GS2022-2

Updates to bedrock geology mapping in the Gull Rapids area following construction of the Keeyask hydroelectric dam, northeastern Manitoba (parts of NTS 54D5, 6)

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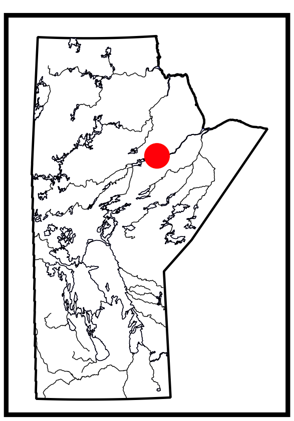
In Brief:

- Bedrock mapping of outcrops made accessible or created by Keeyask hydroelectric dam construction at Gull Rapids allow for minor changes of the regional geology
- Regionally thick glacial overburden limit bedrock exposures but warrant a future surficial mapping and sampling study

Citation:
Böhm, C.O. and Rinne, M.L. 2022: Updates to bedrock geology mapping in the Gull Rapids area following construction of the Keeyask hydroelectric dam, northeastern Manitoba (parts of NTS 54D5, 6); *in* Report of Activities 2022, Manitoba Natural Resources and Northern Development, Manitoba Geological Survey, p. 5–11.



Summary

Bedrock geological studies in the Gull Rapids area were previously conducted in 2003–2004, to document the geological record prior to construction of the Keeyask hydroelectric dam. The addition of bedrock geological data collected in summer 2022 from previously nonexistent or inaccessible exposures allows for some updates of the regional geology mapping done in the Keeyask dam region of the Gull Rapids area, specifically the geology as portrayed at a scale of 1:250 000. The new bedrock data, in combination with high-resolution aeromagnetic data to probe beneath regionally thick overburden cover, refine the geology shown on the existing 1:250 000 scale bedrock compilation. The ubiquitous glacial overburden in the region evidently resulted in misinterpretation of contact positions and distribution of geological units, and may warrant the undertaking of surficial geological studies in the Keeyask hydroelectric dam area.

Introduction

In 2003 and 2004, the Manitoba Geological Survey (MGS), in collaboration with the universities of Alberta and Waterloo and supported by Manitoba Hydro, undertook detailed bedrock mapping at 1:1000 to 1:200 scales in the Gull Rapids area (Böhm et al., 2003a, b, 2006; Bowerman et al., 2004; Downey et al., 2004), west of Gillam, where the lower Nelson River spills into Stephens Lake (present site of the Keeyask hydroelectric dam; Figure GS2022-2-1). The 2003 and 2004 bedrock mapping and follow-up analytical studies provided a detailed record of the geology at Gull Rapids. In conjunction with the Gull Rapids studies, mapping of areas upstream the lower Nelson River to Split Lake were conducted in 2003–2005 (Hartlaub et al., 2003, 2004; Kuiper et al., 2003, 2004; Hartlaub and Kuiper, 2004; Kuiper and Lin, 2004a, b). Together, these studies provided a record of the geology east of Stephens Lake along the lower Nelson River prior to the Keeyask hydroelectric dam construction, which resulted in water level alterations and changes in bedrock exposures and access.

Since the completion of the aforementioned geological studies, an approximately 25 km long all-weather access road was built by Manitoba Hydro between Provincial Road 280 northeast of Split Lake and the Keeyask hydroelectric dam site (Figure GS2022-2-1). This new road, together with aggregate quarry sites along the way, provides access to potential bedrock exposures for a previously largely inaccessible and geologically poorly documented transect along this portion of the Superior boundary zone (Figure GS2022-2-1).

