they all formed in an arc setting, and (pending further analyses) are tentatively interpreted to represent continued magmatism associated with the Partridge Breast Lake arc.

Figure 4a: Outcrop photograph of a xenolith of porphyritic quartz monzonite in the Chipewyan batholith.

Figure 4b: Example of the foliated hornblende-biotite tonalite (unit 4).

Figure 4d: Fracture-controlled sulphides in granite to granodiorite (unit 6).

Figure 4d: porphyritic granite (unit 9) that mostly occurs in the S. part of the map area.

Chipewyan domain

Figure 5a: Chipewyan batholith with characteristic megacrystic potassium feldspar crystals (unit 10).

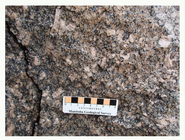


Figure 5b: granitoid rock interpreted as part of the Chipewyan batholith.

Chipewyan batholith (unit 10)

The Chipewyan batholith is distinguished by its megacrystic potassium feldspar crystals. This granitic body is thought to be mostly homogeneous (MacHattie, 2001) but at Northern Indian Lake a few different phases of granitoid were identified and interpreted to be part of the Chipewyan batholith.

The main phase of this batholith is characterized by a medium-grained groundmass and potassium feldspar megacrysts up to 4 cm (**Figure 5a**). It is weakly to moderately magnetic, weakly foliated and homogeneous. The estimated average composition is quartz (30–40%), biotite (5–10%), pyrite and rare chalcopyrite (<1%), magnetite (<1%), trace amount of apatite and plagioclase feldspar. A very similar granitoid rock with phenocrysts of potassium feldspar, but not megacrystic, was considered a phase of the Chipewyan batholith but not separated into different map (**Figure 5b**).

A syenogranitic phase (unit 10a), which is restricted to a few outcrops east of Oldman River and tentatively assigned to the Chipewyan batholith, is fine to medium grained and composed of 60–70% euhedral to subhedral K-feldspar, 20–30% anhedral to subhedral quartz, 10 % plagioclase, <5–10% biotite and trace magnetite.

Collaboration with University of Manitoba

During the summer we had one student from University of Manitoba carrying out field work for her BSc thesis, which involved detailed mapping of the Chipewyan and Southern Indian Domain boundary zone (**Figure 6**). The purpose of this project is to determine the nature of the boundary zone between the Chipewyan Batholith and the Southern Indian Domain at Northern Indian Lake. A secondary objective is to compare the geochemical and petrologic character of the Southern Indian Domain between the locations Northern Indian Lake, Southern Indian Lake and Partridge Breast Lake using whole rock lithogeochemistry and U-Pb (LA-ICP-MS) geochronology. The Chipewyan Batholith Complex is a major granitoid unit in the Trans Hudson Orogen bordering the Southern Indian Domain at Northern Indian Lake in Manitoba. It is thought to be in large part subduction related and represents a volume of magmatism similar in scale to the Central Finnish Batholith and the Peruvian Batholith complex of the central Andes. There are multiple phases to the intrusion and the relative and absolute relations between the units and how they are related geochemically to the Southern Indian Domain in Southern Indian Lake and Partridge Breast Lake has not been determined. This project will contribute to the understanding of the Southern Indian Domain and its relation to the Chipewyan batholith.

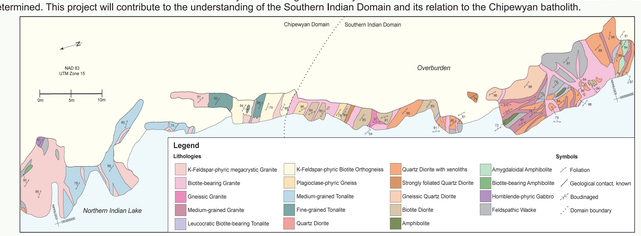
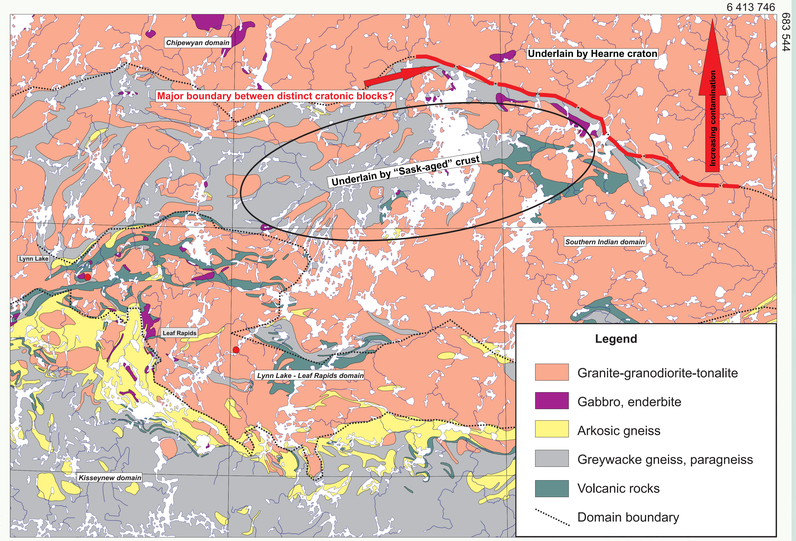


Figure 6: Detailed map at the Chipewyan boundary domain by R. Hiebert

Regional Tectonic Implications and Mineral Resource Potential



An exotic fragment of latest Archean to earliest Paleoproterozoic (ca. 2.5-2.3 Ga) orthogneiss exposed at Southern Indian Lake marks the first occurrence of "Sask-aged" crust in this part of the Trans Hudson orogen. Zircons of this age are present as detrital and inherited grains in sedimentary, volcanic and plutonic rocks throughout the region (Kremer et al., 2009; Rayner and Corrigan 2004), which suggests that this isolated continental fragment is an important geotectonic component in the evolution of and may underlie significant portions of the Southern Indian domain.

