GS-10 Bedrock and surficial geological field investigations in the Nejanilini Lake area, northern Manitoba (parts of NTS 64P5, 12 and 13)

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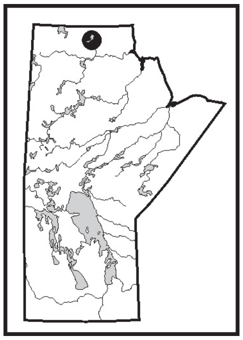

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Summary

The Nejanilini Lake area is situated in the central portion of the Nejanilini Domain, one of Manitoba's last large tracts of land that is relatively unknown and unexplored in terms of its geological nature, evolution and mineral potential. The study area at Nejanilini Lake offers access to bedrock exposures of all dominant rock types of the Nejanilini Domain, including 1) presumably Archean felsic and mafic igneous granulites and granitoid gneisses, K-feldspar-porphyritic granite and monzogranite, 2) a supracrustal belt composed of quartzite, calcsilicate paragneiss, semipelitic paragneiss and metagabbro, and 3) presumably Paleoproterozoic leucogranite, monzogranite, syenite and pegmatite intrusions. In addition, the Nejanilini Lake area contains a wide variety of spectacularly preserved Quaternary geological landforms including drumlins, eskers and tunnel channels. Glacial erratics play a significant role in the appearance of the landscape and their characteristics and distribution provide information contributing to a better understanding of the Quaternary geology of the region.

Introduction

Bedrock and surficial mapping in the Nejanilini Lake area was carried out to support mineral exploration activities in the region and to advance the currently limited geological understanding of a large tract of land in Manitoba's far north. Nejanilini Lake is located approximately 30 km south of the Nunavut–Manitoba border, within the Nejanilini Domain that forms part of the south flank of the Hearne Province of the Rae-Hearne Archean craton (Figure GS-10-1). The Nejanilini Domain comprises Archean high-grade igneous gneisses and presumably Paleoproterozoic supracrustal rocks that have together been affected by varying degrees of plutonism and thermotectonism during the Paleoproterozoic Trans-Hudson orogeny. The nature and age of these rocks, as well as the timing of high-grade metamorphism and polyphase deformation, are uncertain and part of the focus of the new geological studies at Nejanilini Lake.

This report summarizes field observations and data collected during three weeks of 1:50 000-scale bedrock and surficial geological mapping at Nejanilini Lake in July 2005. Nejanilini Lake, which is centrally located within the Nejanilini Domain, offers easy lakeshore access to all major rock types. The area was last mapped in the 1970s by the Manitoba Geological Survey, and the results of this work are presented on the Nejanilini Lake 1:250 000-scale bedrock compilation map (Manitoba Industry, Trade and Mines, 2002). The 2005 mapping program was focussed on the northern portion of Nejanilini Lake, and included detailed petrographic–petrological and structural mapping of bedrock exposures combined with mapping and description of the surficial geology. A large number of representative bedrock samples were collected for thin section, geochemical, isotopic and geochronological analysis. In addition, a total of 18 diamict samples for kimberlite and base metal indicator analysis were taken at an approximate spacing of 3 to 5 km within the bedrock mapping area.

Regional setting

The southeast margin of the Hearne Province has been regionally subdivided into six geological domains: the Mudjatik, Peter Lake (present only in Saskatchewan), Wollaston, Seal River, Great Island and Nejanilini domains (Figure GS-10-1). The domains are distinguished by their cover rocks, the proportion or absence of basement rocks, and their dominant structural trends.

The Nejanilini Domain is presently thought to consist largely of Archean continental crust of the Hearne craton, which consists mainly of granitoid gneiss of amphibolite and granulite metamorphic grade. The orthogneiss contains enclaves of migmatized supracrustal rocks and is intruded by younger, presumably Paleoproterozoic plutons (e.g., Manitoba Industry, Trade and Mines, 2002, and references therein). Orthogneiss of possible Archean age is typically composed of hypersthene-bearing granodiorite to monzogranite (opdalite to monzocharnockite), which shows varying degrees of alkali metasomatism and contains widely scattered, discontinuous inclusions of hypersthene-bearing, intermediate to mafic gneiss. Clark and Schledewitz (1988) referred to this complex, which they interpreted to be Archean in age, as the Nejanilini granulite massif. They interpreted a sample of monzocharnockite from this complex to be Archean in age, based on its Rb-Sr age of 2577 ±42 Ma, with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7057. Neodymium (crustal residence) model ages of a variety of granitoid samples, which include rock types mapped as presumably Archean granulite-grade felsic basement and Proterozoic granitoid intrusions, cluster in the tight range of 3.0 to 3.2 Ga (Böhm et al., 2004). These data suggest that the younger

