GS-26 GEOLOGY AND STRUCTURE OF THE NORTH CARIBOU TERRANE-UCHI SUBPROVINCE BOUNDARY IN EASTERN MANITOBA, WITH EMPHASIS ON VOLCANIC AND VOLCANICLASTIC ROCKS OF THE BLACK ISLAND ASSEMBLAGE

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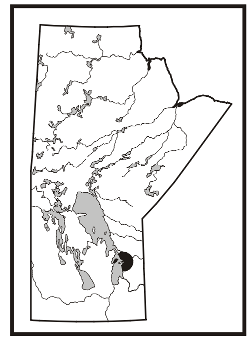

Bailes, A.H. and Percival, J.A. 2000: Geology and structure of the North Caribou Terrane-Uchi Subprovince boundary in eastern Manitoba, with emphasis on volcanic and volcaniclastic rocks of the Black Island assemblage; *in* Report of Activities 2000, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 161-174.

SUMMARY

The Black Island assemblage of the Uchi Subprovince is exposed in a steeply dipping, north- and northeast-facing, greater than 3 km thick, monoclinal structural panel that records fabrics generated during juxtaposition with the adjacent, older North Caribou Terrane to the east. The lower third of the exposed Black Island assemblage consists of aphyric pillowed basalt and basaltic andesite, and overlying massive, porphyritic basalt and basaltic andesite (Gray Point sequence) that display normal mid-ocean ridge basalt (N-MORB) geochemical affinities. The upper two-thirds of the exposed Black Island assemblage consists of subaqueously deposited andesite and volcaniclastic rocks with calc-alkalic geochemical affinities (Drumming Point sequence). The abrupt change in tectonomagmatic setting from the N-MORB–type Gray Point basalt (?ocean floor–back arc) to calc-alkalic Drumming Point andesite flows and volcaniclastic rocks (?arc), combined with a basal Drumming Point volcaniclastic unit containing rounded fragments, suggests that the contact between the Gray Point and overlying Drumming Point sequence is an unconformity or disconformity.

The North Caribou Terrane, to which the Black Island assemblage is juxtaposed, comprises a ca. 3.0 Ga basement complex (tonalite with a layered igneous complex) and an unconformably overlying supracrustal sequence, the Lewis–Storey assemblage. The Lewis–Storey assemblage is composed of arkosic grit, quartzite, komatiite flows, iron-formation and carbonate. It is interpreted to represent a rift sequence similar to the less than 3.0 Ga and greater than 2.92 Ga Conley assemblage quartzite–carbonate–iron-formation–komatiite package, 80 km to the east at Wallace Lake (Sasseville and Tomlinson, 2000).

During juxtaposition of the Black Island assemblage and the North Caribou Terrane (at ca. 2.71–2.70 Ga), both the Black Island assemblage and the North Caribou Terrane were affected by D_1 structures and concurrent deposition of arkose and conglomerate (Hole River sedimentary rocks) in strike-slip basins during continued D_1 oblique convergence. Subsequent deformation was focused in shear zones during D_2 and D_3 transcurrent shear events.

Elucidation of the complex structural history along the boundary between the Uchi Subprovince and the North Caribou Terrane at the west end of the Rice Lake greenstone belt provides a much-improved geological context in which to conduct exploration activities. The previously unrecognized rift succession (Lewis–Storey assemblage) on the east shore and under Lake Winnpeg, in combination with the large areal extent of older ca. 3.0 Ga crust, opens up new exploration possibilities in this underexplored and previously poorly understood area.

INTRODUCTION

Mapping of excellent exposures on Black Island and along the adjacent east shore of Lake Winnipeg at 1:20 000 scale (Bailes and Percival, 2000; Percival and Bailes, 2000) was undertaken to characterize the nature of the boundary between two important tectonic elements of the western Superior Province (Fig. GS-26-1), the ca. 3 Ga continental crust of the North Caribou Terrane and the 2.99 to 2.70 Ga greenstone belts of the Uchi Subprovince. An understanding of the nature of this interface between the North Caribou Terrane and the younger greenstone belts of the Uchi Subprovince is important for tectonostratigraphic reconstruction of the western Superior Province and also to reveal controls on gold mineralization.