The northern access road to the Keeyask dam and changes in exposure at Gull Rapids due to hydroelectric dam construction warranted collection of new geological information both along the road corridor and at the dam site. Permission granted by Manitoba Hydro to use the access road and work onsite at the Keeyask dam area allowed the MGS to proceed with geological mapping and sampling work in August 2022, when the authors conducted two weeks of geological fieldwork in the Keeyask dam area (Figure GS2022-2-1). This geological fieldwork included

- one week of geological mapping and sampling along and off the Keeyask dam northern access road, focused on possible bedrock exposures accessible by truck and foot traverses; and
- one week of detailed geological follow-up mapping in the Keeyask dam area, focused on new or changed bedrock exposures accessible by truck and on foot, providing an update to the previous bedrock mapping at Gull Rapids.

Bedrock geology of the Keeyask dam region

Gull Rapids (location of the Keeyask hydroelectric dam) is located at the northwestern margin of the Superior craton in northeastern Manitoba. It is situated between variably retrogressed Archean granulites of the Split Lake block (northwestern Superior province) to the southwest and Paleopro-

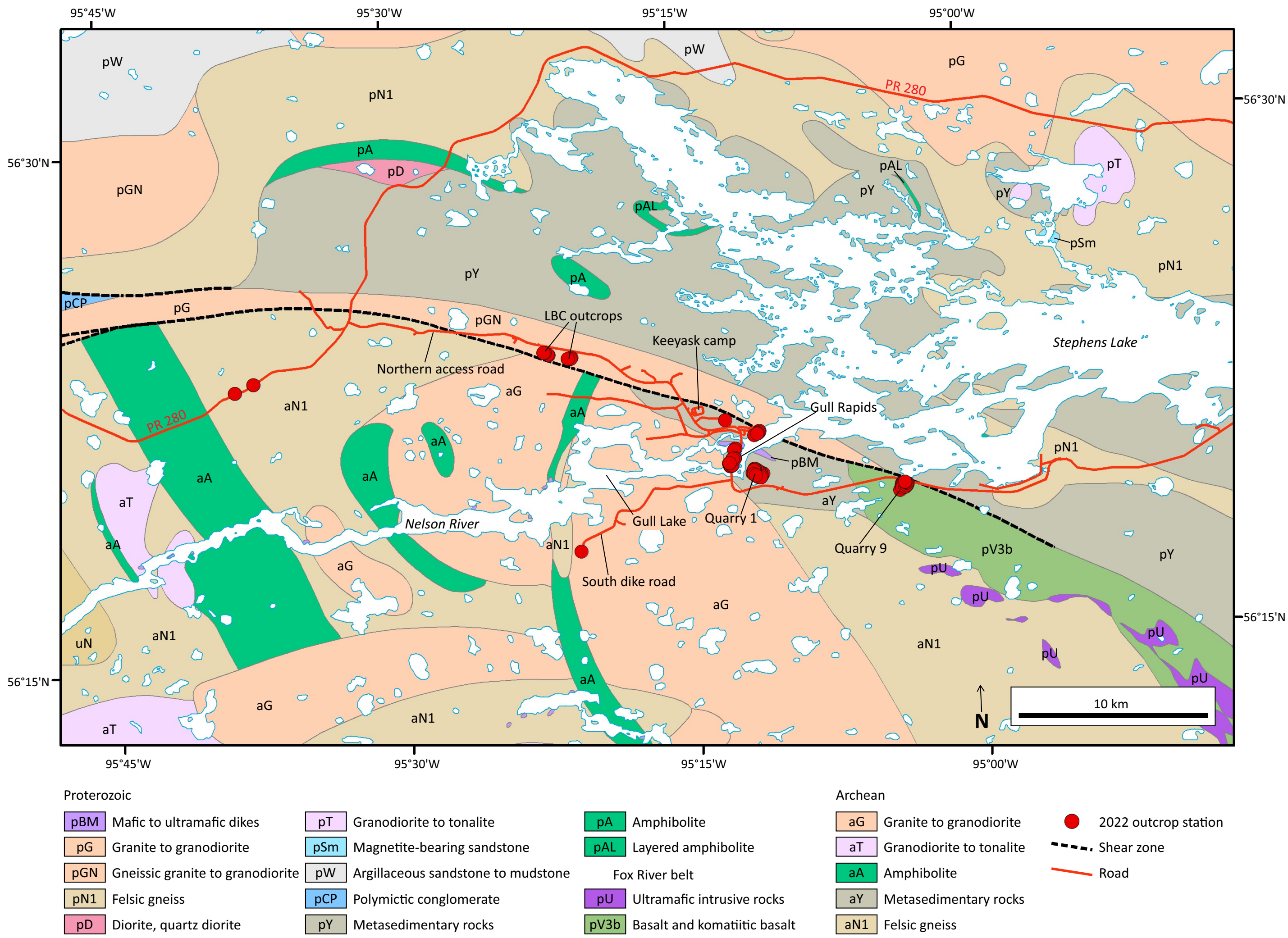


Figure GS2022-2-1: *Regional bedrock geology of the Keeyask hydroelectric dam area, modified after the 1:250 000 scale Precambrian bedrock geology map issued by the Manitoba Geological Survey (2022). The 2022 station locations (red circles) were accessed primarily by road and on foot, with access to the Keeyask dam site via a side road off Provincial Road 280 (PR 280, labeled). Locations referenced in the text (Keeyask main camp, quarry 1, quarry 9, south dike road) are labeled near map centre. Abbreviation: LBC, Looking Back creek.*

