GS-25 TECTONOSTRATIGRAPHIC PANELS AND EARLY DEFORMATION IN THE ISLAND LAKE GREENSTONE BELT (NTS 53E15 AND 16), NORTHWESTERN SUPERIOR PROVINCE, MANITOBA

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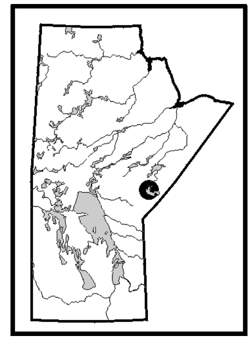

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SUMMARY

The Island Lake greenstone belt is composed of the volcanic and volcanogenic sedimentary rocks of the Hayes River Group and sedimentary rocks of the Island Lake Group, all of which are intruded by various plutons. Field mapping, geochemical and geochronological work demonstrate that the Hayes River Group consists of lithologically, geochemically and chronologically distinct panels, and that at least three distinct volcanic episodes are recorded in this greenstone belt, at ca. 2852 Ma, ca. 2744 Ma and ca. 2730 Ma. New mapping also led to the elucidation of the geometry of folding and the recognition of a stratigraphy in the panel south of the Savage Island Shear Zone.

INTRODUCTION

The Island Lake greenstone belt is one of the best exposed, continuous greenstone belts in the northwestern Superior Province. The aim of this study is to better understand the depositional, structural, volcanic and regional tectonic history of this belt. A nine-week field program was conducted in each of the summers of 2001 and 2002 to supplement previous mapping in the greenstone belt and to collect samples for geochemical, isotopic and geochronological analysis. Results from mapping and preliminary geochemical and geochronology data are presented in this report, along with a recalculation of the Nd isotope data of Stevenson and Turek (1992) using new geochronological results presented here and in Parks et al. (2001). Also presented is a new structural interpretation for the Jubilee Island area, which was an area of focus during fieldwork completed this summer.

The Island Lake greenstone belt was mapped at a scale of 1:63 360 by Godard (1963 a, b) and at 1:20 000 by Neale (1981), Neale and Weber (1981), McGregor and Weber (1982), Neale et al. (1982), Weber et al. (1982a, b), Gilbert et al. (1982, 1983) and Gilbert (1984a, b, 1985a, b). A Nd isotope study was carried out by Stevenson and Turek (1992), and U-Pb geochronology was conducted by Turek et al. (1986) and Corfu and Lin (2000). The geology of mineral occurrences has been described by Theyer (1998), Lin and Cameron (1997) and Lin and Corfu (2002). The current study is, in part, a continuation of the work started by Lin et al. (1998), Corfu and Lin (2000) and Parks et al. (2001).

GEOLOGICAL SETTING

The Island Lake greenstone belt is part of the Island Lake Terrane and is flanked to the south by the ca. 3.0 Ga crust of the North Caribou Terrane and to the north by the less than 2.86 Ga Munro Lake Terrane (Thurston et al., 1991). The North Caribou Terrane represents an old protocratonic nucleus that occupies a large part of the northwestern Superior Province and acted as a stable platform to which other terranes were subsequently accreted (Thurston et al., 1991). The Munro Lake Terrane is interpreted to represent a younger than 2.86 Ga rift sequence that was built on the reworked northern margin of the North Caribou Terrane (Skulski et al., 2000). The Island Lake Terrane (defined as greater than 2886 Ma by Thurston et al., 1991) was considered to be a separate terrane from the North Caribou and Munro Lake terranes because it has a unique geological history and is slightly younger than the North Caribou Terrane and slightly older than the Munro Lake Terrane. New geochronology and isotopic work is redefining the age and nature of the Island Lake Terrane, and therefore its importance in the tectonic evolution of the northwestern Superior Province.

The Island Lake greenstone belt (Fig. GS-25-1) is variably metamorphosed from greenschist to lower amphibolite facies. It has traditionally been divided into two groups: the younger sedimentary rocks of the Island Lake Group (ILG), which unconformably overlie the dominantly volcanic rocks of the Hayes River Group (HRG). In addition, the central part of the greenstone belt is intruded by the extensive ca. 2744 Ma Bella Lake pluton (Corfu and Lin, 2000). The present study and the work of Corfu and Lin (2000) have shown, however, that the Hayes River Group consists of five geochemically and geochronologically distinct tectonostratigraphic panels that are separated by shear zones. These