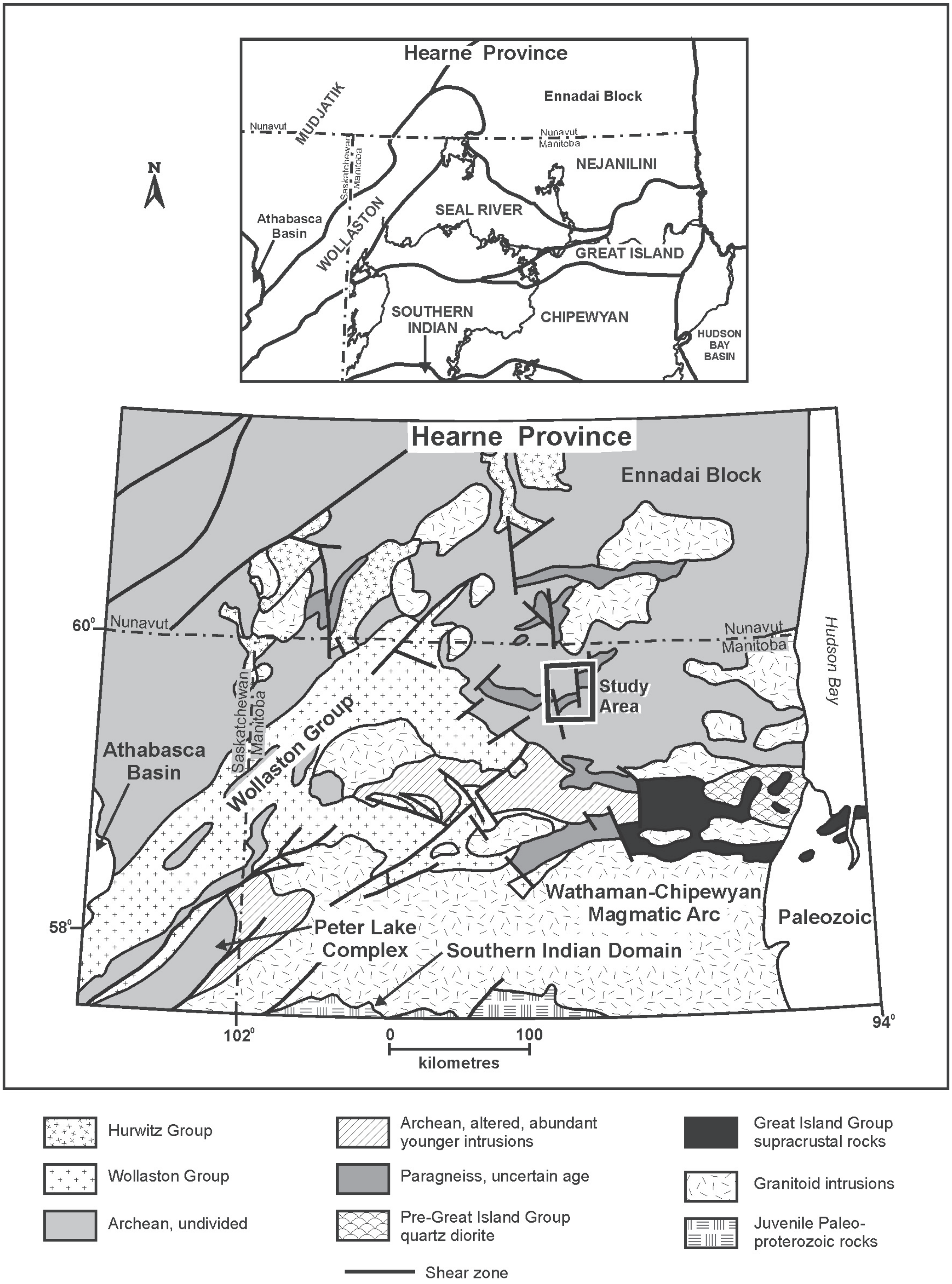

***Figure GS-10-1:** Lithotectonic elements of the Trans-Hudson Orogen–Rae-Hearne craton region (*modified after *Manitoba Industry, Trade and Mines, 2002).*

granitoid intrusions, Paleoproterozoic and/or Neoarchean in age, inherited their Nd isotope composition from the Meso- to Neoarchean basement from which they were derived and through which they passed. A ca. 2.8 Ga Nd model age of a metapelite from Nejanilini Lake suggests a Neoarchean average sediment provenance, likely from the Hearne basement (Böhm et al., 2004).

West of Nejanilini Lake, the Nejanilini Domain comprises foliated grey tonalite to granodiorite gneiss. This unit extends into Nunavut, where it is considered to be equivalent to the Archean Kasba grey gneiss (Eade, 1973; Loveridge et al., 1988) and to grey tonalitic gneiss in the Mudjatik Domain to the west. A composite sample of the Kasba grey gneiss yielded U-Pb zircon ages of 3274 ±18 Ma and 2777 +95/–66 Ma (Loveridge et al., 1988), possibly indicating that the grey tonalite was emplaced at ca. 2.78 Ga and contains ca. 3.27 Ga zircon inheritance. Alternatively, the Kasba grey gneiss may represent a composite unit that includes Archean rocks of more than one age.

South of the Nejanilini Domain, the contact with younger rocks of the Seal River and Great Island domains is occupied by a zone of younger, presumably Paleoproterozoic granitic rocks. These younger granitic plutons are present throughout the Nejanilini Domain, forming discrete intrusions with broad K-feldspar alteration haloes (Clark and Schledewitz, 1988). The metasedimentary and metavolcanic rocks of the Seal River Domain are separated from accreted juvenile Paleoproterozoic terranes to the south by the Wathaman-Chipewyan plutonic complex, the remnant of a continental magmatic arc (Figure GS-10-1; Meyer et al., 1992; Halden et al., 1990).

Bedrock geology of Nejanilini Lake

The simplified bedrock geology of the Nejanilini Lake area is summarized in Figure GS-10-2, and the preliminary geological map PMAP2005-3 (Anderson and Böhm, 2005). Due to extensive glacial drift cover, bedrock exposures at Nejanilini Lake are limited. The north-trending Quaternary landforms are in stark contrast to the dominantly east-trending bedrock geology at Nejanilini Lake (Figure GS-10-2), and the rare, largely lichen-covered bedrock exposures dominantly occur along east-trending lake shorelines, ridges, frost-heaved outcrops and block fields (felsenmeer).

