GS-16 Archean and Paleoproterozoic geology of the northwestern Split Lake Block, Superior Province, Manitoba (parts of NTS 54D4, 5, 6 and 64A1)

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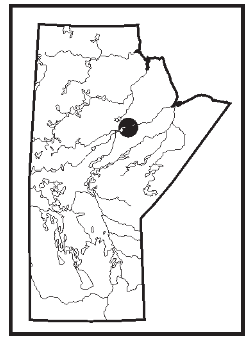

Hartlaub, R.P., Böhm, C.O., Kuiper, Y.D., Bowerman, M.S. and Heaman, L.M. 2004: Archean and Paleoproterozoic geology of the northwestern Split Lake Block, Superior Province, Manitoba (parts of NTS 54D4, 5, 6 and 64A1); *in* Report of Activities 2004, Manitoba Industry, Economic Development and Mines, Manitoba Geological Survey, p. 187–194.

Summary

The Split Lake Block is a shear zone–bounded lozenge of Archean and Paleoproterozoic rock that lies along the northwestern paleomargin of the Superior Province. The oldest units in the area include pelite, and mafic to ultramafic granulite that is interpreted to be supracrustal in origin. An igneous complex, composed of anorthosite, anorthositic gabbro, gabbro and mafic tonalite, has an unknown age relationship to these supracrustal rocks. Both the supracrustal rocks and the igneous complex occur as coherent bodies and as disrupted layers, rafts and xenoliths in younger granite, granodiorite and tonalite. The presence of granulite-facies mineral assemblages in Archean rocks indicates that the Split Lake Block was deeply buried during the Neoarchean. Local retrogression of the granulite-facies assemblages occurred during a later amphibolite-facies event. Overall, the lithological and metamorphic characteristics of the Split Lake Block are similar to those of the bounding Pikwitonei Granulite Domain. Additional isotopic study will be required, however, before a detailed chronological comparison is possible.

A suite of weakly metamorphosed and variably deformed mafic dikes crosscuts the high-grade Archean rocks and constitutes at least 15% of the exposed outcrop in the Split Lake Block. Leucogranite, pegmatite and aplitic rocks of the Paleoproterozoic Fox Lake granite increase in both abundance and volume toward the northern shore of Split Lake.

Introduction

The northwestern margin of the Archean Superior Province has been subdivided into several subdomains, based on differences in their geological history. One of the largest subdomains, the Split Lake Block, is an approximately 100 by 40 km lozenge that is structurally bounded by the Assean Lake and Aiken River deformation zones to the north and south, respectively (Corkery, 1985; Figure GS-16-1). To the east, the Split Lake Block is truncated by the Proterozoic Fox River Belt. South of the Aiken River deformation zone, the Pikwitonei Granulite Domain may represent an equivalent, and much larger, extension of the Split Lake Block (Corkery, 1985; Heaman et al., 1999). The best exposed rocks of the Split Lake Block are found on Split Lake and along the stretch of the Lower Nelson River that runs northeast from Split Lake to Gull Rapids. Mapping was carried out along this section during a two-week period in 2003 (Hartlaub et al., 2003) and a four-week period in 2004. Pleistocene and Recent clay and silt deposits blanket much of the Split Lake Block (Corkery, 1985), precluding extensive mapping away from the major waterways.

The Split Lake Block was chosen for detailed mapping, petrography, geochronology and geochemistry for several important reasons:

1) The Split Lake Block borders, and may contain fragments of, an exotic block of ancient crust (Böhm et al., 2000). The total extent of this exotic block, and the timing of its accretion with the Superior Province, need to be better defined.
2) Although U-Pb and isotopic studies of the northwestern Superior Province commenced in 1995 (Heaman and Corkery, 1996; Böhm et al., 1999), a detailed study of the Split Lake Block has never been carried out. A thorough study is critical to understanding the relationship between the Split Lake Block and the Pikwitonei Granulite Domain.
3) The study area is located along the same continental paleomargin as the economically important Thompson Nickel Belt (TNB). Determining the position and geological history of the paleomargin of the northern Superior Province will allow for improved exploration activities. A better understanding of the local geology is also critical for long-term planning of the region's mineral and hydroelectric potential.