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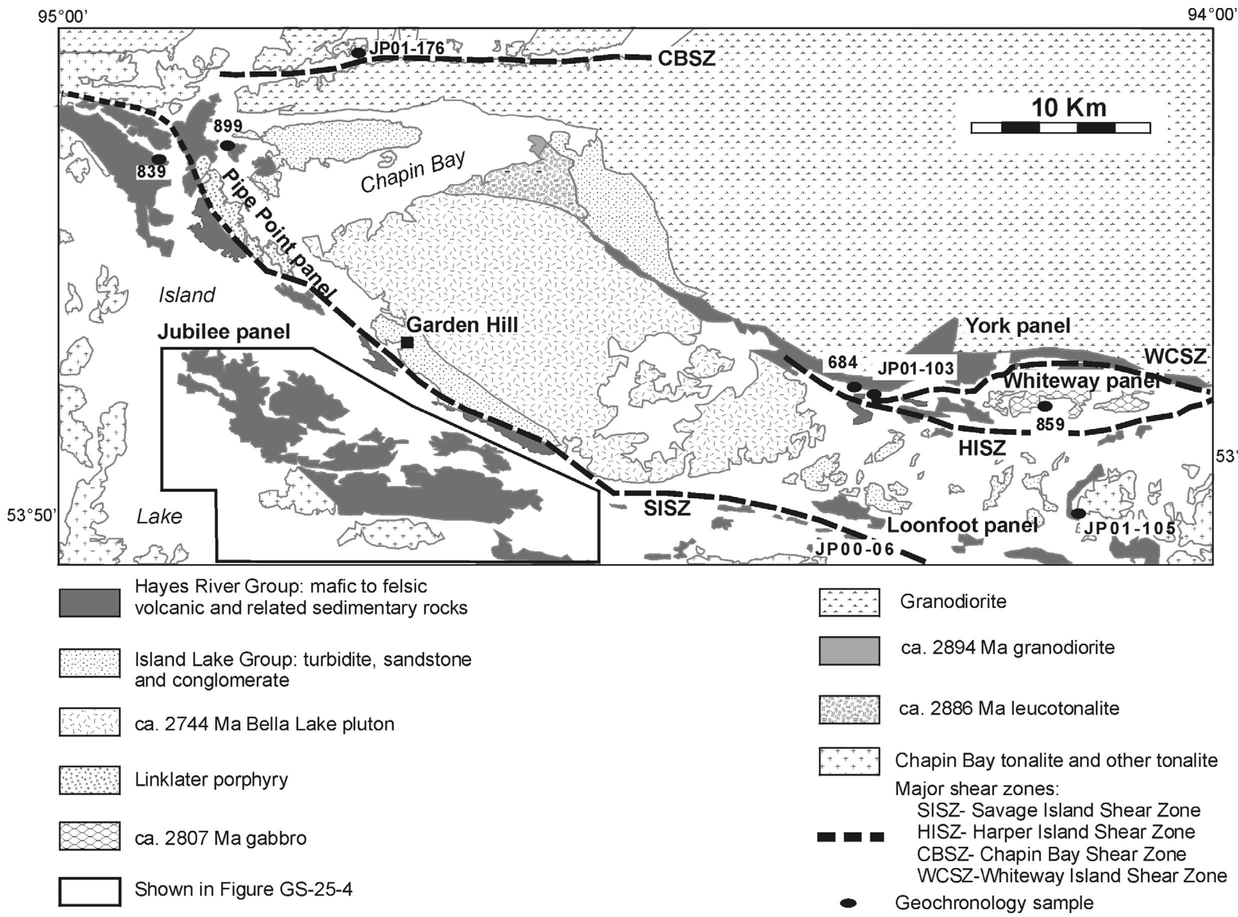

Figure GS-25-1: Simplified geology of the Island Lake greenstone belt.

panels are here named the Jubilee panel (JP), Loonfoot panel (LP), Whiteway panel (WP), York panel (YP) and Pipe Point panel (PPP). It is clear that the use of the term 'Hayes River Group' needs to be re-evaluated for all of the volcanic rocks in this greenstone belt.

The Island Lake Group consists of sedimentary rocks including polymictic conglomerate, sandstone, and turbidite sequences; a detailed description is given in Lin et al. (1998) and Weber et al. (1982b). Based on detrital zircon work, this group has sampled material as old as ca. 3014 Ma (J. Parks, unpublished data, 2001). The age of sedimentation in the ILG is constrained to a maximum of ca. 2712 Ma, the youngest detrital zircon analyzed to date (Parks et al., 2001), and to a minimum of ca. 2699 Ma, the age of a crosscutting dike of the Horseshoe Island porphyry (Turek et al., 1986). Both the ILG and HRG are intruded by various plutons.

TECTONOSTRATIGRAPHY AND GEOCHEMISTRY IN THE HAYES RIVER GROUP (HRG)

Lin et al. (1998) first suggested that the HRG in the Island Lake greenstone belt could be divided into shear-zone–bounded panels that were possibly geochemically and chronologically distinct (Fig. GS-25-1). These shear zones are the Savage Island Shear Zone (SISZ), the Harper Island Shear Zone (HISZ) and the Whiteway Channel Shear Zone (WCSZ). Samples have been collected from all of the tectonostratigraphic panels for U-Pb geochronology, major- and trace-element geochemistry, and Nd isotopic analysis. Geochemical data presented here are preliminary and repeat analyses are planned, at research grade, to more accurately determine the trace-element composition of critical samples. Geochemical analyses have so far been used to help constrain and characterize the nature of the different panels but, with further analyses planned, a detailed petrogenetic study of the units will follow. Multi-element diagrams for each panel are presented here and have been normalized to the primitive mantle values of Sun and McDonough (1989).

