Geological Survey
of Canada

Current Research
2000-C15

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2000

Natural Resources Canada Ressources naturelles Canada

Canada

Catalogue No M44-2000/C15E-IN
ISBN 0-660-18034-0

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Authors' address

J.A. Percival *(joperciv@NRCan.gc.ca)*
J.B. Whalen *(jwhalen@NRCan.gc.ca)*
Continental Geoscience Division
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8

Observations on the North Caribou terrane–Uchi Subprovince interface in western Ontario and eastern Manitoba[1]

J.A. Percival and J.B. Whalen
Continental Geoscience Division, Ottawa

Percival, J.A. and Whalen, J.B., 2000: Observations on the North Caribou terrane–Uchi Subprovince interface in western Ontario and eastern Manitoba; Geological Survey of Canada, Current Research 2000-C15, 8 p. (online; http://www.nrcan.gc.ca/gsc/bookstore).

Abstract: West of the Red Lake belt, boundaries between Mesoarchean rocks of the North Caribou terrane and Neoarchean rocks of the Uchi Subprovince are both intrusive and tectonic. Old plutonic units (>2.8 Ga) occur as remnants in younger plutons within broad lobes flanked by greenstone belts. The English Lake magmatic complex, exposed obliquely by an extensional detachment north of the Wanipigow Fault, provides insight into the crustal architecture. Tonalite (3.0 Ga) gives way downward to interlayered quartz diorite, diorite, and gabbro that show increasing metamorphic effects with depth. Neoarchean plutons commonly occupy higher structural levels. The fault-block-like geometry north of the Wanipigow Fault may have formed during early sinistral displacement that offset the Black Island and Hole River sequences in Lake Winnipeg from correlative units 65 km to the east in the Rice Lake belt.

Résumé : À l'ouest de la ceinture de Red Lake, les limites entre les roches mésoarchéennes du terrane de North Caribou et les roches néoarchéennes de la Sous-province d'Uchi sont à la fois intrusives et tectoniques. Des unités plutoniques anciennens (>2,8 Ga) se rencontrent sous la forme de vestiges dans des plutons plus jeunes au sein de larges lobes bordés par des ceintures de roches vertes. Le complexe magmatique d'English Lake, qui a été mis à nu de façon oblique par un décollement par extension au nord de la faille de Wanipigow, nous donne un aperçu de l'architecture de la croûte. En descendant dans la séquence, de la tonalite (3,0 Ga) passe à de la diorite quartzique, à de la diorite et à du gabbro interlités qui traduisent un métamorphisme de plus en plus intense à plus grande profondeur. Les plutons néoarchéens se retrouvent fréquemment à des niveaux structuraux plus élevés. La configuration géométrique rappelant celle des blocs-failles au nord de la faille de Wanipigow peut avoir été formée lors d'un déplacement sénestre précoce qui a décalé les séquences de Black Island et de Hole River dans le lac Winnipeg par rapport à des unités corrélatives situées à 65 km vers l'est dans la ceinture de Rice Lake.

[1] Contribution to the Western Superior NATMAP Project

INTRODUCTION

A major objective of the western Superior NATMAP project is to investigate relationships between fragments of Mesoarchean (>2.8 Ga) age and Neoarchean supracrustal rocks. The North Caribou terrane is one of the largest blocks with continental affinities in the western Superior Province (Thurston et al., 1991), although its core is dominated by Neoarchean plutons of the Berens River plutonic complex (Stone, 1998; Corfu and Stone, 1998). Tectonic juxtaposition of Neoarchean supracrustal assemblages against older units of the North Caribou terrane during accretion of the Superior Province was proposed by Stott and Corfu (1991). Recent work in the Confederation (Rogers et al., 1999, 2000) and Red Lake belts (Sanborn-Barrie et al., 2000) indicates conformable or unconformable relationships, rather than tectonic contacts, between ca. 2.74 Ga and older units. For example, in the Red Lake belt the Confederation assemblage lies with angular unconformity on the ca. 2.99 Ga Balmer assemblage (Sanborn-Barrie et al., 2000). Further west in the Beresford Lake area, an early high-strain zone separates sedimentary rocks younger than 2704 Ma from the ca. 2.85 Ga Garner Lake komatiitic sequence (Brommecker et al., 1993), and at Wallace Lake, an early shear zone separates a platform sequence older than 2.92 Ga from undated mafic volcanic rocks of the Big Island Formation (Sasseville and Tomlinson, 2000).