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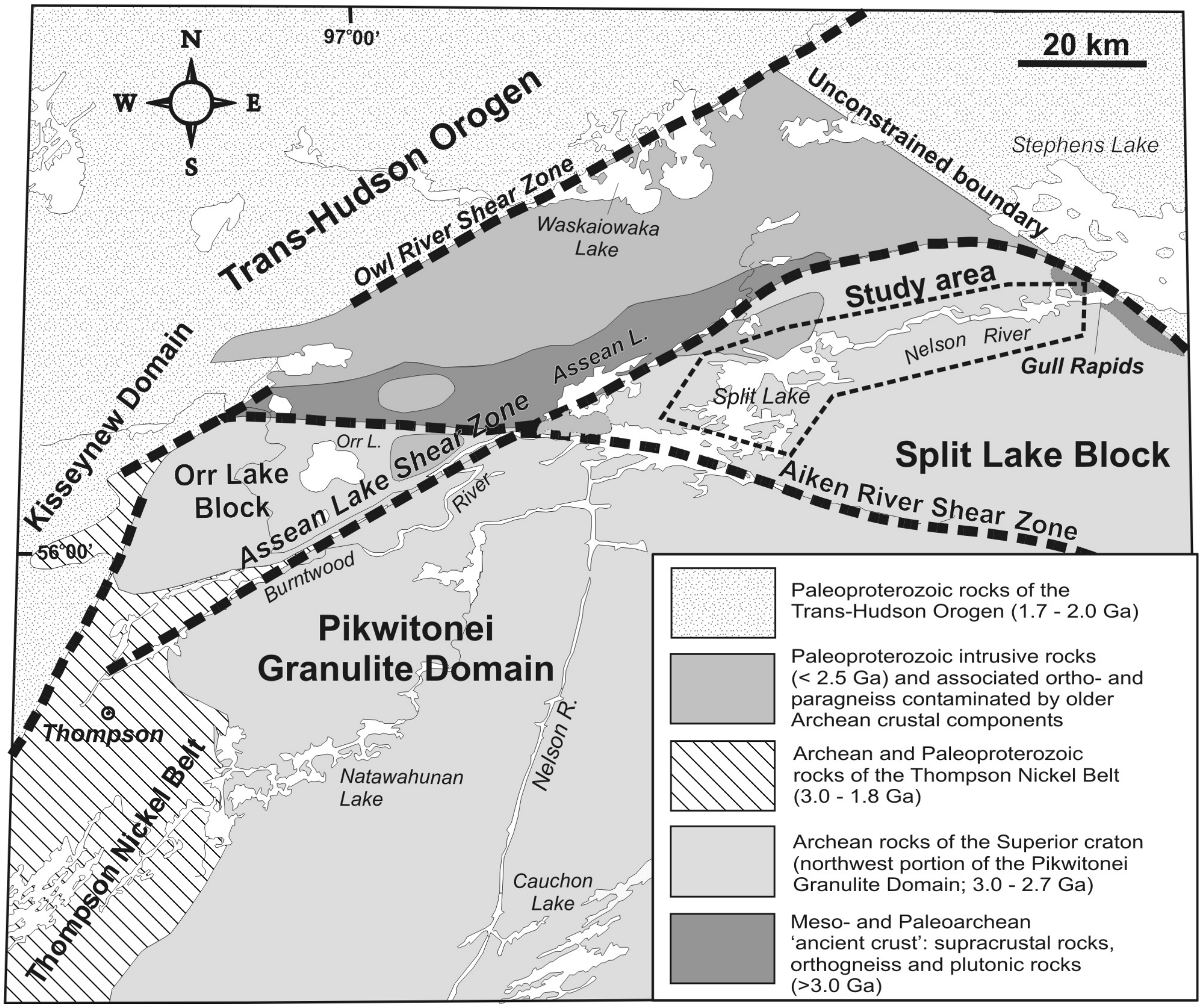

Figure GS-16-1: *General geology of the northern Superior Province. Dashed polygon outlines the study area.*

General geology

Mafic and ultramafic granulite and pelite, and an igneous complex composed of anorthosite, anorthositic gabbro, gabbro and mafic tonalite (Figures GS-16-2, -3), represent the oldest rocks in the area. Younger granite, granodiorite and tonalite intrusions contain numerous disrupted layers, rafts and xenoliths of the older rocks. These granitoid rocks are interpreted to be Archean because they have undergone ca. 2.7 Ga (Böhm et al., 1999) granulite-facies metamorphism. Orthopyroxene-bearing in situ melts are widespread; however, an Archean amphibolite-facies overprint affects some of the high-grade Archean rocks in the Split Lake Block (Böhm et al., 1999).