Pipe Point panel (PPP)

The Pipe Point panel (central panel from Parks et al., 2001) is located in the northwestern portion of the map area and is north of the SISZ. This panel consists of mafic and felsic volcanic rocks and related gabbroic rocks. The basalt units in this panel are pillowed and aphyric. A deformed quartz porphyry has been dated at ca. 2730 Ma (sample 899 from Parks et al., 2001); however, its origin is controversial and it may be intrusive and therefore represent a minimum age for this panel. A felsic tuff with well-preserved volcanic features (e.g., volcanogenic clasts) was mapped this summer, and sampled for U-Pb geochronology to better constrain the age of this panel. The rocks in this panel are metamorphosed to greenschist facies, and are moderately to strongly deformed. Few locations preserve good candidates for geochemical sampling due to pervasive alteration and weathering along foliation planes in outcrop, and only two samples were taken this summer for geochemical analysis.

Jubilee panel (JP)

The Jubilee panel is located to the south of the SISZ, and is continuous across the entire map area (panel I from Parks et al., 2001; Fig. GS-25-1). This panel consists of mafic and felsic volcanic rocks, as well as associated volcanogenic sedimentary rocks and gabbroic intrusions. The stratigraphy and structure in this panel are discussed below. Two basaltic suites can be recognized, based on field mapping and preliminary geochemical data: one suite in the northern section of this panel and one in the south. Three felsic tuff units along the length of the panel have been dated, and all three samples yielded a U-Pb zircon age of ca. 2852 Ma (Corfu and Lin, 2000 and sample 839 from Parks et al., 2001).

The northern suite has a relatively flat profile on a multi-element diagram with a low total abundance of rare earth elements (REE), at 2 to 3 times primitive mantle (Fig. GS-25-2a). Spurious variations in La and Th will hopefully be improved with research-grade analyses. Note that, on this diagram, neither Nd nor Ta is present due to analytical uncertainties in their measurements. Basalt from the southern suite is enriched in Th and has a significant negative Nb anomaly (Fig. GS-25-2b). Lanthanum and cerium are relatively enriched compared to the middle REE, and the heavy rare earth elements (HREE) are slightly depleted.

Loonfoot panel (LP)

The Loonfoot panel is located in the eastern part of the map area, north of the SISZ and south of the HISZ (panel II from Parks et al., 2001; Fig. GS-25-1). This panel consists of mafic volcanic rocks, as well as rare occurrences of associated felsic volcanic rocks. Two basaltic suites can be recognized, based on field mapping and preliminary geochemical data: one suite in the northwestern section and the other in the eastern section of the panel (Lin et al., 1998; this study). The basalt in the northwestern suite is dark green to black, pillowed, has thin selvages, is aphyric and commonly contains epidote veining and sulphides. It is metamorphosed to greenschist facies. This suite is enriched in light rare earth elements (LREE) and Th, and slightly depleted in HREE (Fig. GS-25-2c). It also has a significant negative Nb anomaly. The eastern suite basalt is light green to grey, pillowed and massive, aphyric and commonly contains extensive quartz-carbonate veins. It is metamorphosed to greenschist facies. This suite has a flatter REE profile than rocks in the northwestern part of the panel and a lower abundance of these elements (Fig. GS-25-2d). Again the samples show a negative Nb anomaly and Th enrichment. An interlayered felsic tuff in the eastern part of the panel yielded a U-Pb zircon age of ca. 2744 Ma (sample JP01-105, J. Parks, unpublished data, 2002).

Whiteway panel (WP)

The Whiteway panel (panel III from Parks et al., 2001) is located in the eastern part of the map area (Fig. GS-25-1), and is north of the HISZ and south of the WCSZ. This panel consists of mafic volcanic rocks, gabbroic intrusions and rare lenses of volcanogenic sedimentary rocks. The basalt in this panel is pillowed, aphyric, has thin selvages and commonly exhibits sulphide alteration. A gabbroic intrusion in the basaltic package has a U-Pb zircon age of ca. 2807 Ma (Corfu and Lin, 2000), and five detrital zircons from a sedimentary lens have yielded essentially identical ages of ca. 2897 Ma (sample 859 from Parks et al., 2001). These ages bracket volcanism in this panel to a minimum of 2807 Ma, but possibly as old as 2897 Ma. This panel is metamorphosed to greenschist facies and is weakly to strongly deformed. This basaltic suite again shows strong enrichment in Th and LREE, and slight depletion in HREE (Fig. GS-25-2e). The rocks also have strong negative Nb and Ta anomalies and moderate negative Ti anomalies. This panel is geochemically similar and may correlate with the northwestern suite of the Loonfoot panel. This possibility is under further investigation.