In this paper we review field relationships at the southern margin of the North Caribou terrane in the western Uchi belt between Trout Lake and Lake Winnipeg, and provide some preliminary speculations concerning their implications. Our observations, augmented by available maps and geochronology, will 1) aid in regional lithotectonic map compilation for the Western Superior NATMAP Project; 2) form the framework for a geochemical and tracer isotopic study of granitoid units; and 3) act as a guide for future field activities.

GEOLOGICAL FRAMEWORK

The North Caribou terrane (Thurston et al., 1991), identified by the presence of 3.0–2.8 Ga supracrustal and intrusive rocks, is interpreted as the nucleus to which Neoarchean supracrustal assemblages were accreted (Williams et al., 1992; Stott, 1997). Much of the core of the region is dominated by Neoarchean plutonic rocks of the Berens River plutonic complex (2745–2695 Ma; Ermanovics, 1970a, b; Ermanovics and Wanless, 1983; Stone, 1998; Corfu and Stone, 1998), such that mainly northern and southern fringes of Mesoarchean remnants remain undigested. Along the southern margin these take the form of 3.0 Ga tonalite units, recognized mainly in Manitoba, and 2.99 Ga, 2.92 Ga, 2.89 Ga, and 2.84 Ga volcanic and associated intrusive rocks in the Uchi–Confederation, Red Lake, and Garner Lake greenstone belts. In addition, platform and rift sequences of arkose, iron-formation, and komatiite, such as the older than 2.92 Ga Conley Formation at Wallace Lake, may mark break-up of the ancient craton.

In the western Uchi Subprovince, Neoarchean volcanic sequences, in the age range 2740–2710 Ma, occur in a string of greenstone belts (Fig. 1). Contacts with older units range from conformable, through unconformable, to tectonic. These volcanic rocks are apparently conformably overlain by metasedimentary rocks with detrital zircons as young as 2704 Ma, which also occur to the south of the Sydney Lake–Lake St. Joseph fault zone, in the English River Subprovince.

TROUT LAKE BATHOLITH

The Trout Lake batholith represents part of a southern lobe of the North Caribou terrane that separates the Red Lake and Confederation–Birch–Uchi belts (Fig. 1; Noble, 1989; Thurston et al., 1991; Stott and Corfu, 1991). The batholith comprises gneissic, foliated and massive units ranging in composition from tonalite to leucogranite, with ages between 2.84 Ga and 2.70 Ga (Noble, 1989). Here we report structural

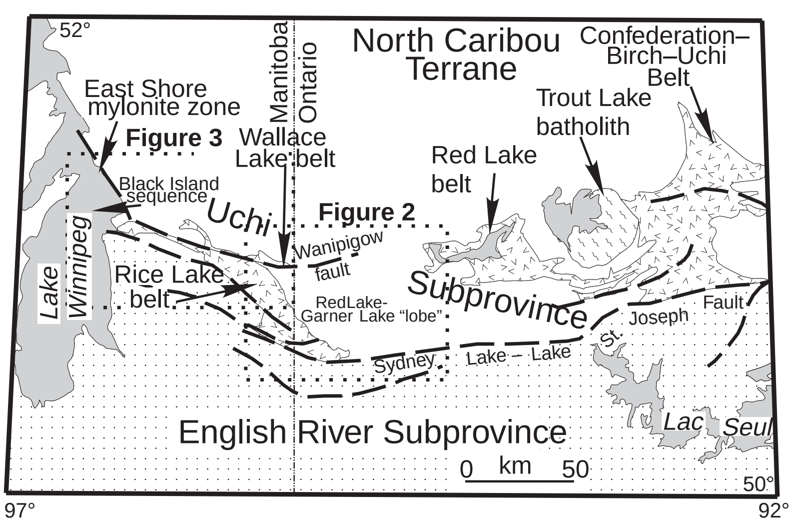

Figure 1.

Geological sketch map of the western Uchi Subprovince showing locations of major features discussed in the text.

observations based on four days of reconnaissance in the Trout Lake area. In addition, all units were sampled for a geochemical and isotopic tracer study, to examine the sources and petrogenesis of the various plutonic bodies.