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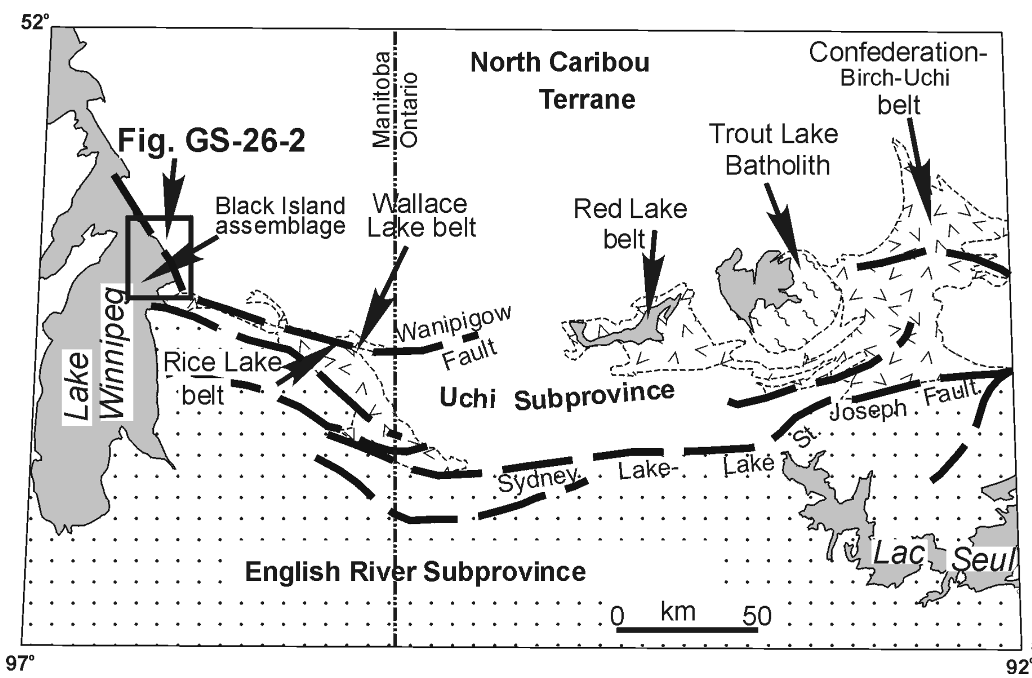

Figure GS-26-1: Major lithotectonic components of the western Superior Province in southeastern Manitoba and adjacent Ontario. The study area, shown by the rectangle, is located on the east shore of Lake Winnipeg and straddles the interface between the Uchi Subprovince and the older North Caribou Terrane.

This contribution documents the geology and geochemistry of volcanic rocks of the Black Island assemblage, part of the Uchi Subprovince. Other aspects of the geology, which are only briefly covered in this report, will be contained in subsequent contributions. Unit numbers used in this report correspond to those in Figures GS-26-2, -3 and -5 and on preliminary maps by Bailes and Percival (2000) and Percival and Bailes (2000).

GEOLOGICAL FRAMEWORK

Introduction

The Black Island assemblage, which outcrops in the southwestern part of the study area, forms the most westerly exposures of the Rice Lake greenstone belt in Manitoba (Fig. GS-26-1, -2). Together with the Red Lake greenstone belt of Ontario, these Uchi Subprovince volcanic rocks are important hosts for lode gold mineralization. Ermanovics and Wanless (1983) considered the Black Island assemblage to belong to the Neoarchean 2.73 Ga Bidou Lake subgroup, which is the dominant volcanic component of the Rice Lake greenstone belt.

The North Caribou Terrane, which forms the northeast and south portion of the study area, extends at least 400 km to the east (Fig. GS-26-1) and is one of the largest blocks with continental affinities in the western Superior Province (Thurston et al., 1991; Percival et al., 2000). The North Caribou Terrane is considered to be a Mesoarchean protocontinent (ca. 3.0 Ga; Thurston and Chivers, 1990) around which younger, Neoarchean supracrustal assemblages, including those of the Uchi Subprovince, assembled during accretion of the Superior Province (Stott and Corfu, 1991). More recent work by Rogers et al. (1999, 2000) and Sanborn-Barrie et al. (2000), however, indicates that at least some Mesoarchean–Neoarchean interfaces are conformable or unconformable contacts, rather than tectonic contacts.

North Caribou Terrane

East Shore Plutonic Complex

On the east shore of Lake Winnipeg, the North Caribou Terrane consists of a tonalitic basement (units 1–2, East Shore plutonic complex), unconformably overlain by a west-facing sedimentary-volcanic platform sequence (units 3–7, Lewis–Storey assemblage; Fig. GS-26-2, -3). The hornblende-biotite tonalite basement (unit 1) beneath the unconformity is coarse grained, homogeneous and characterized by blue quartz. It resembles tonalite and tonalite gneiss units dated in the vicinity at 3006 to 2998 Ma (Ermanovics, 1970, 1981; Krogh et al., 1974; Turek and Weber, 1994; V. McNicoll, unpublished data, 2000). The tonalite locally contains north-trending, chlorite-grade shear zones with prominent shear bands and, on the shore of Lake Winnipeg, grades to the east into a layered (on a 1–100 m scale) igneous complex (unit 2) consisting of sheets and pods of tonalite, quartz diorite, diorite and gabbro.