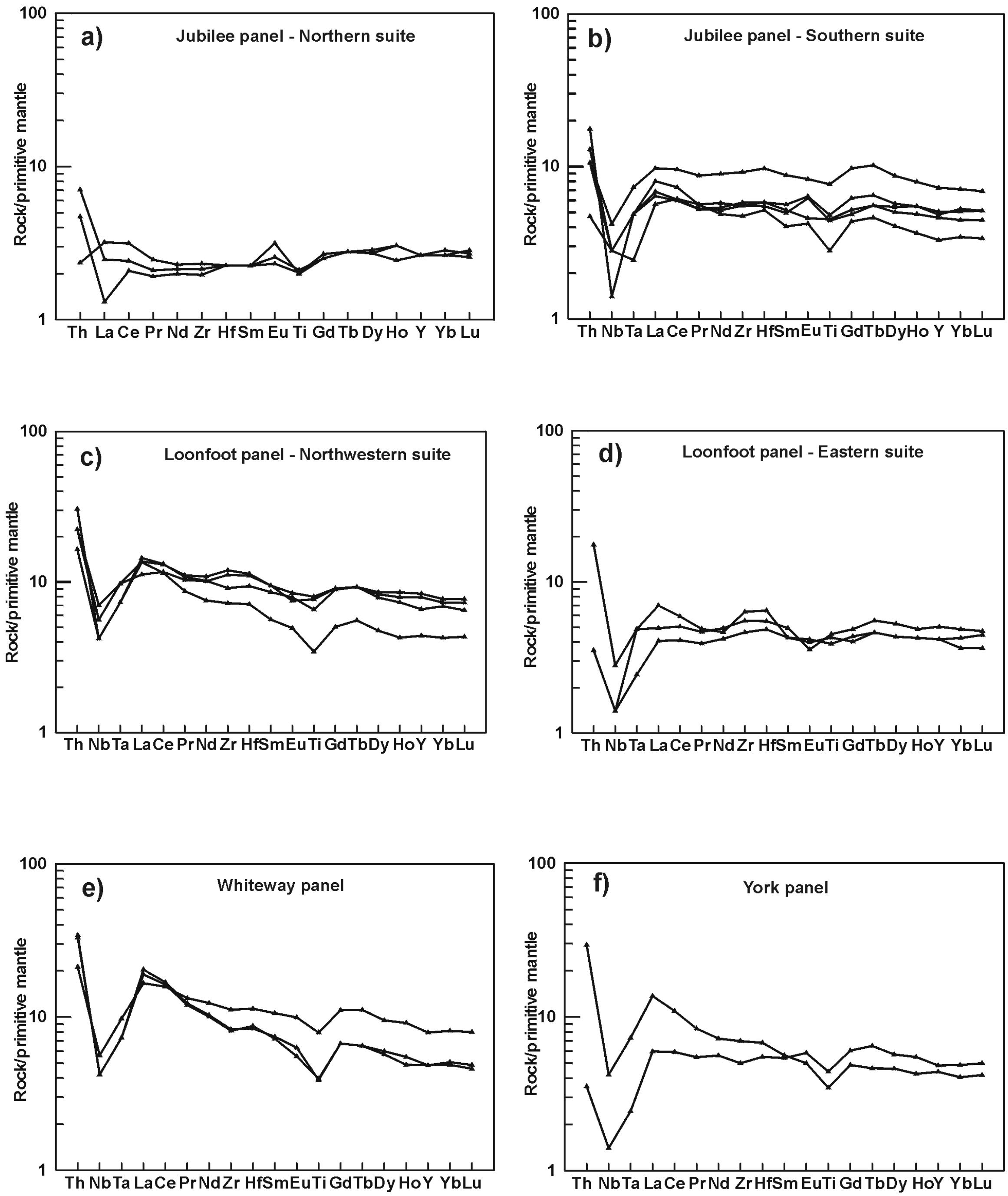

Figure GS-25-2: Multi-element plots of geochemical data. All values are normalized to the primitive mantle values of Sun and McDonough (1989). See text for discussion of data.

York panel (YP)

The York panel (panel IV from Parks et al., 2001) is located in the eastern part of the map area, and is north of the WCSZ (Fig. GS-25-1). Dominant rock types are mafic and ultramafic volcanic rocks. The basalt is most commonly pillowed, has thin selvages and is aphyric. A granodiorite that intrudes the basalt in this package has been collected for U-Pb dating to place a minimum age constraint on the age of this sequence. This panel is metamorphosed to amphibolite facies and is strongly deformed. Only two samples have been analyzed to date and they differ considerably in terms of LREE and Th characteristics (Fig. GS-25-2f). Both samples show relatively flat HREE profiles and negative Nb anomalies. The geochemistry of this unit is under further investigation to constrain the apparent range in variation.