terozoic amphibolite-facies sedimentary and igneous rocks of the eastern Kisseynew domain (southeast Trans-Hudson orogen) to the north and east (Figure GS2022-2-1). The Gull Rapids area, located along the lower Nelson River, includes a spectacularly exposed sequence of late Archean, multiply deformed and upper-amphibolite– to granulite–facies supracrustal rocks that are juxtaposed against, and derived from, middle Archean, granulite-facies orthogneiss of the Split Lake block (Böhm et al., 1999). Extensive, late Archean felsic injection sheets and anatectic melts crosscut the supracrustal rocks and orthogneiss, and are further truncated by large numbers of Paleoproterozoic mafic dikes. The Gull Rapids area records a complex tectonic history, the bulk of which occurred during late Archean (Kenoran) rather than Paleoproterozoic (Hudsonian) orogenesis (Downey et al., 2009).

Early investigations of the Gull Rapids area delineated supracrustal rocks, which are abundant just east of Gull Rapids at Stephens Lake, as being part of the Paleoproterozoic Burntwood group (Haugh and Elphick, 1968; Haugh, 1969; Corkery, 1975, 1985). Detailed mapping in the Gull Rapids region in 2003 and 2004, combined with lithogeochemical, isotopic and geochronological analyses, identified more lithological and structural complexity than was previously known. From west to east, the following are the principal, dominantly south-trending lithological building blocks at Gull Rapids (e.g., Böhm et al., 2006): Mesoarchean granodiorite and derived gneissic rocks (3.18–3.14 Ga and 2.86–2.85 Ga; Bowerman et al., 2004), Archean amphibolite interpreted as metabasalt and metagabbro, Archean metasedimentary rocks including dominantly iron-rich metagreywacke gneiss (ca. 2.70 Ga youngest detrital zircons; Bowerman et al., 2004) with banded iron formation and rare lenses of ultramafic to mafic metaconglomerate, voluminous Neoarchean granitoid injection sheets and pegmatite dikes (ca. 2.69–2.61 Ga; Downey et al., 2009), and west- to northwest-trending Paleoproterozoic mafic dikes (2.07 Ga; Bowerman et al., 2004). For detailed descriptions of the lithologies and structures at Gull Rapids consult Böhm et al. (2003a, b), Bowerman et al. (2004) and Downey et al. (2004).