A voluminous suite of weakly metamorphosed and variably deformed, Proterozoic mafic dikes crosscuts the Archean basement. A single, 150 m wide, unmetamorphosed ultramafic intrusion (websterite) is exposed at the eastern end of Split Lake. The youngest rocks in the study area are leucogranite, pegmatite and aplitic rocks that are interpreted to be related to the 1825 Ma (Heaman and Corkery, 1996) Fox Lake granite. These leucogranitic rocks increase in both abundance and volume toward the northwest end of Split Lake.

Archean

Mafic granulite

Mafic granulite is black and fine to medium grained, and locally displays compositional layering (Figure GS-16-4a). The rock is composed primarily of plagioclase, pyroxene and amphibole. Where compositional layering is well developed, horizons that contain >10% garnet are common. Orthopyroxene±garnet melt segregations constitute up to 5% of this unit. Xenoliths, rafts and disrupted layers of mafic granulite are abundant within the granodiorite plutons. The

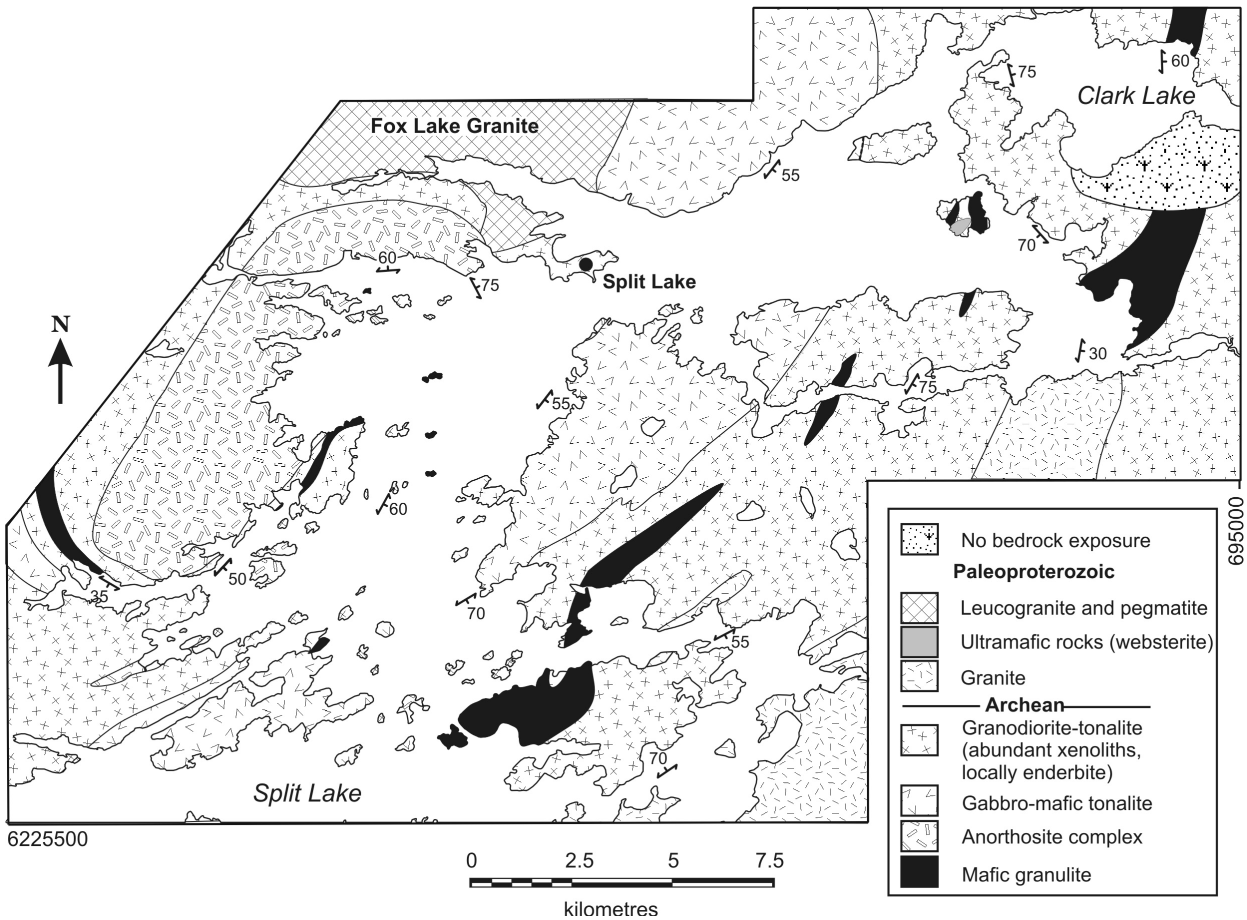

Figure GS-16-2: *Simplified geology of the Split Lake area.*

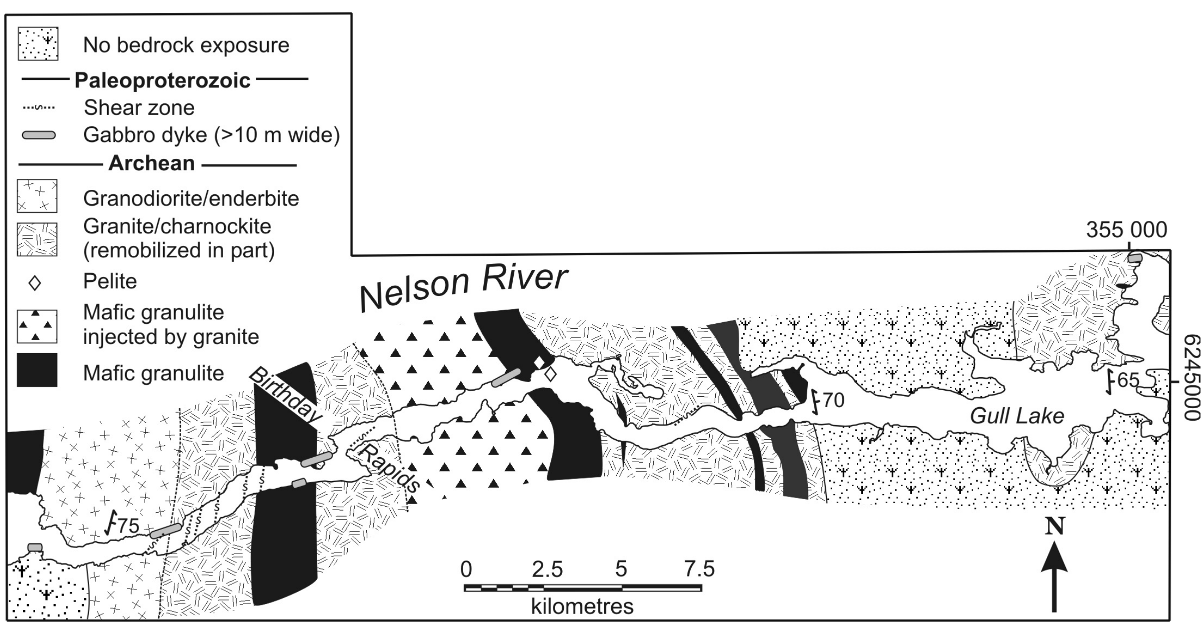

Figure GS-16-3: *Simplified geology of the Lower Nelson River from Gull Rapids to Clark Lake.*