STRUCTURE AND STRATIGRAPHY IN THE JUBILEE PANEL

The Island Lake greenstone belt has experienced multiple episodes of deformation. These deformation events have been responsible for folding much of the ca. 2852 Ma supracrustal rock sequence in the area and for producing four distinct shear zones found in this belt. The structure of these shear zones is discussed in Lin et al. (1998) and Parks et al. (2001). A major focus of the field program this summer was to investigate structure and stratigraphy in the oldest (2852 Ma) supracrustal package (Jubilee panel). To this end, detailed mapping was conducted that led to the recognition of major folds and elucidation of the stratigraphy of the volcanic rocks in this panel. Preliminary results are summarized below.

Stratigraphy

In the Jubilee Island area, primary features are locally well preserved and a continuous section of basalt (oldest), felsic volcanic and sedimentary rocks (youngest) is observed. The basalt (noted as northern suite above) is pillowed and massive, has thin selvages and is aphyric. Locally this basalt displays well-preserved primary structures, such as well-rounded pillows with cusps and flow-top breccia units that indicate tops are to the north (Fig. GS-25-3). A felsic volcanic unit overlies the basalt, and consists of tuffaceous beds and quartz-feldspar–phyric flows. Stratigraphically overlying this unit is a sedimentary unit that consists of a broad range of metasedimentary rocks, from argillite through sandstone to conglomerate. Primary features are well preserved, and features such as graded bedding indicate tops are also to the north. This sequence of units is repeated by folding in this area.

In the Confederation Island–Henderson Island area, a continuous section of basalt (oldest) to felsic volcanic rocks (youngest) is observed. The basalt unit (noted as southern suite above) is pillowed, aphyric and contains epidote as well as quartz-carbonate veining. Overlying the basalt is a felsic volcanic unit that is composed mainly of tuffaceous beds that have 1 to 2 mm rounded quartz and feldspar crystals set in a buff to grey, fine-grained felsic matrix. This unit is normally well foliated with pervasive chlorite alteration along planes of foliation. This package is also repeated by folding.

Separating these two stratigraphic packages is a shear-bounded package of rocks that includes basaltic and sedimentary units, as well as gabbroic intrusions.

Structure

Deformation in this area has produced tight to isoclinal folds. An axial-planar foliation strikes southeasterly to easterly and dips steeply south. Minor folds in sedimentary rocks are parasitic to the map-scale folds, and plunge both moderately to the west-northwest and shallowly to the east-southeast. Two macroscopic folds have been identified in the Jubilee panel: an anticline in the Jubilee Island area and a syncline in the Confederation Island–Henderson Island area (Fig. GS-25-4). These folds are defined by younging direction reversal, stratigraphic repetition of units and similar geochemical characteristics of the basalt in the limbs of the folds. Juxtaposed between these two fold structures is a shear-bounded package of basaltic and sedimentary rocks. This package is strongly deformed and sheared, both

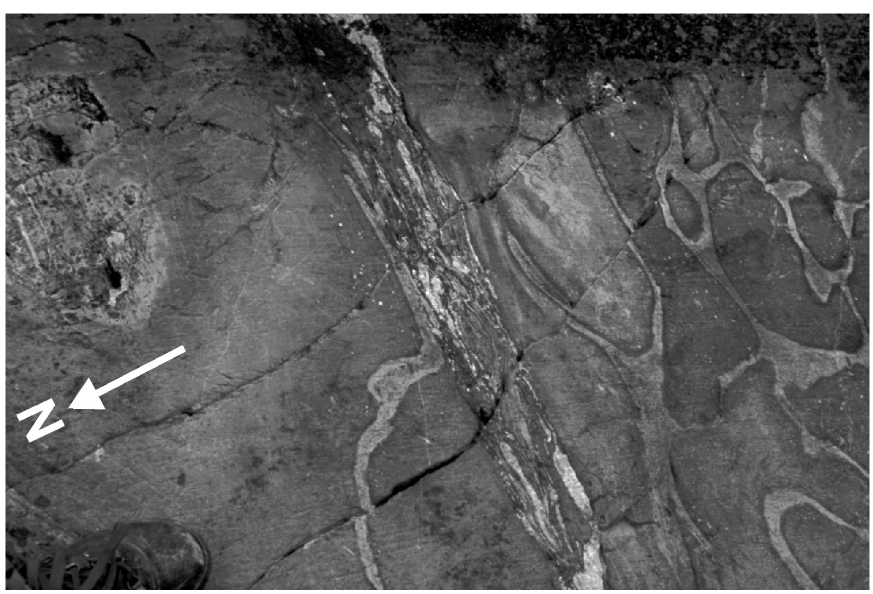

Figure GS-25-3: Well-preserved flow-top breccia and rounded pillows with cusp structures in the western part of the Jubilee panel. Tops are to the north.