Main lithological units

Bedrock exposures at Nejanilini Lake can be grouped into three main mappable units as described below: 1) presumably Archean high-grade granitoid basement rocks with subordinate mafic lenses and layers (orthogneiss), 2) a predominantly metasedimentary supracrustal belt (paragneiss), and 3) younger, possibly Paleoproterozoic granitic to monzonitic intrusions and pegmatite. Metamorphic grade reached upper amphibolite to granulite grade in most exposures of the ortho- and paragneiss units as evidenced by mobilizate layers and patches. Structurally, these gneisses show evidence for polyphase deformation with at least three generations of foliation and folds. In the following descriptions, the unit numbers correspond to those shown in Figure GS-10-2.

Archean basement rocks

Granulite-grade granitic to tonalitic intrusive rocks (charnockite to enderbite) represent the predominant rock types in the Nejanilini Lake area. These felsic intrusive rocks contain minor enclaves of mafic granulite, and bound the supracrustal metasedimentary rocks to the north, east and south. Although no clear contact relationships have been observed, these rocks are provisionally interpreted to represent the Archean crustal basement to the supracrustal rocks at Nejanilini Lake. Metamorphic layering and foliations are weakly developed along the eastern shore of Nejanilini Lake, and generally trend southwest, subparallel to the general trend of the lakeshore. As shown on Figure GS-10-2, these fabrics also parallel a northeast-trending linear aeromagnetic low that coincides with the apparent eastern extent of the supracrustal succession at Nejanilini Lake, and may thus indicate the presence of a discordant structural feature. In the northern portion of the mapped area, intercalated felsic and mafic granulites contain a very well developed metamorphic layering and foliation that trends generally west, subparallel to fabrics in the adjacent supracrustal rocks. Regional-scale aeromagnetic trends south of Nejanilini Lake indicate the presence of macroscopic folds, in accord with the highly variable orientations of mesoscopic fabrics observed in this area. Exposures displaying the contact relationship with younger, presumably Paleoproterozoic, intrusive rocks are rare, but relatively undeformed dikes and pods of pegmatitic quartz syenite are observed locally, and are interpreted to represent the latest phase of Paleoproterozoic magmatism. The potential Archean basement rocks are described below from oldest to youngest and their general distribution in the Nejanilini Lake area is shown in Figure GS-10-2.

Mafic granulite (unit 1)

Mafic granulite forms a minor component of the presumed Archean basement, and occurs as blocky xenoliths in weakly foliated opdalite (granodiorite) and enderbite (tonalite), and also forms discrete layers and enclaves, which may represent sills and transposed dikes, within thick packages of enderbite gneiss. The mafic granulites are dark green to black, and typically exhibit a coarse-grained, granoblastic texture defined by recrystallized plagioclase, pyroxene and hornblende. The predominate rock types are pyroxene-bearing hornblendite and metagabbro, with minor occurrences of metapyroxenite.