Based on Noble's (1989) study, the oldest unit in the complex is a tonalitic gneiss to the west of the Confederation Lake belt, dated at 2838 +3.8/-2.7 Ma. These rocks are characterized by an early gneissic layering (S_1), concordant tonalitic veins, and mafic pods, probably representing dismembered dykes, all folded into F_2 isoclines and transected by weakly foliated granodiorite dykes. These relatively rare tonalite gneiss units correspond in age to that of the Woman assemblage, however volcanic rocks of this age may be absent from the Confederation belt (Rogers et al., 2000).

The main phase of the body, located in eastern Trout Lake, consists of foliated and gneissic tonalite (ca. 2.80 Ga; Noble, 1989), with sparse enclaves of tonalite gneiss, diorite, and amphibolite. The medium-grained, homogeneous biotite tonalite generally carries a single penetrative northwest-striking, steeply dipping tectonic foliation. Migmatitic zones, in which both injected and in situ leucosome veins parallel the foliation, are present on the kilometre scale. A second set of structures, steep folds with east-southeasterly trends, is particularly prominent in the migmatitic rocks, perhaps indicating that north-south shortening was preferentially accommodated within the highly ductile zones.

A body of hornblende-biotite granodiorite adjacent to the Red Lake belt on the west, has an age of 2699 ± 1 Ma (Noble, 1989) and likely corresponds to the sanukitoid suite of the Berens River plutonic complex (Stone, 1998). Massive biotite granite in western Trout Lake may be younger still, as it contains enclaves of granodiorite, tonalite, diorite, and gabbro, and dykes of similar composition cut all other units.

A northeast-striking, ductile shear zone with moderate southeast dip cuts tonalite in the north-central Trout Lake batholith. This 5 km wide zone has an internal panel with moderately strong downdip lineations, in which normal motion (southeast side down) is indicated by extensional shear bands and sigmoidal porphyroclasts.

RED LAKE–GARNER LAKE 'LOBE'

This region, which straddles the Ontario–Manitoba border (Fig. 1, 2), is geometrically similar to the Trout Lake batholith. On the east, adjacent to the Red Lake belt, the heterogeneous Atikaki batholith (Atkinson, 1999) appears to be the structurally oldest unit. The tonalite-granodioritic body includes abundant gneissic phases and supracrustal remnants. Whereas some gneiss units appear to have been derived from homogeneous rocks through strain and metamorphic differentiation, others that contain refolded folds may be remnants of an older generation of plutons. In contrast, the Killala–Baird batholith (Fig. 2) southwest of the Red Lake belt is a homogeneous, weakly foliated granite, dated at 2704 ± 1 Ma (Corfu and Andrews, 1987).

In the western part of the Red Lake–Garner Lake 'lobe' is an area with magnetic characteristics similar to those of the Berens River plutonic complex (Stone, 1998) to the north and east. Observations near the western margin of the lobe confirm the presence of large homogeneous plutonic bodies. At Obukowin Lake (Fig. 2), sparse supracrustal remnants consist of a less than 30 m wide couplet of paragneiss and fine-grained amphibolite with locally preserved pillow outlines. In the southern half of the lake, these rocks occur as semicontinuous enclaves within homogeneous, foliated biotite granodiorite, with local K-feldspar porphyritic phases. The northern part of the lake is dominated by hornblende- and biotite-bearing granodiorite, monzodiorite, and diorite. Biotite granite occurs as widespread pegmatite, aplite dykes, and small masses. Both the supracrustal and foliated plutonic rocks carry a southeast-striking foliation that is commonly folded about west-plunging hinges, accompanied by a moderately plunging rodding or mineral lineation.