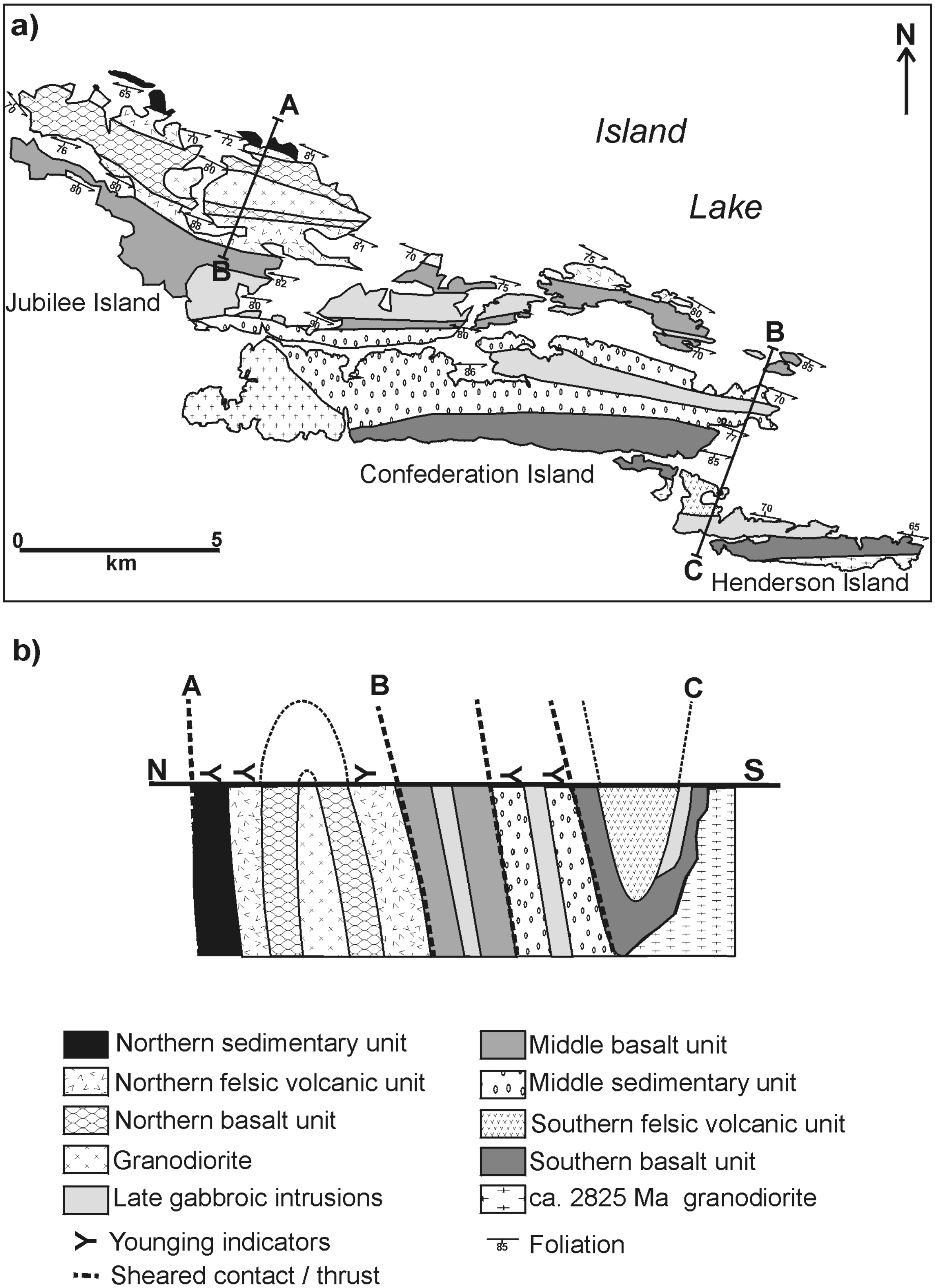

Figure GS-25-4: a) Detailed map of the Jubilee panel. b) Composite schematic cross-section of the geometry of the structure in this area; cross-section shows the interpreted anticline, syncline and thrust sheet; cross-section lines are shown in (a).

along its lithological contacts and internally (Fig. GS-25-5), and is interpreted to represent a thrust-sheet structure. In general, the degree of deformation in this panel varies from weak in the west to strong in the east. Primary features are well preserved in the west (Fig. GS-25-3), and are only rarely preserved as the limbs of the folds become more intensely deformed and sheared in the eastern part of the panel (Fig. GS-25-5).

TIMING OF DEFORMATION

A major objective of this project is to place geochronological constraints on the timing of deformation in this greenstone belt. In the Jubilee panel, a postkinematic quartz-porphyry dike yielded a preliminary zircon age of ca. 2724 Ma (sample JP00-06 from Parks et al., 2001). This dike cuts an early foliation that is subsequently seen to be transposed by the SISZ, and may place constraints on the early deformation event in this area (Fig. GS-25-6). An undeformed, post-tectonic granodiorite that intrudes the folded rocks in the Jubilee panel was collected this summer for U-Pb zircon analysis. The age of this granodiorite will also place a minimum age on the early deformation event. A sheared pretectonic tonalite in the CBSZ (sample JP02-176, this study) yielded a U-Pb zircon age of ca. 2747 Ma, and provides a maximum age for deformation along the CBSZ.