Field observations at Gull Rapids further indicated that the supracrustal units are multiply deformed, based on the development of multiple foliations and refolded folds (Böhm et al., 2003a, b; Downey et al., 2004). Detailed structural examinations by Downey (2005) delineated five generations of deformation at Gull Rapids, some of which were subsequently dated by Downey et al. (2009) between ca. 2.69 Ga (D_1) and 2.61 Ga (D_4).

Due to the earthworks and construction of the Keeyask hydroelectric generation site at Gull Rapids and resulting upstream flooding, the western two-thirds of the documented bedrock geological record, summarized at 1:5000 scale in Böhm et al. (2006), has become inaccessible.

Newly mapped bedrock exposures

Quarry 1

Detailed mapping was carried out at a bedrock quarry approximately 500 by 250 m located immediately southeast of the Keeyask dam (Figure GS2022-2-2). The dominant lithology along the southern and western sides of the quarry is massive to foliated, layered grey granodiorite, locally showing a character-

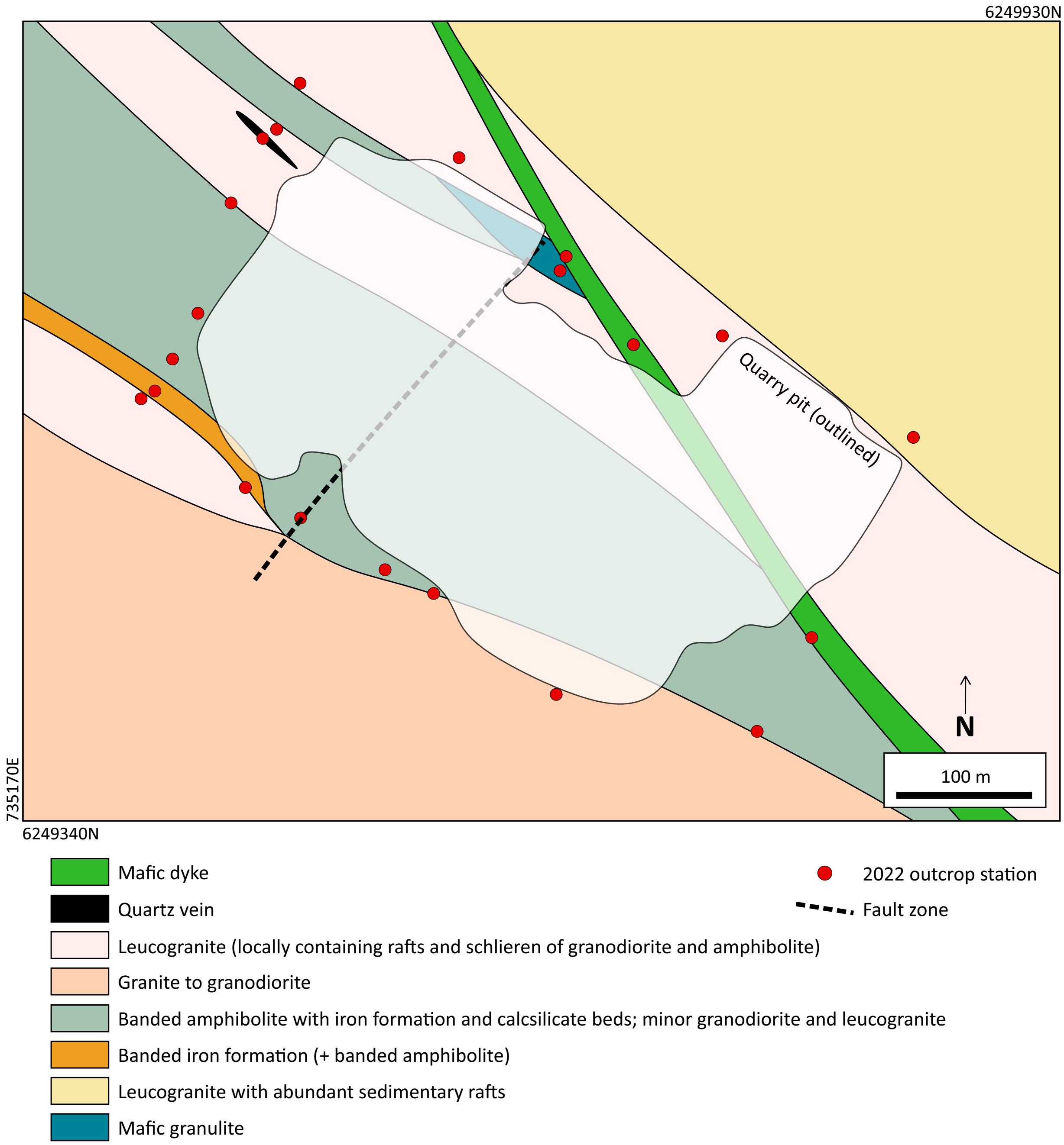


Figure GS2022-2-2: *Bedrock geological sketch map of quarry 1, located southeast of the Keeyask dam (all co-ordinates are in UTM Zone 14, NAD83).*

istic texture of black retrogressed garnet-amphibole clots. Along the western side of the quarry, the granodiorite is injected by leucogranite and the granitic units include abundant amphibolite interpreted as xenoliths or rafts (Figure GS2022-2-3a). The amphibolite is fine grained and dark grey green on fresh and weathered surfaces, and is commonly layered. Several 1–2 m wide, strongly deformed layers and lenses of mainly oxide-facies banded iron formation are hosted within the amphibolite (Figure GS2022-2-3b) and are prominently exposed at the northwestern corner of the quarry. Calcsilicate layers up to 2 m wide have also been observed in the layered amphibolite (Figure GS2022-2-3c), largely exposed near the granodiorite contact along the southwestern side of the quarry.