The ca. 3.0 Ga East Shore plutonic complex and English Lake complex share distinctive geochemical features. Both have rocks, ranging in composition from tonalite through diorite and gabbro, that have multi-element profiles with modest negative Ti and Nb anomalies and strongly depleted Th and Rb. These distinctive geochemical characteristics suggest generation from an ultradepleted mantle source.

The unconformable western margin of the East Shore plutonic complex is locally well preserved in zones of low strain on the shore of Lake

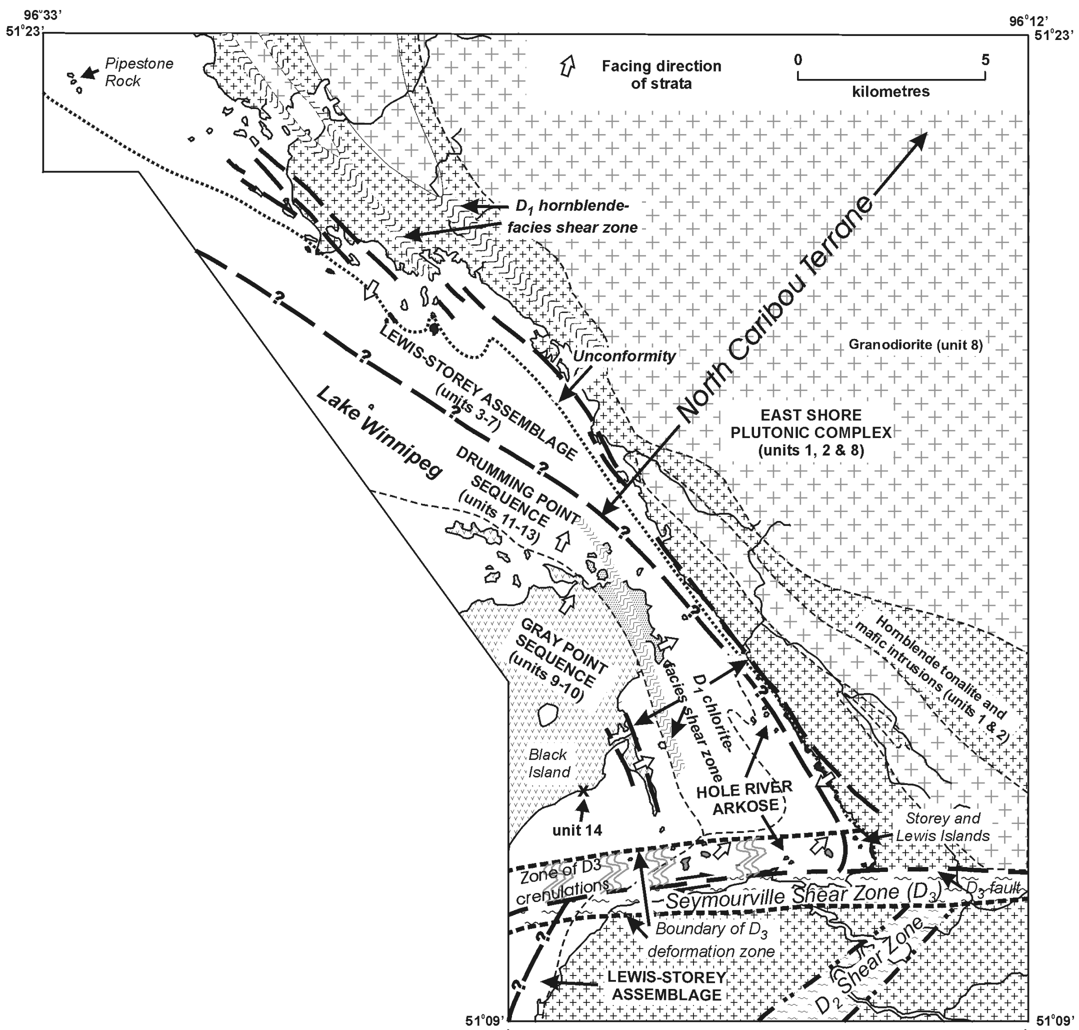

Figure GS-26-2: Simplified geology of the study area, showing the distribution of the main rock sequences and structures.