Two dikes have been dated in the HISZ. The first is a tonalite dike that is only weakly foliated and contains xenoliths of strongly foliated mafic rock (Fig. GS-25-7). This dike yielded a U-Pb zircon age of ca. 2722 Ma (sample 684 from Parks et al., 2001). The second dike is strongly internally foliated and folded within the country rock (Fig. GS-25-8). This dike yielded a zircon age of ca. 2701 Ma (sample JP01-103, J. Parks, unpublished data, 2002).

Figure GS-25-5: Deformed basalt in the eastern part of the Jubilee panel; deformation is strong in this area, with S- and Z-folds common at the outcrop scale.

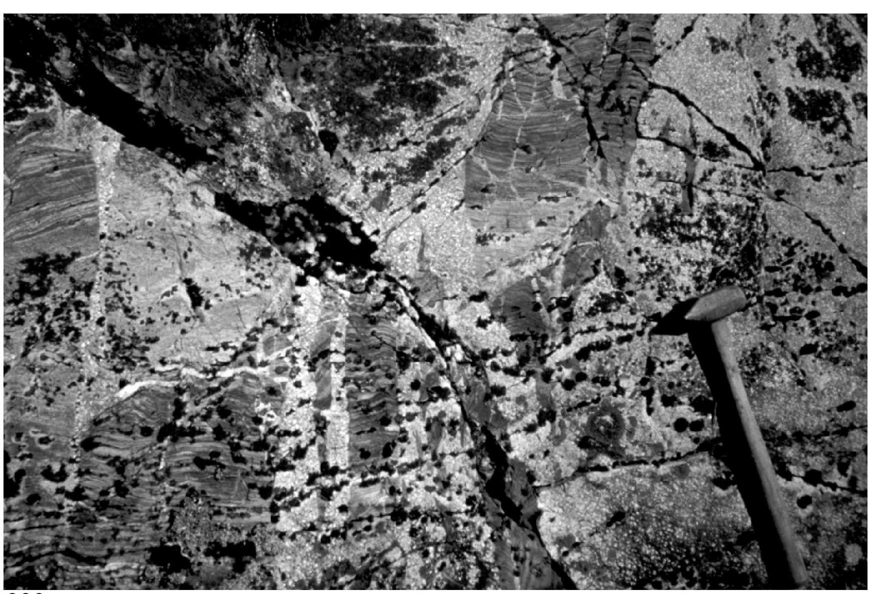

Figure GS-25-6: Coarse-grained porphyry dikes (running top to bottom in photo), cutting foliation in deformed mafic material (foliation running left to right in photo), sample JP00-06.

Figure GS-25-7: Weakly foliated tonalite dike containing xenoliths of foliated mafic material, sample 684.

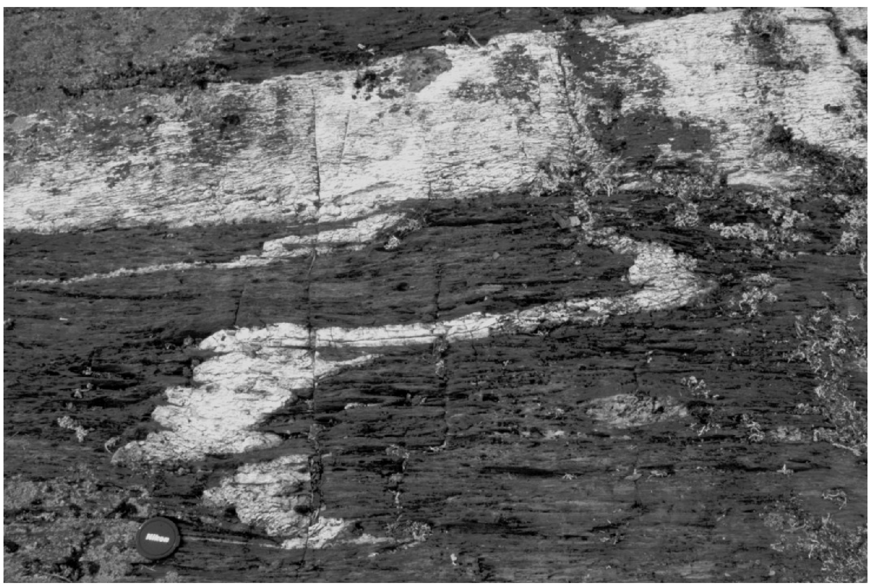

Figure GS-25-8: Strongly foliated dike folded within the country rock, sample JP01-103.

Three possibilities may explain why the older dike is less deformed than the younger one: 1) zircons analyzed from the older dike are inherited; 2) parts of the HISZ have been activated more than once; or 3) the older dike is more competent and did not experience as much deformation as the younger one did during movement along the HISZ.