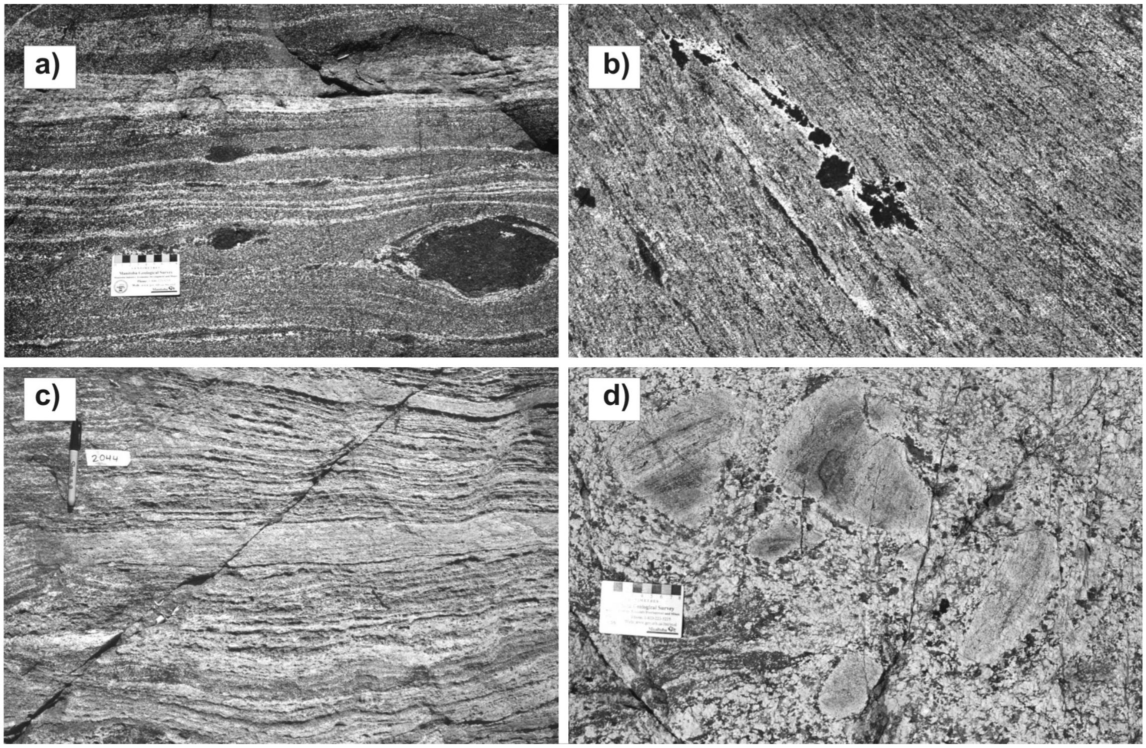

Figure GS-16-4: *Archean rocks of the Split Lake Block:* ***a)*** *mafic granulite with dismembered ultramafic horizon injected by tonalite sheets (sample 9704-2252, UTM 676672, 6232355);* ***b)*** *deformed gabbro with orthopyroxene-bearing in situ melt (sample 9704-2234, UTM 676580, 6237244);* ***c)*** *strongly layered granodiorite gneiss (sample 9704-2044, UTM 322224, 6241549);* ***d)*** *granodiorite containing numerous xenoliths of anorthosite (sample 9704-2278, UTM 680207, 6228785).*

fine- to medium-grained nature and local compositional layering of the mafic granulite may indicate that its protolith was a mafic volcanic rock. The garnet-rich horizons may represent iron-rich interflow sediments. Four samples of the mafic granulite were collected in 2003 from locations along the Gull Rapids to Birthday Rapids section of the Nelson River for whole-rock geochemical study. When normalized to chondritic values, these samples have a primitive-MORB–like signature with a slight enrichment in LREE and no negative Nb anomaly.

A single 3 m wide horizon of possible felsic volcanic rock was identified on east-central Split Lake. The horizon is fine grained, light grey weathering and interlayered with the mafic granulite. Quartz phenocrysts, abundant plagioclase and amphibole, 5% disseminated sulphides, and trace zircon and apatite were identified in thin section.

Ultramafic rocks

Ultramafic rocks occur as large blocks, disrupted hornblendite layers and isolated xenoliths within granodiorite. This unit likely represents an end member of the mafic-granulite volcanic sequence; however, the only age constraint is that this unit must be older than the plutonic suite and granulite metamorphism (i.e. >2.7 Ga). A single large boudin of talc (soapstone) that likely represents hydrated ultramafic rock was identified directly east of Robertson Island on Split Lake.

Pelite

Sedimentary rocks are extremely rare in the Split Lake Block, occurring primarily as thin horizons interlayered with mafic granulite. Several exposures of rusty brown–weathering pelite were identified on the Lower Nelson River in 2003 (Hartlaub et al., 2003). These exposures consist of well-layered quartz, feldspar, biotite, garnet and sillimanite, with trace sulphides±graphite. The only pelitic rocks identified on Split Lake were found as decimetre-thick garnet-rich layers that contained minor graphite and rare cordierite. These layers are interlayered with mafic granulite and may represent iron-rich interflow sediments.

Anorthosite complex

A large (at least 50 km^2; Hartlaub and Kuiper, 2004) anorthosite complex is well exposed along the northwestern shore of Split Lake. Corkery (1985) interpreted the complex as having an anorthositic core that was surrounded by layered gabbroic anorthosite and anorthositic gabbro. The anorthosite and anorthositic gabbro are composed of coarse-grained plagioclase and 0–20% clinopyroxene. Thin-section examination indicates that the clinopyroxene is partially to entirely replaced with hornblende and biotite. Trace amounts of opaque minerals are also present. Locally, textures indicative of magma differentiation are present, as is well-developed igneous layering.