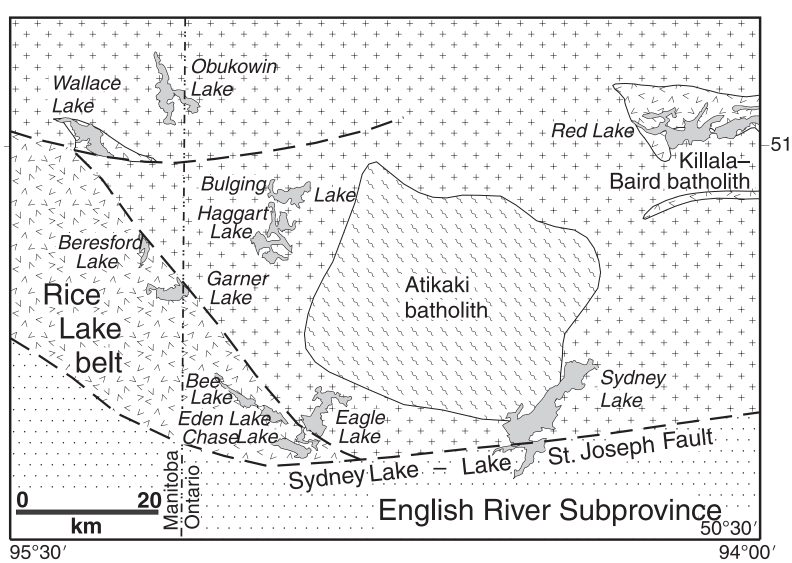

Figure 2.

Geological sketch map of the Red Lake–Garner Lake lobe of the North Caribou terrane, showing locations discussed in the text.

To the southeast in the Haggart–Bulging lakes area (Fig. 2), narrow supracrustal slivers are dominantly metasedimentary in the east and amphibolite further west. Both are associated with narrow gneissic zones, perhaps derived from schlieric plutonic rocks. Most of the area consists of south-southeast-striking, kilometre-scale sheets of weakly to strongly foliated biotite granodiorite, hornblende-biotite granodiorite, and biotite granite. All contain enclaves of diorite, gabbro, and rare tonalite gneiss in addition to supracrustal rafts. Broad zones of strong foliation and well developed gently south-southwest-plunging (10–30°) rodding lineation, as well as local folds, suggest distributed transcurrent shear.

Near the southwestern margin of the lobe, in the Eagle–Chase lakes area (Fig. 2), lithologically similar plutonic units are characterized by a southeasterly striking foliation with a moderate dip to the southwest. The oldest plutonic phase is equigranular, medium-grained hornblende-biotite granodiorite that is cut by the volumetrically dominant equigranular to K-feldspar-porphyritic biotite granodiorite. Dioritic enclaves are rare, whereas granite dykes that transect the foliation are common.

Foliation intensity increases within a 1 km wide zone adjacent to the contact with supracrustal rocks of the Bee Lake segment of the Rice Lake belt (Fig. 2), where a moderately southwest-plunging rodding lineation becomes prominent. To the south, at the contact with metagabbroic rocks, steeply southwest-dipping glassy mylonite contains microfolds and shear bands that indicate south-over-north (i.e. reverse-sense) displacement.

A coarse clastic sequence in northern Midway Lake bounds the phyllonitic gabbroic unit on the south (Shklanka, 1967). Well preserved sedimentary structures exposed in the Midway Lake synform (Borowik, 1998) suggest a west-facing stratigraphic progression from argillite, through coarse-grained arkosic sandstone, with high-energy features such as crossbedding and channel scours, to matrix-supported conglomerate. Rounded to angular boulders of various granitic compositions, including pink pegmatitic leucogranite, dominate the clast population; the remainder consists of mafic and porphyritic felsic metavolcanic clasts. The basal contact of the sedimentary unit is a high-strain zone that encompasses the structurally underlying mafic metavolcanic rocks. The high-strain zone, characterized by fine grain size, attenuated, discontinuous layering, dismembered quartz veins, a strong stretching lineation, dextral shear bands, and isoclinal ‘Z’ folds, is folded about gently west-plunging hinges.

The coarse clastic sequence extends westward through Eden and Bee lakes (Fig. 2; Shklanka, 1967). Based on the evolved composition of granitic clasts, the unit appears to be one of the stratigraphically youngest of the belt, and could represent a Timiskaming-type sequence. It is possibly equivalent in age to the San Antonio Formation in the Bissett area, 50 km to the northwest.

BLOODVEIN–WANIPIGOW RIVER CORRIDOR

Rocks of Mesoarchean age have been identified north of the Wanipigow Fault, at Wallace Lake (Turek and Weber, 1991; D.W. Davis, pers. comm. cited *in* Sasseville and Tomlinson, 2000), and near the Jeep mine (Turek et al., 1989). Northeast of Wanipigow Lake, the Little Beaver supracrustal belt (Fig. 3; Poulsen et al., 1994) includes mafic and felsic metavolcanic, wacke, and conglomeratic metasedimentary units of uncertain age and stratigraphic affinity, although Poulsen et al. (1996) postulated a history predating 2.8 Ga. It is cut by the weakly foliated Clinton–Poundmaker quartz-porphyritic biotite tonalite on the south and west, and by late biotite and muscovite leucogranite bodies on the east. The tonalite contains large xenoliths of sheared tonalite and quartz-vein-riddled mafic schist with sinistral shear-sense indicators, possibly representing an early phase of movement on the Wanipigow Fault.