NEODYMIUM ISOTOPE DATA

Stevenson and Turek (1992) completed a Nd isotopic investigation in the western part of the Island Lake greenstone belt. The ε_{Nd} values determined by Stevenson and Turek (1992) have been recalculated with the new U-Pb age date from this study (Fig. GS-25-9). Of particular interest is the range in positive to negative ε_{Nd} in this dataset, as well as a cluster of data points around a 3.0 Ga crustal ε_{Nd} evolution line. The older 2852 Ma volcanic package shows a range in positive to negative ε_{Nd} values, whereas the 2730 Ma volcanic rocks have entirely positive ε_{Nd} values. In contrast, a 2730 Ma tonalite and a suite of 2744 Ma tonalite and porphyry have entirely negative ε_{Nd} values. This range in data shows clearly that the rocks in this greenstone belt are strongly yet variably influenced by Mesoarchean crust of the ca. 3.0 Ga North Caribou Terrane. These data warrant further study to isotopically characterize the crust in this greenstone belt.

CONCLUSIONS AND FURTHER WORK

The Hayes River Group consists of lithologically, geochemically and chronologically distinct panels, and at least

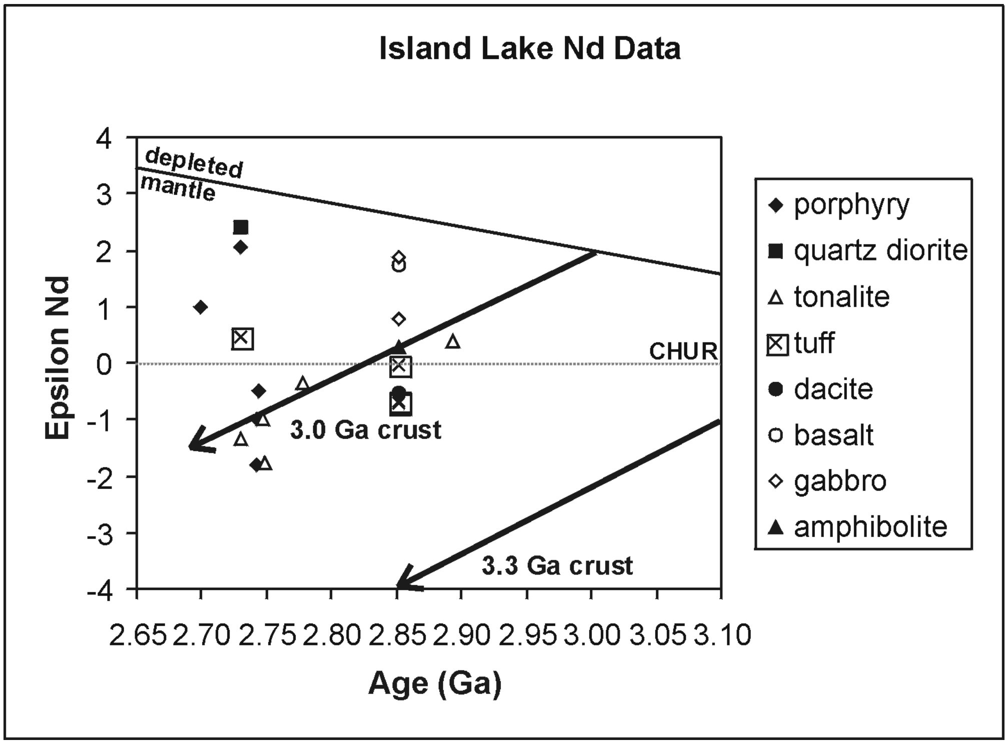

Figure GS-25-9: ε_{Nd} vs. age (Ga) plot, recalculated from data presented by Stevenson and Turek (1992); see text for discussion.

three volcanic episodes, at ca. 2852 Ma, ca. 2744 Ma and ca. 2730 Ma, are recorded as one group in this greenstone belt. New mapping this summer led to elucidation of the geometry of folding and recognition of a stratigraphy in the panel south of the Savage Island Shear Zone. The Nd isotopic characteristics of this greenstone belt are complex, and include both juvenile rocks and rocks influenced by Mesoarchean crust.

To further constrain the geological evolution of the Island Lake greenstone belt, additional U-Pb analyses will be done at the Jack Satterly Laboratory, Royal Ontario Museum (ROM). High-resolution geochemical analyses, including Sm-Nd work, are also planned to help characterize the different panels. In addition, variations in crustal contamination in the belt will be studied, using combined Nd isotopes and geochemistry, in the hope of identifying juvenile and contaminated units. These studies will help determine the significance of this greenstone belt in the context of its location on the margin of the North Caribou Terrane. Detailed microstructural work will be conducted on samples taken this summer. In particular, work will be done to test the geometry of the folds in the Jubilee Panel presented above, and the nature of the early deformation event.

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