The Chipewyan batholith is a continental magmatic arc formed in response to subduction under the southeastern Hearne craton margin and stitches the Southern Indian domain to the Hearne craton. The Chipewyan batholith shows evidence of increasing crustal contamination northward (εNd values ranging from +2 in the south to -7 in the north), which is interpreted to represent greater interaction with the Hearne craton in that direction (MacHattie, 2001). This stands in contrast to arc rocks associated with the Partridge Breast Lake assemblage, which have documented contamination interpreted to result from interaction with Sask-aged rocks exposed at Southern Indian Lake prior to accretion to the Hearne craton and the emplacement of the Chipewyan batholith. This data suggests that the two domains could be underlain by separate cratonic entites (**see map above**).

The margins of Archean cratons are considered important regional vectors for diamond exploration. The diamondiferous Pikoo kimberlite, discovered in 2013 by North Arrow Minerals Inc., is located in east-central Saskatchewan and, along with the Fort a la Corne kimberlite field, marks the second major diamond occurrence in areas thought to be underlain at depth by the mostly buried Sask craton. Stable and radiogenic isotopic analyses will be conducted on several samples collected during the field season at Northern Indian Lake. This study aims to better constrain and delineate the Archean crustal architecture in northern Manitoba and test the hypothesis presented above. The results could have significant bearing on diamond exploration in the region.

Bimodal arc volcanic rocks of the Partridge Breast Lake assemblage have temporal links and geochemical affinities akin to volcanic rocks in the Lynn Lake – Leaf Rapids domain, which host the Ruttan and Fox Lake volcanogenic massive sulphide (VMS) deposits. Frohlinger (1972) reported assay results up to 2.2% Cu from a narrow, 1.2 m long malachite-rich fracture in arc volcanic rocks of the Partridge Breast Lake assemblage in west-central Southern Indian Lake. North of Partridge Breast Lake, values up to 6.85% Cu were reported from garnet-biotite schist with laminated pyrite, pyrrhotite and chalcopyrite stringers (Manitoba Assessment File 71519), perhaps representing metamorphosed VMS-style mineralization.

Mapping and sampling elsewhere in Southern Indian domain has documented several occurrences of base and precious metals. A granodiorite located south of Partridge Breast Lake (approximately 40 km west of Northern Indian Lake) contains significant iron-staining that appears to be fracture-controlled to pervasive; however fresh visible sulphide is scarce. A sample collected from this location for assay in 2008 yielded 1.36% Zn, despite lacking visible sulphide. Fracture - controlled sulphide also occurs in granodiorite (unit 6) in the Northern Indian Lake area. These structures host stringers, blebs, and disseminations of pyrite, chalcopyrite and pyrrhotite associated with quartz and magnetite, and suggest potential for porphyry-style mineralization.

An interesting association of sulphide and pegmatite is present in the Southern Indian domain. In the northeast portion of Southern Indian Lake, a pegmatite containing pale, euhedral beryl crystals up to 2 cm surrounded by fine- to very-fine-grained massive to semi-massive sulphide yielded assay results up to 1.5 g/t Au and 0.4 wt.% Zn (Kremer et al., 2009b,c); the nature and significance of this association remains unknown.

References

Corkery, M.T. and Lenton, P.G. 1990: Geological Report GR85-1, 9 maps.
Corrigan, D., Hajnal, Z., Nemeth, B. and Lucas, S.B. 2005: Canadian Journal of Earth Sciences, v. 42, p. 421–434.
Cranstone, J.R. 1972: Resources and Environmental Management, Mines Branch, Publication 71-2J, 82 p.
Frohlinger, T.G. 1972: Manitoba Department of Mines, Resources and Environmental Management, Mines Branch, Publication 71-2l, 91 p.
Kremer, P.D. 2008: Report of Activities 2008, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 87–98.
Kremer, P.D. and Martins, T. 2014: Geology of the Northern Indian Lake area, Manitoba; Preliminary Map, PMAP 2014-6, scale 1:50 000.
Kremer, P.D., Rayner, N. and Corkery, M.T. 2009a: Report of Activities 2009, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, p. 94–107.
Kremer, P.D., Rayner, N. and Corkery, M.T. 2009b: Geoscientific Presentation PRES2009-13.
Kremer, P.D., Rayner, N. and Corkery, M.T. 2009c: Geoscientific Presentation PRES2009-14.
Lafrance, B. and Varga, M. 1996: Saskatchewan Energy and Mines, Miscellaneous Report 96-4, p. 119–124.
MacHattie, T.G. 2001: MSc thesis, Memorial University, St. John's, Newfoundland.
Martins, T. and Kremer, P.D. 2013: in Report of Activities 2013, Manitoba Mineral Resources, Manitoba Geological Survey, p. 114–122.
Rayner, N. and Corrigan, D. 2004: Geological Survey of Canada, Current Research 2004-F1, 14 p.

Acknowledgments

The authors thank C. Epp and R. Hiebert for providing enthusiastic field assistance and help with sample preparation. Logistical support provided by N. Brandson and E. Anderson is truly appreciated. The authors would also like to acknowledge B. Lenton and P. Lenton with help preparing figures and maps.