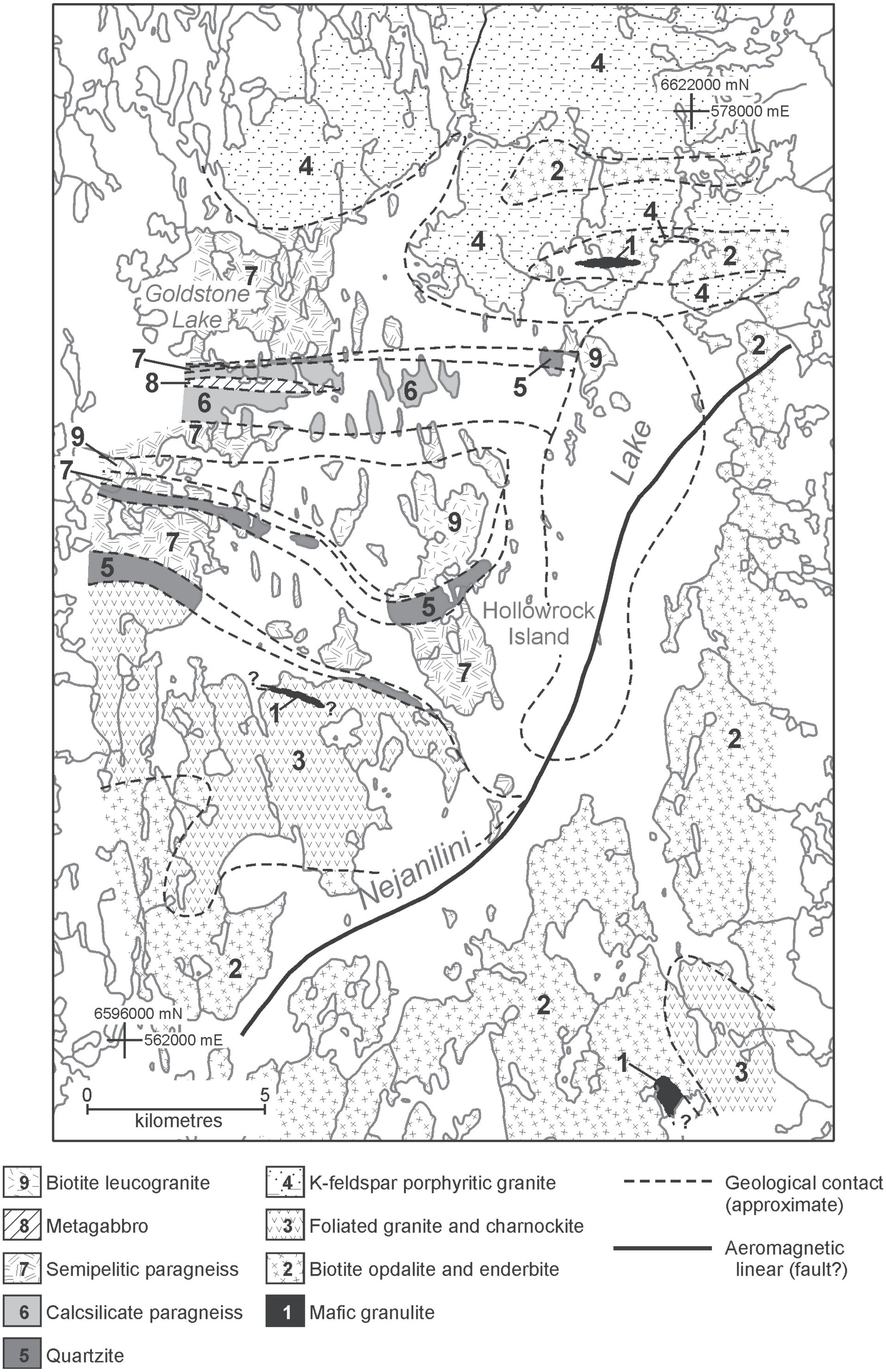

Figure GS-10-2: *Simplified bedrock geology of the Nejanilini Lake area.*

The mafic granulite typically contains a weakly to moderately developed foliation, with a variably developed metamorphic layering defined by leucocratic and mesocratic gneiss. These rocks contain small amounts (5–10%) of plagioclase-clinopyroxene-hornblende±quartz±orthopyroxene mobilizate, which typically forms relatively undeformed patches and veinlets (Figure GS-10-3a).

Biotite opdalite and enderbite (unit 2)

Biotite opdalite and enderbite form the dominant rock types along the east side of Nejanilini Lake (Figure GS-10-3b). These rocks typically weather light grey to pink, and characteristically exhibit waxy grey-green to honey brown fresh surfaces. A weak to moderately developed foliation is typical, and locally parallels a