Gabbro to mafic tonalite

Gabbro to mafic tonalite outcrops as a ≥1 km thick unit along the margins of the anorthosite complex (Figure GS-16-2). This unit, referred to as hornblende and hornblende-biotite gneiss by Corkery (1985), is medium to coarse grained and grey to black weathering. These rocks are strongly gneissic and contain up to 60% hornblende and biotite, plagioclase, and trace to 15% quartz. Orthopyroxene-bearing in situ melt is locally present (Figure GS-16-4b). Like the rocks of the anorthosite complex, this unit is injected by tonalite-granodiorite and lacks xenoliths. The apparent spatial association between gabbro to mafic tonalite and the anorthosite complex may indicate that the two units are coeval; however, no contacts between the two were observed.

Granite, granodiorite and tonalite (locally enderbite)

Large bodies of variably deformed, pale orange– and white-weathering granodiorite, tonalite and leucotonalite constitute >50% of exposed rock throughout the Split Lake Block. This unit ranges from nearly massive with random clots of mafic minerals to strongly foliated gneissic and/or migmatitic (Figure GS-16-4c). The pock-marked appearance of the clotted intrusions is related to preferential weathering of retrogressed pyroxene agglomerations. Granodiorite grades locally into tonalite, and both units contain abundant orthopyroxene where they host numerous mafic granulite and ultramafic xenoliths. The majority of xenoliths and rafts within this unit are amphibolite and hornblendite. These xenoliths were likely retrogressed from granulite grade by fluids in the intrusions. Anorthosite xenoliths are abundant in the granodiorite and tonalite of central and northern Split Lake (Figure GS-16-4d).

The granodiorite and tonalite are compositionally similar to melt segregations from the mafic granulite and, therefore, some of these intrusions may have been produced via partial melting during granulite-grade metamorphism. Consistent with this is the presence along the Lower Nelson River, east of Birthday Rapids, of a granite and mafic granulite leucosome that have nearly identical ca. 2.7 Ga ages (Böhm et al., 1999).

Proterozoic

Fault gouge

Several outcrops of lithified fault gouge occur along a major south-southeast-trending lineament. The fault gouge is composed of a fine-grained chloritized groundmass containing angular to well-rounded blocks of country rock (Figure GS-16-5a). The margins of this unit are defined by narrow shears in the host rocks. The fault gouge is crosscut by a mafic dike, which constrains the timing of this fault to Neoarchean or Paleoproterozoic.

Gabbro dikes

A voluminous suite of mafic dikes crosscuts the gneissic fabric of their Archean hostrocks in the Split Lake Block. The dikes range from 20 cm to >10 m in width, and many are composite bodies comprising two or more intrusive episodes. These dikes are aphanitic to coarse grained (Figure GS-16-5b), depending on width, and locally have pegmatitic segregations of intermediate composition. Euhedral plagioclase laths are ubiquitous and, although hornblende and chlorite alteration is common, relict pyroxene cores are common in the larger intrusions. Igneous layering, defined by plagioclase laths, is present in some of the largest mafic dikes (Figure GS-16-5c). Although these dikes have not been caught up in the strong Archean deformation and metamorphism of their hostrocks, some are highly disrupted and strained in discontinuous Proterozoic shear zones. A mafic dike cuts gouge within a major northwest-trending fault, indicating that this structure is Archean or late Paleoproterozoic in age. The sheer volume of mafic dikes in the Split Lake Block indicates that significant Proterozoic crustal growth occurred in the northern Superior Province.