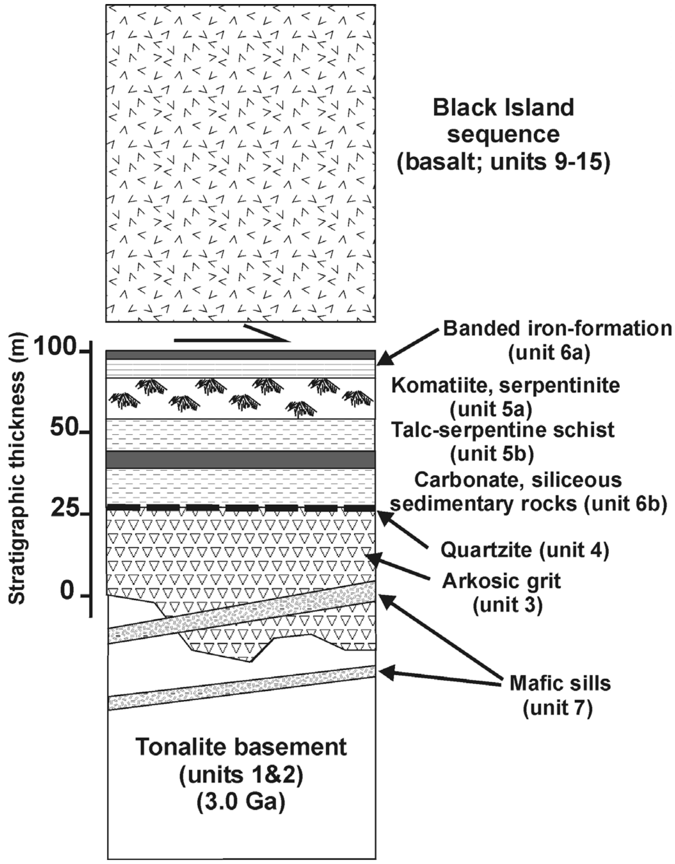

Figure GS-26-3: Schematic cross-section showing the stratigraphy of the Mesoarchean Lewis–Storey assemblage (units 3–7). The east-facing Lewis–Storey assemblage, a probable rift-platform sequence, lies unconformably on ca. 3.0 Ga tonalitic basement (units 1–2) and is in structural contact with Neoarchean volcanic rocks of the Black Island sequence (units 9–15). Unit numbers correspond to those on the preliminary maps by Bailes and Percival (2000) and Percival and Bailes (2000).

Winnipeg. Six exposures of the unconformity, on islands and shoreline outcrops on eastern Lake Winnipeg, allow it to be traced along strike for more than 30 km.

Lew–Storey assemblage

The East Shore plutonic complex is unconformably overlain, along its western margin, by a massive to thick-bedded grit (unit 3), consisting of angular quartz and plagioclase detritus with up to 10% chloritic matrix. Angular pebbles and cobbles of hornblende-bearing tonalite, identical to the basement, are locally present within a few metres of the base of this 15 to 40 m thick, generally unsorted grit unit (Fig. GS-26-4a). Thinly laminated, fine-grained quartzite (unit 4; Fig. GS-26-4b), which occurs in units up to a few metres thick in association with muscovite-rich schist, aluminosilicate-bearing schist and talc schist, is locally present as a thin veneer along the shoreline. Although a contact is not exposed, sedimentary rocks of units 3 and 4 are structurally overlain by komatiite (subunit 5a), which is exposed on Lewis Island. The komatiite displays well preserved spinifex textures defined by radiating clinopyroxene needles up to 20 cm long (Fig. GS-26-4c). Iron-formation (subunit 6a) on Storey Island, surrounded by serpentinite and talc schist (subunit 5b), consists of millimetre- to centimetre-scale layers of carbonate, chert, magnetite and sericite schist (Fig. GS-26-4d). Mafic sills (subunit 7b) up to 15 m thick intrude both the basement and cover sequence adjacent to the unconformity.

A prominent, positive, north-northwest-trending aeromagnetic anomaly that extends beneath Lake Winnipeg, from Storey and Lewis islands in the southeast to Pipestone Rock in the northwest, may delineate iron-formation (unit 6) and ultramafic rocks (unit 5), and the extension of the Lewis–Storey assemblage beneath the lake. The similar trend of the basal unconformity below the Lewis–Storey assemblage along the eastern shoreline of Lake Winnipeg is consistent with this interpretation of the magnetic anomaly.

The Lewis–Storey assemblage may correlate with the less than 3.0 to greater than 2.92 Ga Conley assemblage, a quartzite–carbonate–iron-formation–komatiite package 80 km to the east. This is supported by the presence of a similar, poorly preserved, sedimentary-volcanic sequence halfway between these two localities in the Wanipigow River area. At Wanipigow Lake, east-trending tonalite and supracrustal units resemble those observed in eastern Lake Winnipeg, although an unconformity was not noted. The tonalite is bordered to the south by a chloritic grit unit up to 10 m thick and is overlain by fine-grained, thinly laminated siliceous siltstone. Sporadic magnetite-chert and hematite-chert ironstone is also present at this structural level. Gabbroic sills with minor serpentinite schist layers occur structurally above the iron-formation, as well as within the tonalite. These units are variably highly strained, and are separated by the dextral Wanipigow Fault from a metagreywacke unit to the south (Weber, 1991).