ENGLISH LAKE MAGMATIC COMPLEX

Parts of the North Caribou terrane are also present 20 km to the west, in the English Lake magmatic complex (Fig. 3; Weber, 1990, 1991). This body consists mainly of tonalite (3003 ± 2 Ma; Turek and Weber, 1994) and granodiorite in the east, and grades to layered, pyroxene-bearing quartz diorite, diorite, and gabbro toward the west. The degree of metamorphism also increases toward the west, judging by the local presence of garnet and clinopyroxene in leucosome and thorough migmatization of mafic rocks. The complex is bound to the west by the north-northeast-trending English Lake shear zone, a 1 km wide, west-dipping, brittle-ductile shear with a downdip stretching lineation and west-side-down (i.e. normal) movement sense. A penetrative, steeply dipping, south-southeast-striking S_1 foliation is generally parallel to igneous layering. This relatively strong foliation is cut by anorthosite (Fig. 4), hornblendite, and tonalite dykes with an east-striking S_2 foliation that may represent a distinctly younger magmatic episode. One hornblendite plug (Young and Theyer, 1990) carries xenoliths (up to 80 cm in diameter) of coarse-grained pyroxenite, itself containing nodules up to 30 cm wide of gabbro, talc rock, and olivine pyroxenite. To the west of the English Lake shear zone are massive to weakly foliated granite and granodiorite with minor diorite that are thought to represent relatively high structural levels. The English Lake magmatic complex is interpreted as an oblique cross-section to mid-crustal depths, exhumed along the English Lake shear zone, which is inferred to be an extensional detachment. Geochemical studies are underway to establish petrogenetic linkages among various mafic, intermediate, and felsic plutonic phases. One of the goals is to test the hypothesis that a vertically zoned Neoarchean intrusive complex cuts the crustally zoned Mesoarchean plutonic arc complex.

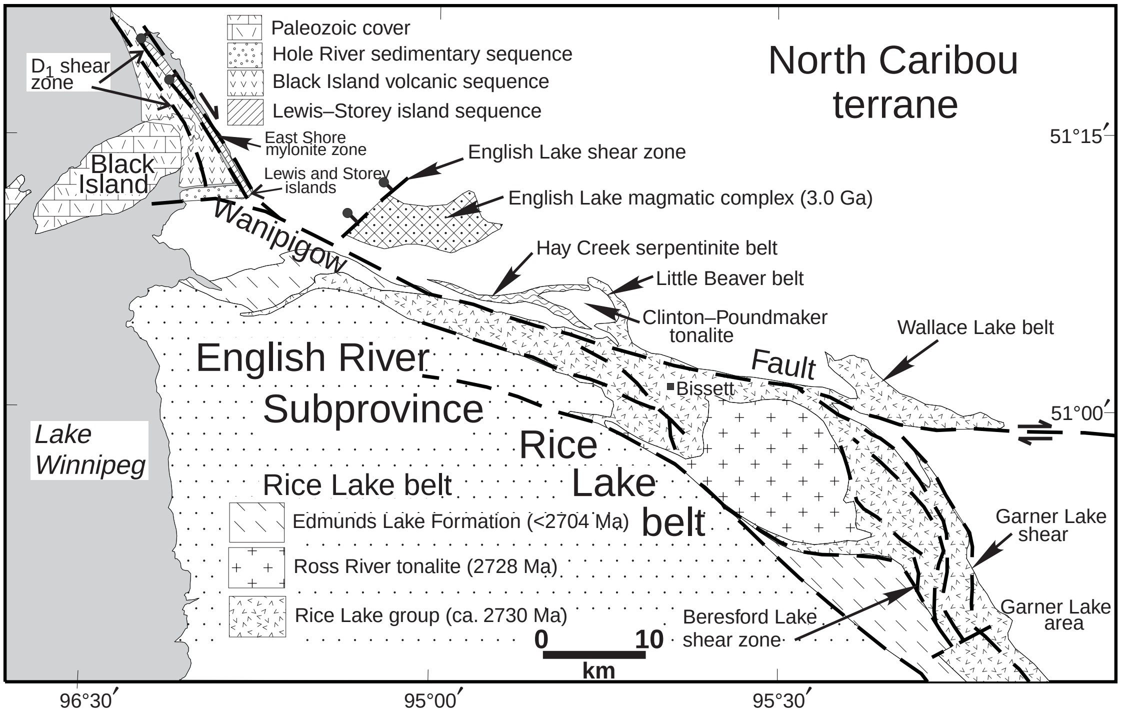

Figure 3. *Geological sketch map of the western Uchi Subprovince in Manitoba, showing distribution of subprovinces, greenstone belts, and major faults.*