The northern and eastern parts of the quarry are dominated by leucogranite that is coarse grained to pegmatitic and contains up to 10% biotite in aggregates and clots. Along the southeastern side of the quarry, leucogranite includes xenoliths of biotite gneiss interpreted as paragneiss. A southeast-trending (~140°) mafic dike at least 10 m thick transects the eastern part of the quarry (Figure GS2022-2-2).

The northeastern side of the quarry exposes medium- to coarse-grained, layered to banded and commonly folded amphibolite interpreted as retrogressed mafic granulite. This interpretation is based on abundant feldspathic mobilizate and melt pods (Figure GS2022-2-3d). As elsewhere, the amphibolite is injected by leucogranite. A prominent zone of chloritic phyllite a few metres wide marks a brittle-ductile shear zone with locally abundant quartz veining that trends approximately 225° across the quarry. In summary, the rock types exposed at quarry 1 represent a remarkable variety and are similar to the main lithological units along the eastern part of Gull Rapids along strike to the north-northwest (Böhm et al., 2006).

Quarry 9

Quarry 9 is located east-southeast of the Keeyask dam, in an area outlined as basalt on the 1:250 000 scale Precambrian bedrock geology map issued by the Manitoba Geological Survey in 2022 (Figure GS2022-2-1). Detailed mapping of this quarry revealed bedrock consisting almost entirely of foliated, grey, medium- to coarse-grained gneissic granodiorite with schlieren structures (Figure GS2022-2-3e). The gneissic granodiorite locally hosts quartz veins and leucogranitic pegmatite dikes up to 1 m in width. A single 1–2 m wide zone of biotite phyllite trends northwest across the quarry and is interpreted as a minor shear zone. The northeastern corner of the quarry exposes a contact, trending approximately 120°, between a massive diabase dike and gneissic granodiorite. Small diabase offshoots into the gneissic granodiorite suggest the latter to be Archean.