The Lewis–Storey assemblage (units 3–7) is interpreted to be part of a platform-rift succession (cf. Thurston and Chivers, 1990) to the greater than 3.0 Ga protocontinent (East Shore plutonic complex, units 1–2). Basal grit (unit 3) may have developed through chemical weathering and slight downslope transport of basement units exposed as a result of plume-related uplift (cf. Rainbird and Ernst, in press). Deposition of quartzite (unit 4) and carbonate-bearing iron-formation (unit 6), accompanied by komatiitic magmatism (unit 5), probably reflects thermal subsidence during initial rifting. Younger mafic sills (subunit 7b) could be a distal expression of magmatism related to the drift phase of continental breakup.

Black Island Assemblage

The Black Island assemblage consists of lower greenschist facies volcanic and volcaniclastic rocks that form a steeply dipping, northeast-facing sequence, more than 2 km thick (Fig. GS-26-5), exposed in shoreline outcrops on Black Island and on smaller islands to the north (Bailes and Percival, 2000). The lower third of the section (units 9–10) consists of basalt and basaltic andesite flows (Gray Point sequence), and the upper two-thirds (units 11–13) consists of andesite flows and associated volcaniclastic rocks (Drumming Point sequence). Preliminary geochemistry (*see* 'Geochemistry of Volcanic Rocks, Black Island Assemblage' section) shows the Gray Point sequence to be MORB-like ([?] arc rift–ocean floor) and the Drumming Point sequence to be transitional calc-alkaline (?arc-like).

Ermanovics (1981) considered the Black Island assemblage (units 9–14) to correlate with the Bidou Lake subgroup exposed 65 km to the east. This appeared to be supported by a U-Pb zircon date of 2732 ± 10 Ma (Ermanovics and Wanless, 1983) from a rhyolite breccia (unit 14) on southeast Black Island and the ca. 2730 Ma age of the Bidou Lake subgroup (Poulsen et al., 1996) at Bissett. However, the rhyolite (unit 14) dated at Black Island has a faulted contact and an uncertain relationship to the main volcanic formations (units 9–13). The fault contact between the unit 14 rhyolite breccia and units 9 to 13 is significant, because rocks of unit 14 face south, whereas those of units 9 to 13 face north and northeast.

Hole River Sedimentary Sequence

The Hole River sedimentary sequence is composed of pink- and grey–weathering, sandstone–pebbly sandstone (unit 17) and rare conglomerate (unit 16). Uranium-lead zircon data on the Hole River sand-