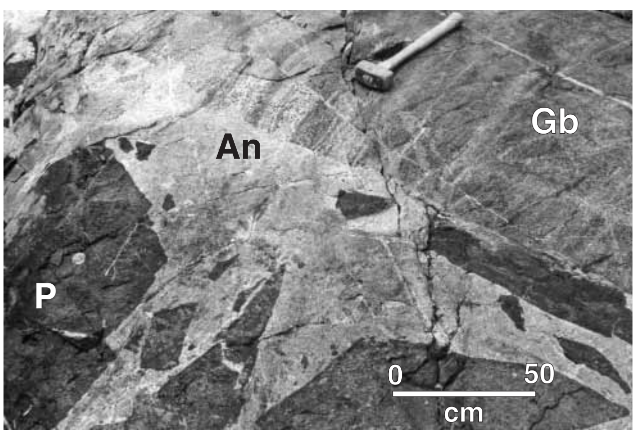

Figure 4. *Foliated, layered metagabbro (Gb) of the 3.0 Ga English Lake magmatic complex cut by dyke of massive anorthosite (An) with pyroxenite (P) enclaves. Dykes of tonalite, anorthosite, and hornblendite carry a weak east-west foliation in some parts of the complex and may represent superimposed Neoarchean magmatism.*

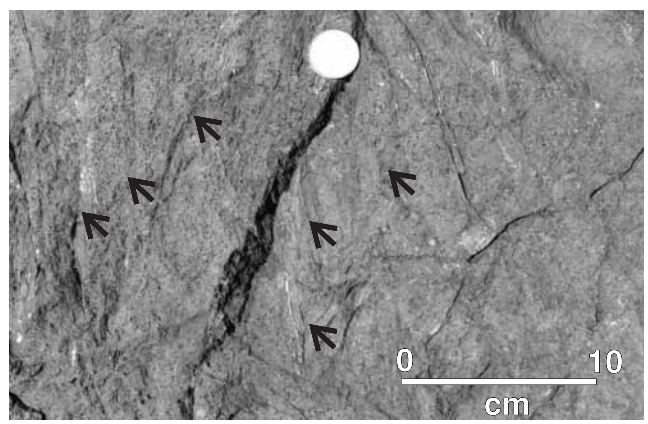

Figure 5. *Spinifex-textured ultramafic flow, Lewis Island, eastern Lake Winnipeg. Amphibole crystals to 10 cm (indicated by arrows) may be pseudomorphs after pyroxene.*

EASTERN LAKE WINNIPEG AREA

In eastern Lake Winnipeg (Fig. 3), low-grade supracrustal rocks of the Black Island volcanic belt (2732 ± 10 Ma; Krogh et al., 1974) and Hole River sedimentary sequence have been correlated respectively with the Bidou Lake subgroup and San Antonio Formation of the Rice Lake, belt 65 km to the east (Ermanovics, 1981). In the southeast, on Lewis and Storey islands, magnetic rocks are exposed that correspond to a prominent, north-trending, positive aeromagnetic anomaly. These rocks include komatiite and iron-formation, which together with minor carbonate and abundant arkosic sandstone, resemble the Conley Formation of the Wallace Lake belt, 75 km to the east (Sasseville and Tomlinson, 2000). The komatiite is dark to pale green, with local spinifex textures consisting of clusters of radiating amphibole to 10 cm long that are presumed to be pseudomorphous after pyroxene (Fig. 5). This package is inferred to underlie the magnetic anomaly, although only nonmagnetic arkose and conglomerate are exposed on the northern strike extension. To the west, the Black Island sequence consists of mafic, intermediate, and felsic metavolcanic rocks as well as minor tonalite plutons (Ermanovics, 1970a, 1981). Both the Lewis–Storey islands and Black Island sequences carry a steep, north-trending high-strain S_1 foliation that is localized in a zone, at least 3 km wide, in which a millimetre-scale tectonic lamination obliterates the primary features. Phyllonite units within the shear zone (Fig. 6) locally contain quartz-carbonate vein stockworks (Fig. 7) with a potential of gold mineralization. The S_1 foliation is isoclinally folded about moderately west-northwest-plunging F_2 hinges and subsequently crenulated by west-southwest-striking F_3 folds and axial planar foliation. Hole River sedimentary rocks are pink arkose units with a single penetrative east-trending foliation, which resembles the S_3 fabric in style and orientation. This interpretation contrasts with that of Ermanovics (1981), who related deformation of the Hole River rocks to the cataclastic effects of the east-striking Wanipigow Fault. The tectonostratigraphic sequence, structural trends, and overprinting relationships observed in eastern Lake Winnipeg correspond closely to those of the Rice Lake belt, where local north-trending D_1 structures juxtapose Meso- and Neoarchean sequences (Brommecker et al., 1993), and are overprinted by northwest-striking D_2 and east-trending D_3 structures (Poulsen et al., 1996).