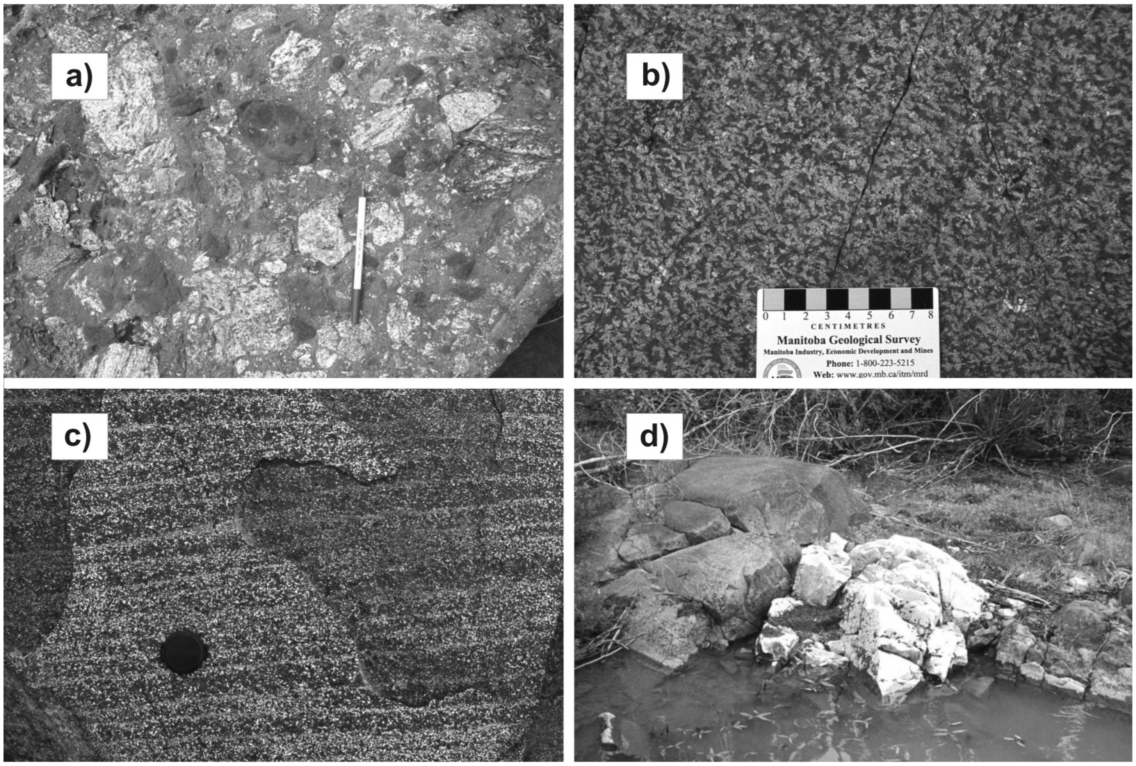

Figure GS-16-5: *Paleoproterozoic rocks of the Split Lake Block:* ***a)*** *lithified fault gouge containing angular to rounded ultramafic, mafic and felsic clasts; this gouge is crosscut by a 1 m wide northeast-trending mafic dike (sample 9704-2084, UTM 685513, 6234284);* ***b)*** *close-up of a coarse-grained, northeast-trending, 15 m wide gabbro dike exposed near Birthday Rapids (sample 9704-2073, UTM 326351, 6240398);* ***c)*** *igneous layering in a 20 m wide, northeast-trending gabbro dike exposed along the western side of Split Lake (sample 9704-2177, UTM 675098, 6233637);* ***d)*** *aplitic dike of the Fox Lake granite crosscutting undeformed ultramafic rocks (websterite; sample 9704-2014, UTM 316614, 6237762).*

Ultramafic sill (websterite)

A massive, brown-weathering, medium-grained ultramafic sill is exposed along a 150 m wide section on the shore of an island in northeastern Split Lake. The ultramafic body intrudes the surrounding Archean gneiss but is completely undeformed itself. The intrusion can be classified as websterite, comprising orthopyroxene and clinopyroxene with minor amounts of olivine (Corkery, pers. comm., 2004). Steel grey serpentine veins and carbonate alteration were noted throughout but are most abundant near the margins of the body. A single 2 m wide aplitic dike that crosscuts the ultramafic sill (Figure GS-16-5d) indicates that this unit is coeval with or older than the Fox Lake granite.

Coarse-grained granite and pegmatitic dikes

Coarse-grained granite with abundant segregations of distinctive blue-grey quartz occurs sporadically from Gull Rapids to central Split Lake. This granite is massive to weakly foliated and contains abundant xenoliths. On central Split Lake, a single body of this unit appears to be axial planar to late folding. Straight-sided, muscovite-bearing, white and pink pegmatitic granite dikes also occur throughout the region. These pegmatitic granite bodies are cut by pegmatitic to aplitic dikes of the Fox Lake leucogranite.