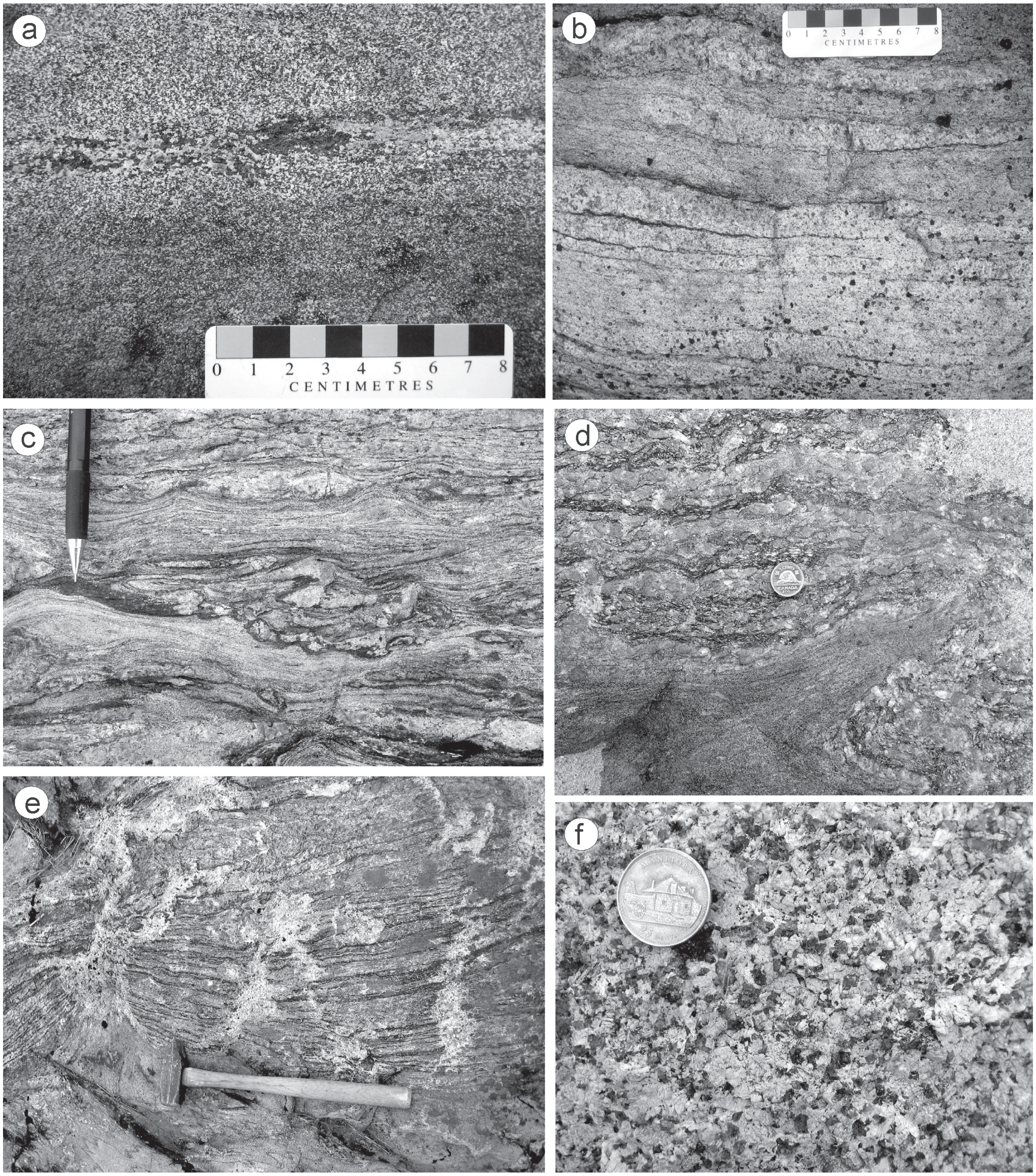

Figure GS-10-3: *Outcrop photographs of bedrock exposures from Nejanilini Lake:* ***a)*** *mafic granulite with coarse-grained mobilizate;* ***b)*** *hypersthene-bearing biotite opdalite gneiss with granitic layers and veins;* ***c)*** *strongly transposed calcsilicate gneiss with minor interlayered semipelitic paragneiss; strongly boudinaged layers of diopside-rich calcsilicate define rootless, tight to isoclinal, Z-asymmetric folds;* ***d)*** *semipelitic paragneiss showing rhythmically alternating biotite-rich and sillimanite (faserkiesel)-rich domains, folded into a tight, Z-asymmetric fold;* ***e)*** *semipelitic garnet-sillimanite-biotite paragneiss with coarse-grained cordierite-garnet-plagioclase-quartz mobilizate concentrated in boudin necks and along shear bands (hammer for scale);* ***f)*** *coarse-grained, relatively undeformed granite to syenite.*

weak to moderate metamorphic layering defined by centimetre-scale leucocratic and mesocratic layers. These rocks typically have a fine- to medium-grained, equigranular, granoblastic texture, and locally contain up to 10%, pale brown, hypersthene. Irregular veins and patches of coarse-grained to locally pegmatitic, hypersthene-bearing quartz syenitic and granitic (quartz-plagioclase-biotite± orthopyroxene±clinopyroxene) leucosome account for up to 10% of these outcrops, and are relatively undeformed.

Foliated granite and charnockite (unit 3)

Foliated granite and charnockite, with minor granodiorite and tonalite (opdalite to enderbite), predominate in the southwest portion of the mapped area. These rocks typically weather light pink, and have a medium-grained, granoblastic texture. Biotite is the principal mafic phase, and locally accounts for up to 20% of these rocks. Pale green, equant clinopyroxene occurs locally (up to 5%). Although typically equigranular, these rocks locally contain up to 2 to 3% anhedral to subhedral, K-feldspar phenocrysts up to 2 cm across. In some locations, the porphyritic material occurs as xenoliths in foliated granite, as well as dike-like bodies, suggesting a potentially complex emplacement history. These rocks contain abundant dikes of weakly to undeformed quartz syenite and pegmatitic leucogranite, as well as rare xenoliths of amphibolite gneiss and mafic granulite.

K-feldspar porphyritic granite and monzogranite (unit 4)

K-feldspar porphyritic granite and monzogranite are the main rock types in the north and northeast Nejanilini Lake area (Figure GS-10-2). These rocks weather a distinctive reddish pink to beige, and typically consist of homogeneous, weakly to strongly foliated, medium- to coarse-grained porphyritic granite with up to 25%, 0.5 to 3.0 cm, subhedral K-feldspar phenocrysts. Strongly foliated outcrops exhibit a well-developed augen texture. In the northeast, porphyritic granite contains enclaves of enderbite gneiss and mafic granulite, suggesting an intrusive relationship. No dikes of this material were observed in the adjacent supracrustal succession.

Nejanilini Lake supracrustal rocks

The west-central and northwest portion of Nejanilini Lake is underlain by a west-trending succession of metasedimentary rocks, which includes semipelitic paragneiss, calcsilicate paragneiss, quartzite and metagabbro. Although presently undated, this succession is lithologically similar to lower parts of the ca. 2.1 Ga Wollaston Group in Saskatchewan, suggesting it may represent a Paleoproterozoic cover sequence that unconformably overlies an Archean basement. Alternatively, the Nejanilini Lake supracrustal rocks could be related to Huronian-type sediments of the ca. 2.4 Ga Hurwitz Group in Nunavut and the N.W.T. (e.g., Aspler and Bursey, 1990). The U-Pb analysis of detrital zircon will be used to constrain the age and better understand the regional correlation of the quartzite and semipelitic paragneiss at Nejanilini Lake.

The metasedimentary rocks contain granulite-facies mineral assemblages (cordierite-sillimanite-biotite±garnet ±hypersthene) that are compatible with the granulite-facies metamorphism recorded in the adjacent Archean rocks, perhaps suggesting both underwent granulite-facies metamorphism in the Archean. It is also possible, however, that these granulite-facies mineral assemblages were produced during Hudsonian thermotectonism at temperatures and pressures slightly above the typical middle to upper amphibolite metamorphic grade.

Regional-scale aeromagnetic data indicates that the central portion of the Nejanilini Domain is characterized by a complex structural geometry, which likely includes macroscopic, doubly plunging (i.e., dome and basin type) fold structures. Overprinting relationships observed in outcrop on Nejanilini Lake indicate that the supracrustal rocks contain at least four generations of deformation structure, which include at least three phases of open to isoclinal folding. Given this structural complexity, and the absence of unambiguous younging criteria, the stratigraphy of the Nejanilini supracrustal rocks remains uncertain, and the various units are described below in an order corresponding to that of an idealized Precambrian platformal cover sequence.