Low-grade supracrustal rocks of eastern Lake Winnipeg are bound to the east by the broad, north-trending East Shore mylonite zone, which consists of amphibolite-facies mylonitic and protomylonitic tonalite to quartz diorite, with a gently southeast-plunging lineation and dextral kinematic sense. These rocks contain zircons in excess of 2.9 Ga (Krogh et al., 1974), suggesting that the protolith constitutes part of the North Caribou terrane. A sinistral kink in the zone, visible in the aeromagnetic anomaly, corresponds to a zone of folded mylonitic fabric with sheared fold limbs and greenschist-facies overprint (Fig. 8). Although compositionally heterogeneous and favourably oriented to record north-south shortening, the straight zone lacks a pervasive east-trending D_3 crenular overprint. Hence, latest movement on the ductile shear zone is inferred to represent a discrete D_4 event, and to postdate the Hole River sedimentary rocks. The supracrustal rocks are bound to the south by the dextral, greenschist-facies, cataclastic Wanipigow fault zone (D_5), south of which lies 3.0 Ga tonalite (Krogh et al., 1974).

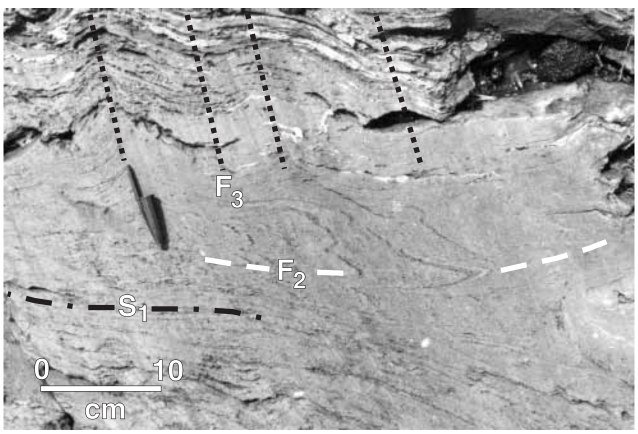

Figure 6. Phyllonite from Gray Point, Black Island illustrating complex, refolded nature of the high-strain rocks. Early (S_1) tectonic laminations in phyllonite are folded isoclinally (F_2) and crenulated by open F_3 folds.

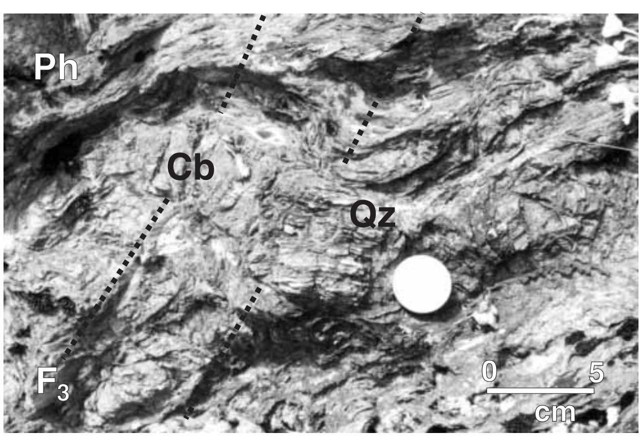

***Figure 7**. Quartz (Qz)-carbonate (Cb) veins in phyllonite (Ph), Gray Point, Black Island. Open F_3 warps of the dominant S_1 tectonic layering are evident.*