Fox Lake granite

The Fox Lake leucogranite consists of three main components on Split Lake: 1) light grey to pink aplitic dikes; 2) pegmatitic dikes and sills; and 3) medium-grained, homogeneous, biotite granite plutons.

Grey and pink aplitic granite dikes are abundant (>5% of most outcrops) north of Robertson Island on Split Lake. These medium-grained to aphanitic, locally quartz- and/or K-feldspar–phyric aplitic dikes increase in abundance and volume toward the town of Split Lake. They have no consistent structural trend, both at outcrop and map scales. Like the aplitic leucogranite, the pegmatitic leucogranite sill and dike networks do not have a consistent structural orientation. The pegmatitic leucogranite contains distinctive K-feldspar crystals that are often >10 cm in length.

Medium-grained biotite granite forms large homogeneous bodies north of the Split Lake townsite and along the southwestern edge of the map area (Figure GS-16-2). A weak foliation defined by the alignment of biotite occurs in these plutons. A single U-Pb zircon age of 1825 Ma (Heaman and Corkery, 1996) was obtained from a sample of this phase of granite.

Metamorphic and structural geology

Archean rocks of the Split Lake Block have undergone at least two, and possibly additional, metamorphic events. The oldest of these is a granulite-facies event that occurred as two distinct pulses (M1a and M1b of Corkery, 1985) between 2705 and 2695 Ma (Böhm et al., 1999). Patches of coarse-grained orthopyroxene-bearing melt related to this phase of metamorphism are locally well developed, especially in the mafic granulite. Due to the high melting temperature of anorthosite, it is the only Archean unit that does not appear to have undergone in situ anatexis. A widespread amphibolite-facies overprint is thought to have occurred at 2620 Ma (Böhm et al., 1999).

The structural geology of the mapped area is dominated by moderately to steeply southeast-plunging, open to tight folds (Kuiper et al., GS-18, this volume; Hartlaub and Kuiper, 2004). An axial-planar foliation to these folds is commonly visible, and the intersection between this foliation and the gneissosity defines an intersection lineation, which is parallel to the fold axis (Kuiper et al., GS-18, this volume). At a few locations, the orientations of the folds vary. This variation is attributed to late rotation and/or folding, perhaps related to movement on the Aiken River and/or Assean Lake deformation zones (Kuiper et al., GS-18, this volume). Late, dextral and sinistral, millimetre- to centimetre-scale, sometimes mylonitic shear zones are present at locations throughout the study area. Their orientations are not consistent. It is speculated that they may be related to late movement on the Aiken River and/or Assean Lake deformation zones, but the relationship is unclear.

Economic considerations

The vast amount of Archean and Proterozoic mafic and ultramafic magmatism in the northwestern Split Lake Block gives the area significant titanium, platinum group element and nickel potential. Specifically, the differentiated anorthosite igneous complex exposed on northwestern Split Lake could be an important target for ilmenite-bearing titanium deposits (e.g., Duchesne, 1999). The lack of visible disseminated sulphides in these rocks is also promising, as platinum group elements and nickel would be more likely to sequester where mafic phases of the intrusion intersect pelitic horizons. The voluminous Proterozoic mafic dikes that inject the region may have some mineral potential, since they are a possible conduit for the conveyance of metals from the mantle to the upper crust.

Future work

The main unresolved problems in the Split Lake Block revolve around the timing and nature of magmatism, metamorphism and deformation. The time of emplacement for the anorthositic complex must be identified, and the relationship between this complex and the surrounding granitoid rocks must be established. Recording the timing of Archean magmatism and metamorphism in the Split Lake Block will enable a detailed comparison to be made with the adjacent Pikwitonei Granulite Domain. This work may also help reveal the cause of deep burial and high-grade metamorphism of the Split Lake Block. The age and provenance of the rare, thin pelitic horizons will be examined in order to identify the nature of basement in the region, and to help constrain the timing of mafic granulite emplacement.

Acknowledgments

Geoff Speers and Jennifer Vinck provided consistently cheerful and knowledgeable field assistance. Neill Brandson is thanked for his prompt and thorough service, which ensured that the camps were always well and properly supplied. The use of Manitoba Conservation facilities in Split Lake greatly aided field operations. Funding for this project has been provided by Manitoba Hydro, the Manitoba Geological Survey and the Natural Sciences and Engineering Research Council of Canada (NSERC).

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