Western end of the south dike road

One exposure of layered felsic gneiss was found about 100 m north of the western termination of the south dike road (Figure GS2022-2-1). The light grey-beige weathered gneiss contains 10–15% fine-grained biotite, mostly along thin seams, and sparse feldspar porphyroclasts up to 4 cm in diameter. The gneiss is interpreted as a granodiorite intrusion and contains up to 20% medium- to coarse-grained quartzofeldspathic mobilizate layers and pods. Gneissosity is steeply dipping and strikes approximately 350°, mimicking the regional fabric of similar felsic intrusive gneisses in the Keeyask dam area.

Looking Back creek

A series of outcrops occur along a ridge dropping off to Looking Back creek, south of the Keeyask dam northern access road (labeled LBC outcrops in Figure GS2022-2-1; the creek is too small to display at the map scale). All exposures along the ridge display highly strained and altered gneiss (Figure GS2022-2-3f), with a main quartzofeldspathic component and up to 30% interlayered mafic bands and lenses. The felsic gneiss layers are greyish green on fresh surfaces, and characteristically tend to weather pale pink to orange. Mafic bands are commonly strongly sheared and resorbed with abundant pale green epidote alteration. Gneissosity and main foliation strike west to northwest. Locally abundant deformed quartz veining follows gneissosity and weaves into east- to southeast-trending shear bands. Gneissic layering commonly varies from a few millimetres to a few centimetres in size. The highly strained gneiss shows abundant intrafolial folding and dextral shearing, representing a major brittle–ductile deformation zone likely subparallel or related to the regional Assean Lake deformation zone.

Future studies

Thick drift cover, from Gull Rapids and extending beyond Provincial Road 280 to the north, blankets bedrock except for a few exposures along Looking Back creek and warrants surficial geological investigations along the northern access road (vast sand deposits) and the lower Nelson River in the Keeyask dam area (high till banks). Surficial mapping and sampling of glacial deposits and erosional features would provide valuable information on the nature, composition and derivation of glacial sediments, including aggregate materials in the region.

Economic considerations

The northwestern Superior craton margin is the site of many exploration targets, most prominently economic nickel in the prolific Thompson nickel belt and shear-hosted gold associated with ancient crust and regional deformation zones at Assean Lake. The extent of the Thompson nickel belt and Assean Lake ancient crust, forming part of the Superior boundary zone, is only partially delineated; the extensions of these zones remain important economic targets. Further mapping along the Superior craton margin contributes to an understanding of the tectonic configuration of this complex zone; it will provide a valuable tool for outlining possible new targets for nickel and gold exploration.