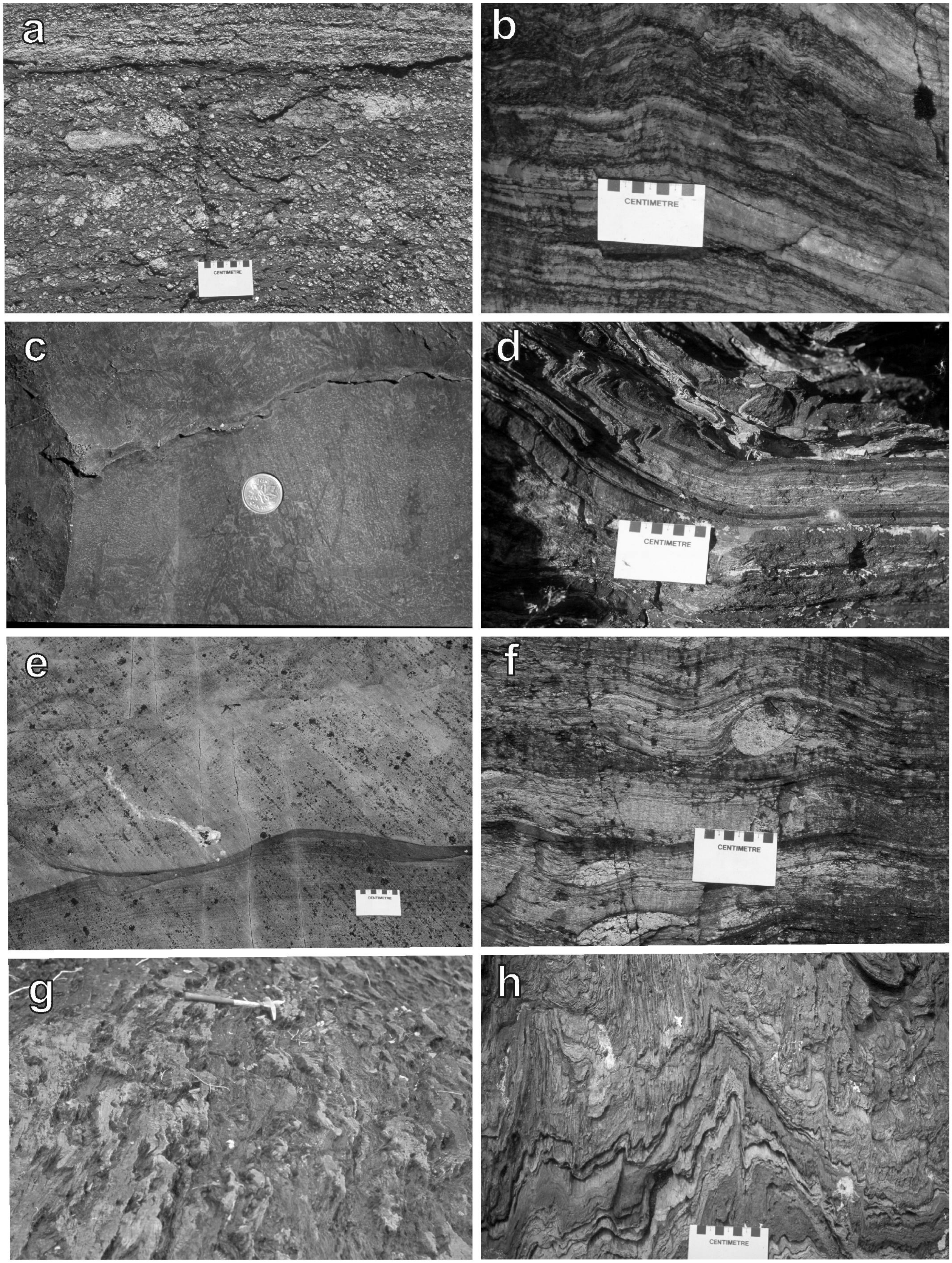

Figure GS-26-4: Photographs of the East Shore plutonic complex, Lewis–Storey assemblage, Hole River sedimentary rocks, and D_1 and D_3 structures: a) crude bedding in a pebbly grit arkose (unit 3) a few metres above the unconformity at the base of the Lewis–Storey assemblage; b) thinly laminated chert and quartzite (unit 4); c) komatiite (unit 5) from Lewis Island, with spinifex texture defined by radiating clinopyroxene needles; d) banded iron-formation (unit 6) from Storey Island, composed of thinly bedded magnetite (dark), carbonate and sericite schist; e) Hole River trough-crossbedded arkose (unit 17); f) Hole River conglomerate (unit 18) with prominent rounded granitic cobbles; g) D_1-shear zone developed in basalt on Gray Point; h) F_3-folds with prominent axial-planar crenulation cleavage deforming S_1-foliated basalt on island south of Gray Point.

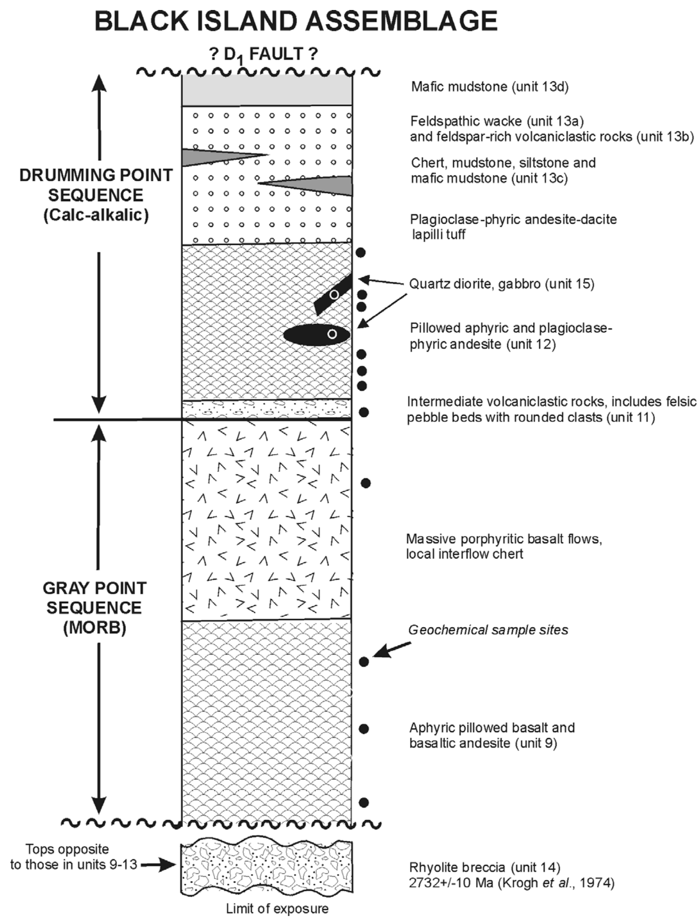

Figure GS-26-5: Schematic stratigraphic section of the Black Island assemblage. Unit numbers correspond with those on preliminary maps by Bailes and Percival (2000) and Percival and Bailes (2000).

stone, obtained with the sensitive high-resolution ion microprobe (SHRIMP), show the youngest detrital grains to be 2706 Ma (V. McNicoll and J. Percival, unpublished data, 2000) and indicate a source and age similar to those of the Edmunds Lake and English River greywackes (<2704 Ma from detrital zircon geochronology; Poulsen et al., 1996) and the San Antonio formation sandstone (youngest concordant grain 2704 ± 14 Ma; Percival et al., 2000).