***Figure 8**. East Shore mylonite zone in sinistral kink zone. Folding and shearing in the kink zone is accompanied by retrogression to greenschist facies. Elsewhere along the zone, the amphibolite-facies mylonite units form a north-northwest-trending straight zone with gently south-plunging stretching lineations and dextral transcurrent kinematic indicators.*

Large-scale palinspastic reconstruction of the western Uchi belt requires approximately 65 km of sinistral slip along a precursor to the Wanipigow Fault to restore the Black Island and Hole River sequences at Lake Winnipeg into proximity with the Rice Lake group at Bissett. This represents a minimum displacement, as 22 km of late dextral movement on the Wanipigow Fault is required to restore Mesoarchean units of the Wallace Lake belt into proximity with those of the Garner Lake belt (Brommecker et al., 1993). After restoration of movement on the Wanipigow Fault, the East Shore mylonite zone could align with the Garner Lake shear (Poulsen et al., 1996), and the D_1 high-strain zone in the Lewis–Storey islands and Black Island sequences in Lake Winnipeg, with the Beresford Lake shear (Brommecker et al., 1993).

DISCUSSION

Fragments of Mesoarchean crust are preserved sporadically along the southern margin of the North Caribou terrane, separated by voluminous Neoarchean plutons. Insight into the three-dimensional crustal architecture may be provided by the oblique cross-section exposed in the English Lake magmatic complex. If our inference that ca. 3 Ga rocks of mafic and intermediate composition dominate the deep parts of the section is correct, it implies that the abundant Neoarchean plutons form sheet-like bodies at high structural levels. Hence, the map pattern of Mesoarchean remnants exposed in large lobes separated by greenstone belts may reflect exhumation of deeper crustal levels in long-wavelength north-trending folds. Emplacement of the voluminous Neoarchean plutons may have occurred during extensional periods along a dominantly transpressive margin (Stott and Corfu, 1991; cf. Grocott et al., 1994).

Evidence for Mesoarchean deformation in the North Caribou terrane derives from a single locality on its northern flank, where the contact aureole of the ca. 2.87 Ga North Caribou pluton transects an older deformation zone in the North Caribou greenstone belt (Thurston et al., 1991). Other possible manifestations include an angular unconformity at the base of the Confederation (ca. 2.74 Ga) assemblage in the Red Lake belt (Sanborn-Barrie et al., 2000), and the presence of structures in 3.0 Ga rocks of the English Lake magmatic complex that predate probable Neoarchean magmatism.

Unlike the Red Lake and Confederation Lake belts, the Bee Lake, Rice Lake, Wallace Lake, and Black Island belts contain evidence of Neoarchean D_1 high-strain zones. Where constrained, these zones juxtapose sequences as old as Mesoarchean, with rocks as young as the Edmunds Lake Formation (<2704 Ma; Fig. 3). We postulate that a common deformation zone, known as the Beresford Lake shear zone in the Rice Lake belt, roots within the English River Subprovince in the south and extends through the belts to the west. Elsewhere in the western Uchi Subprovince, regional north-northwest-trending, upright D_2 structures are the earliest, and are overprinted by a set of east-trending D_3 structures.

Compelling similarities exist between the tectonostratigraphic sequences preserved in supracrustal belts in the Rice Lake and eastern Lake Winnipeg areas that are separated along the Wanipigow Fault by 65 km. However, the fault-bound-block character of the region between the English Lake magmatic complex and Black Island contrasts with the relatively consistent structural levels of the Rice Lake area. The normal faults may have formed during a ductile phase of major transcurrent movement along the Wanipigow Fault.

ACKNOWLEDGMENTS

Tim Corkery (Manitoba Geological Services Branch) is thanked for an introduction to southeastern Manitoba geology, for logistical arrangements, and for numerous discussions. The Manitoba Department of Natural Resources provided accommodation at Bissett. Reliable float-plane service by Green Airways and Kenora Air Services is greatly appreciated. Discussions with Howard Poulsen on the geology of the Rice Lake belt have been instructive. Neil Rogers and Marc St-Onge provided helpful comments on earlier versions of the manuscript.

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Geological Survey of Canada Project 970014