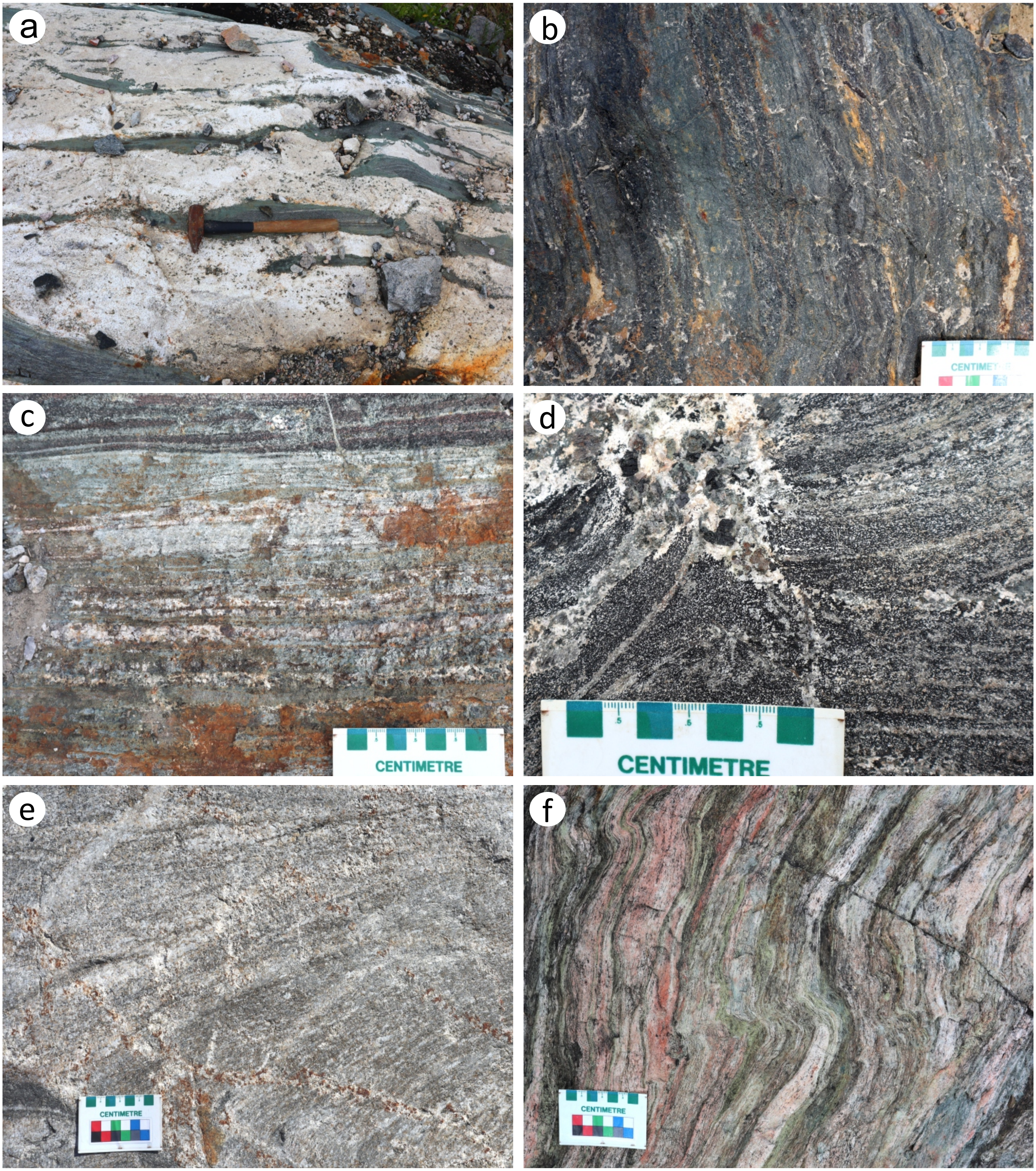


Figure GS2022-2-3: *Outcrop photographs from the Keeyask dam area showing:* ***a)*** *leucogranite with abundant amphibolite rafts (quarry 1);* ***b)*** *layered amphibolite and oxide-facies iron formation (quarry 1);* ***c)*** *pale calcsilicate beds within layered amphibolite (darker amphibolite visible at the top of image; quarry 1);* ***d)*** *amphibolite interpreted as retrogressed mafic granulite (quarry 1);* ***e)*** *gneissic granodiorite (quarry 9); and* ***f)*** *intensely strained gneiss with minor kink bands (near the LBC outcrops shown on Figure GS2022-2-1).*

The formation, emplacement and preservation of diamondiferous kimberlites is broadly controlled by the presence of thick Archean cratonic lithosphere combined with crustal-scale sutures and lineaments (e.g., faults, dike swarms). Geophysical and isotopic investigations (e.g., Böhm et al., 2000; Coyle et al., 2004a, b; Thomas, 2007; Böhm et al., 2008) have proven the existence of ancient crust, regional sutures and dike swarms extending along the Superior boundary zone into the Keeyask dam area. The presence of promising kimberlite-indicator-mineral trends and a greater understanding of ice-flow directions during glaciation has led to northeastern Manitoba being targeted as a likely source for these indicators (e.g., Keller, 2019; Gauthier et al., 2021).

Acknowledgments

The authors thank T. Middleton (Manitoba Hydro) for discussions and generous support of this project.

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