Hole River sandstone is typically massive, monotonous and indistinctly bedded, but locally displays excellent trough cross-bedding (Fig. GS-26-4e), pebble lags and scours. Pebbles in the sandstone are well rounded and include boulders and cobbles of a wide variety of plutonic rocks, vein quartz and volcanic rocks (Fig. GS-26-4f). Bed forms, rounding of pebbles and the wide variety of clasts in the Hole River sandstone suggest that these rocks were likely deposited in a subaerial-fluvial environment. Similar sandstone and conglomerate units of the San Antonio formation at Bissett, 65 km to the east, lie unconformably on volcanic (Bidou Lake subgroup) and plutonic rocks.

Structure

The Black Island assemblage, Lewis–Storey assemblage and adjacent portions of the East Shore plutonic complex carry a penetrative, north-trending, steeply west-dipping S_1 foliation and widespread concordant D_1 high-strain zones up to 40 m wide (Fig. GS-26-4g). These structures are interpreted to have formed in response to structural amalgamation of the Black Island assemblage with the older ca 3.0 Ga East Shore plutonic complex and its rift-margin Lewis–Storey assemblage. Shear-sense indicators, including extensional shear bands and asymmetrical boudinage structures, suggest consistent dextral kinematic sense on D_1 structures. Folds of S_1 foliation, previously considered a separate F_2 generation (Percival and Whalen, 2000), have consistent ‘Z’ asymmetry and can be shown in some high-strain zones to have formed during progressive development of the S_1 fabric; they are therefore termed F_{1a}. In the eastern part of the area, ductile D_1 fabrics are truncated by sheets and plutons of biotite granodiorite (unit 9) that may be correlative with ca. 2715 Ma granodiorite dated by Krogh et al. (1974). Southwest-trending crenulations (F_2) are common in thinly laminated high-strain (D_1) zones and are considered a distinct second generation of structures. A steeply dipping, east-trending zone of dextral greenschist-facies high-strain (D_3) and related crenulation folds (F_3; Fig. GS-26-4h) forms the linear shoreline in the vicinity of Seymourville. This structure translates the basement-cover sequence approximately 7 km to the west, where the basement hornblende tonalite (unit 2) is overlain by grit (unit 3) and komatiite (unit 5) in the Pelican Harbour area.

DESCRIPTION OF UNITS, BLACK ISLAND ASSEMBLAGE

The following description of volcanic and volcaniclastic rock units of the Black Island assemblage is largely derived from least deformed, unfoliated outcrops exposed on islands north of Black Island. The level of deformation of Black Island assemblage rocks increases toward the east and toward the contact with the adjacent North Caribou Terrane. More strongly deformed units on eastern Black Island and on islands to the east are characterized by a north- to north-northwest-trending S_1 foliation and local discrete D_1 shear zones. The boundary between the Black Island assemblage and the North Caribou Terrane is interpreted to be a D_1 shear zone, but lack of exposure prohibits verification of this interpretation.

Aphyric Basalt and Basaltic Andesite (Unit 9)

This unit, more than 1000 m thick, consists of aphyric basalt and basaltic andesite flows (subunit 9a) and mafic tectonite derived through D_1 strain (subunit 9b). The least deformed basalt and basaltic andesite of subunit 9a are exposed in small outcrops along the north and south shorelines of Black Island. These flows are characterized by medium to dark grey-green colour on both fresh and weathered surfaces, an absence of vesicles, and ubiquitous pillow structures with thin (<1 cm) selvages (dark green) and interpillow hyaloclastite domains (Fig. GS-26-6a). One pillowed flow displayed well developed thermal contraction cracks and radial pipe vesicles. Because of the small size of subunit 9a outcrops, no information is available on flow thicknesses or internal flow organization. No interflow sedimentary or tuff units were observed.

Basalt and basaltic andesite (subunit 9a) with S_1 foliation and associated north-trending and steeply dipping mafic tectonite and shear zones (subunit 9b) are exposed on Gray Point. Foliated pillowed basalt (subunit 9a) grades over a few metres into mafic tectonite (subunit 9b; Fig. GS-26-6b). On Gray Point, the D_1 mafic tectonite and shear zones contain numerous quartz-carbonate-chlorite vein stockworks (Fig. GS-26-6c) that were considered by Percival and Whalen (2000) to have potential for gold mineralization. These vein stockworks were sampled during the 2000 field season and submitted for gold analysis. Samples from two sites indicated Au values to be less than 8 ppb.