Quartzite (unit 5)

Quartzite exposures in the northwest portion of Nejanilini Lake define three, roughly east-trending mappable units that can be traced for several kilometres along strike. The quartzite weathers white to pale grey or beige and is composed of more than 95% quartz. It typically has a coarse, granoblastic-polygonal texture. In outcrop, the quartzite ranges from massive to faintly layered, with the layering defined by centimetre-scale domains that contain 2 to 5% fine-grained biotite and muscovite. The quartzite appears to range up to 800 m thick, and is interpreted to mark the base of the Nejanilini Lake supracrustal section. Although the possibility of multiple quartzite units cannot be ruled out, the map pattern is provisionally interpreted to reflect structural repetition of this unit by isoclinal refolding.

Calcsilicate paragneiss (unit 6)

Calcsilicate paragneiss defines an approximately 2 km thick map unit that can be traced for 4 km along strike near the north margin of the supracrustal belt. This unit is bound to the north by quartzite and to the south by a thick package of semipelitic paragneiss, perhaps suggesting a south-younging stratigraphic succession. South of Goldstone Lake, carbonate content within the calcsilicate paragneiss gradually decreases over a few metres at the contact with the semipelitic paragneiss. The calcsilicate paragneiss is pale green to purple grey, with a fine-grained granoblastic texture. These rocks range from finely laminated to thinly layered, with the layering defined by calcareous (carbonate-diopside-epidote rich) layers alternating with micaceous calcsilicate schist. Competency contrasts between these layers has resulted in well-developed boudin structures, which are a characteristic feature of this unit (Figure GS-10-3c). The calcsilicate unit locally contains minor interlayers of semipelitic paragneiss, and is intruded by thick metagabbro sills.

Semipelitic paragneiss (unit 7)

Biotite-rich sillimanite (faserkiesel) cordierite±garnet semipelitic paragneiss forms the dominant lithology of the Nejanilini Lake supracrustal belt (Figure GS-10-2). These rocks have a fine- to coarse-grained granoblastic texture, and locally contain a well-developed layering defined by alternating layers of dark grey pelite and light grey psammite (Figure GS-10-3d). Locally, these rocks contain discrete, strongly boudinaged, layers of calcsilicate, up to 30 cm thick. Mobilizate patches and veins that consist of coarse-grained quartz-feldspar-cordierite-biotite±garnet±sillimanite form up to 20% of these rocks. In many locations, the mobilizate appears to preferentially fill late shear-band structures that discordantly cut two earlier generations of planar fabric and folds (Figure GS-10-3e). Faserkiesel (sillimanite+quartz±biotite metamorphic aggregates; up to 30%) represents a very common and characteristic constituent of the paragneiss. In many locations, the paragneiss contains at least two generations of faserkiesel: an early generation of equant, granoblastic aggregates that parallel the main metamorphic layering, and a later generation of elongate, fibrous aggregates that are discordant to the layering. The paragneiss is locally gossanous, and contains up to 5% finely disseminated sulphides (pyrite-pyrrhotite), with up to 2 to 3% strongly boudinaged quartz veins. Dikes of leucogranite, monzogranite and syenite are common in the paragneiss, and are typically weakly deformed.

Metagabbro (unit 8)

Several up to approximately 1 km thick elongate intrusive bodies of metagabbro occur within the semipelitic and calcsilicate paragneiss in the northwest part of Nejanilini Lake (Figure GS-10-2). The metagabbro is dark grey to green, and ranges from fine- to coarse-grained, with a weakly to strongly developed foliation defined by aligned biotite aggregates. A subophitic texture is locally preserved, although the rock typically exhibits a granoblastic texture defined by recrystallized plagioclase and hornblende±pyroxene. Accessory phases include biotite, garnet, quartz, with trace pyrrhotite and chalcopyrite. The metagabbro ranges from melanocratic to mesocratic, but is typically homogeneous on the scale of individual outcrops. The metagabbro also contains rare, up to a few centimetres wide, discordant quartz-feldspar veins.

Paleoproterozoic intrusive rocks

The youngest rocks observed in the Nejanilini Lake area consist of weakly to moderately foliated leucocratic granite, monzogranite and syenite; the latter typically forming small bodies, dikes and injection veins that are generally pegmatitic.

Biotite leucogranite (unit 9)

Leucogranite is exposed fairly extensively on the northern end of Hollowrock Island, and also occurs as small, isolated exposures on islands to the west and northeast. The leucogranite is typically light beige to pink and fine grained, and includes biotite granite, biotite granite gneiss, and biotite-hornblende granite to quartz monzonite. These rocks are typically weakly to moderately foliated, and contain rare xenoliths of paragneiss and amphibolite. On the eastern shore of Hollowrock Island, contact relationships are well exposed, and indicate that these rocks intrude the supracrustal succession.

Monzogranite and quartz syenite

Pale pink to beige and reddish pink monzogranite and quartz syenite dikes are ubiquitous in the Nejanilini Lake area, and were clearly emplaced late in the tectonic evolution. These rocks range from coarse-grained to pegmatitic, and characteristically display graphic-textured quartz exsolution lamellae in microcline and contain up to 10% biotite (Figure GS-10-3f). Individual dikes range up to several metres thick, and are weakly foliated to massive, relatively undeformed, and cut discordantly across gneissic fabrics in the country rocks. Monzogranite and quartz syenite also occur as irregular to schlieric pegmatitic patches, from decimetres to a few metres in size. Tourmaline is a common accessory mineral in these rocks.

Surficial geology of Nejanilini Lake

In the Nejanilini Lake area, forested areas are restricted to narrow bands along the shores of lakes, as well as isolated patches in sheltered or low-lying areas. The glacial landscape is relatively pristine and, coupled with the absence of trees, the landforms are highly visible from the ground and on airphotos. The landscape is gently rolling and is generally composed of west-trending, basement-cored ridges and north-trending, glacially derived landforms. Besides peatlands, boulders are a significant aspect of the landscape.

The surficial geology and Quaternary stratigraphy were investigated at a limited number of natural exposures and in hand-dug pits. The glacial ice flow direction was determined from the orientation of eskers and streamlined landforms such as drumlins, and by measurement of the ubiquitous glacial striations on bedrock surfaces (Matile, 2005). At 18 sites, glacial diamict samples were taken for indicator minerals and geochemical analysis. The surficial geology of the area was last mapped in the late 1970s by the Geological Survey of Canada, and published as a 1:250 000-scale preliminary map by Dredge and Nixon (1981) and as a final "A" series 1:500 000-scale map by Dredge et al. (1985).

Post-glacial features

In order to properly map surficial sediments, a basic understanding of Holocene, or more specifically post-glacial, processes in the region is required. The Nejanilini Lake area is mostly within the zone of continuous permafrost, with the exception of the southern end of the lake, which is in the Extensive Discontinuous (50–90%) zone (Natural Resources Canada, 2005). Permafrost was encountered as shallow as 20 cm below surface in peatlands and as deep as 2 m in better-drained sediments. The permafrost is expressed on surface by the development of extensive polygonal ground in areas of peatland and frost boils in better-drained sediments, both of which comprise a slightly raised area of several square metres to over a hundred square metres with a trough around the perimeter. The perimeters of the polygons tend to be water-filled grassy zones, whereas the perimeters of the more rounded frost boils tend to be only slightly depressed, with significantly more vegetal cover than the relatively barren, soil-free centres of the frost boils.

Soils are poorly developed in the area. The A and B soil horizons are typically a total of 20 to 30 cm thick. The A horizon is typically dark brown in colour (Munsell colour 10YR 2/2), whereas the B horizon is typically dark yellowish brown (Munsell colour 10YR 4/6). Diamict samples were taken, where possible, from the C horizon or parent material of the soil.

Another post-glacial feature of the landscape, which results from the severe climate, is frost-heaved bedrock and fields of frost-shattered bedrock (Figure GS-10-4). Large blocks of bedrock, in some cases in excess of 8 m across, have been heaved upwards by frost. In many locations, the surface of the bedrock is shattered into smaller blocks as a result of frost action. Shattered bedrock fields (felsenmeer) are identified by the uniformity of the rock lithology and the angular nature of the boulders within them. These shattered bedrock fields are, in places, a significant component of the landscape, and range in size from less than one hundred to several thousand square metres.

In this severe climate, lake ice also plays a role in modifying the landscape. Ice-push ridges resulting from the thermal expansion and contraction of lake ice are ubiquitous along the shores of Nejanilini Lake. In this process, glacial erratics and bedrock blocks are pushed shoreward, repeatedly, by expanding lake ice, and thus form boulder ridges along the shoreline. This process, repeated year after year, has led to the formation of what is informally referred to as 'fortress islands' (Figure GS-10-5).

Glacial geology

Laurentide glacial ice retreated from this area between 7000 and 8000 years BP with glacial Lake Agassiz abutting the ice margin (Dyke et al., 2004). However, no evidence of glacial Lake Agassiz was observed in the Nejanilini Lake area, and the pristine nature of the landforms supports the suggestion that glacial Lake Agassiz did not extend into the area.

***Figure GS-10-4:** The left image is an example of frost-heaved bedrock; whereas the right image is a field of shattered bedrock.*

Figure GS-10-5: Two examples of 'fortress islands': in the left image the centre of an island shows blocks of bedrock up to 8 m across that have been pushed upwards by ice action; in the right image, glacial erratics form high ice-push ridges along the shoreline of a small island.

The glacial stratigraphy of the area comprises an unknown thickness of stratified sand that is more than 5 m thick in places and is overlain by an average of approximately 1 m of glacial diamict. The base of the sand unit was not exposed. Hand-dug pits typically penetrated the diamict. The diamict is typically very light grey in colour, with a very fine sand matrix, highly variable in pebble content, with near-horizontal medium sand stringers. The diamict is discontinuous and noncalcareous.

There are virtually always boulders on surface. The boulders tend to be subrounded to rounded. Boulder lithology changes rapidly with the local bedrock lithology, indicating a generally short distance of glacial transport. In contrast, lithological pebble counts on the 2 to 4 cm fraction of the diamict samples showed a variable, but significant amount of exotic material, suggesting significant glacial transport distances.

Glacial striations are found on bedrock exposures throughout the area. The azimuth of the striations typically ranges between 160 and 180°. In a number of locations, there are several striations on an outcrop that are oriented approximately 20° clockwise from the main set. The striations are all considered to be associated with one glacial event, and fluctuations in azimuth may reflect local variations in the slope of the substrata causing local deflections in the glacier.

Numerous south-trending eskers occur in the area. They are typically found within a meandering tunnel channel, and are typically made up of several interconnected ridges composed of sand to pebbly sand that are occasionally covered by subrounded to rounded boulders (Figure GS-10-6). The eskers are commonly flanked by sand deposits, probably fans, again with or without boulder cover. Large areas of bedrock outcrop with scattered subrounded boulders also occur on the flanks of the eskers.

North-trending drumlins occur throughout the area. The stratigraphy within the drumlins is consistent with that of the region, with the exception of one location where unusually thick (>12 m) diamict was observed. In several

Figure GS-10-6: Typical multiridged esker with rounded boulders on the crest in the foreground.

locations, the subglacial channels that carved the drumlins are clearly evident on airphotos (Figure GS-10-7). There is an extensive array of subglacial channels in the area, from parallel to perpendicular to ice flow. Many of the channels oblique to the ice flow direction appear to be the result of an obstacle that diverted the flow direction. Higher ridges, which appear to be obstacles to subglacial water flow, tend to have north-trending streamlined drumlinoid ridges across the crests.

Throughout the area, glacial erratics tend to be subrounded. However, in the northern portion of Nejanilini Lake a clear transition occurs, from rounded boulders, spatially associated with an esker conduit, to angular, very coarse, boulders outside the esker conduit. The angular boulders are found littering the surface in flat areas and also form 15 m high ridges that appear to be composed of stacked angular boulders. The ridges appear to have random orientations. The angularity of these boulders suggests that they haven't been transported very far, and are believed to be a result of local subglacial plucking of the bedrock. A somewhat rectangular depression in bedrock, which is approximately 2 m deep, was observed in this area and is thought to be a site where subglacial plucking occurred.

To the north within the esker conduit, the gravel becomes coarser boulder gravel, the sand-sized sediment disappears, and the eskerine ridges become less pronounced. The esker conduit is also essentially straight, as opposed to the meandering esker conduits to the south. Boulder gravel becomes typically open framework and clast supported. Two boulder armoured erosional remnants were observed within the esker conduit in this area, which apparently impeded the flow within the conduit and thus resulted in a deposit of very coarse boulder gravel on the leeward (south) side of the obstacles.

Over most of the Nejanilini Lake area, the abundance of eskers, subglacial channels, and rounded to subrounded boulders is suggestive of a subglacial flood environment with at least some separation of the glacier and its substrata. In contrast, the angularity of the boulders in the northern portion of the area, suggests that the glacier was, at least in part, frozen to the substrata. In addition, within the northern portion of the area, the esker texture and morphology completely change over a distance of

Figure GS-10-7: *Drumlins with associated lateral channels; channels are shown on the diagram to the right as solid black lines with arrows representing the direction of water flow. The small lake at the north end of the drumlin was likely eroded by the same current (Airphoto A15306-102, Government of Canada, Department of Energy, Mines and Resources).*

approximately 5 km north to south, and these changes are interpreted to indicate that the esker became less capable of carrying extremely coarse sediment.

The contrasts between the extreme northern portion of the map area and the remaining area to the south, indicates that there was a dramatic change in the nature of glacial activity. One possible explanation for these changes involves bursting of a nearby subglacial reservoir. In this model, amassing water in a subglacial reservoir may have generated a low pressure zone, which could have caused the base of the ice to freeze to the substrata. A present day analogy of glacial ice freezing to the substrata down-ice from a subglacial reservoir is described by Clarke et al. (1984). When the reservoir attained a sufficient volume to break through the ice dam, the resulting high-volume and high-velocity flows could have generated the large number of angular boulders via plucking of bedrock. This abrupt release of water would also explain the large number of subglacial channels, including eskers, to the south and possibly the abrupt textural and morphological changes in the esker in the northern portion of the area. Eskers may be considered the deposit of a waning subglacial flood or a return to normal (possibly seasonal) subglacial drainage (Brennand and Shaw, 1994), suggesting a concentration of flow with decreasing amounts of floodwater. This is supported by the increased amount of bedrock outcrop along esker conduits and the presence of a tunnel channel enclosing the esker.

Another possible explanation for the angular boulders is that in the late stages of glaciation, the esker conduit may have eroded enough ice to generate a local thinning of the glacier which was significant enough to become a low pressure zone in proximity to the esker near the snout of the glacier (T. Brennand, pers. comm., 2005). This would have the effect of freezing the area along the closing esker conduit to the substrata, which in this case was bedrock. With the absence of glacial Lake Agassiz or any other significant ice-marginal lake, the glacier would retreat by way of melting as opposed to floating away as icebergs. Any shifting of the ice during this time of melting would pluck the angular boulders from the underlying bedrock and leave them scattered on the landscape near the esker.

Economic considerations

Archean high-grade rocks of the Nejanilini Domain form part of a stable cratonic crust that may have developed a deep lithospheric keel that extended into the diamond stability field. In addition, the Nejanilini and adjacent crustal domains form the margin of the large Archean Rae-Hearne craton. Both aspects make the study area a prime target for kimberlite exploration. The area is currently being explored for diamondiferous kimberlite by several exploration companies. Improved knowledge of the nature and evolution of the Nejanilini Domain, in conjunction with surficial geological and kimberlite indicator-mineral studies, will facilitate kimberlite exploration in the region.

The supracrustal succession at Nejanilini Lake is tentatively interpreted to represent a platformal cover sequence, which was likely deposited on top of the Archean Hearne craton, either along the passive southeastern margin of the craton, or within an intracratonic basin. The former option would suggest a possible correlation with the ca. 2.1 Ga Wollaston Group in Saskatchewan, whereas the latter would suggest a possible correlation with the ca. 2.4 Ga Hurwitz Group. In either scenario, deposition of the cover sequence is interpreted to record the onset of crustal subsidence in response to continental extension (e.g., Aspler and Bursey, 1990; Patterson and Heaman, 1991). In such settings, basin initiation is often accompanied by mafic-ultramafic magmatism, high heat flow, and resultant hydrothermal circulation, which have the potential to produce significant hydrothermal (i.e., sedimentary exhalative zinc-lead-silver sulphide) and magmatic (i.e., magmatic nickel-copper sulphide) ore deposits. Similar potential may exist in the Nejanilini Lake supracrustal succession.

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