Porphyritic Basalt and Basaltic Andesite (Unit 10)

This 700 to 1200 m thick unit consists of massive basalt and basaltic andesite flows that weather pale buff-brown to rarely dark grey-green and are pale grey-green to rarely dark green on fresh surfaces. Least deformed exposures of this unit occur on islands directly north of Black Island; more deformed and less well exposed outcrops occur on small islands east of Gray Point. The flows lack amygdales and pillow structures, and contain only rare spherulites. Flow contacts are defined by chilled margins and by local interflow units of chert less than 3 m thick (Fig. GS-26-6d). Thicker massive flows commonly display subtle

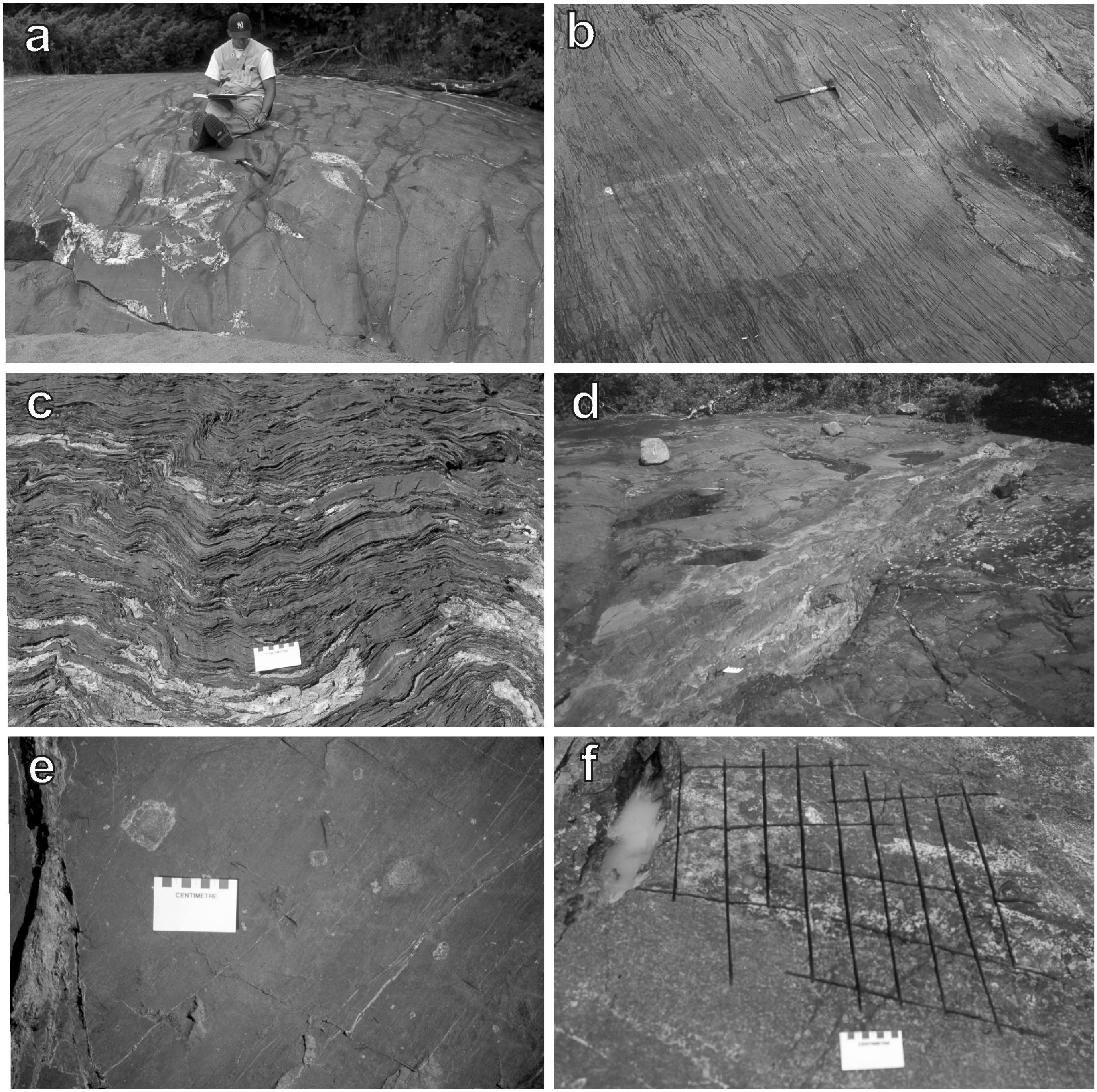

Figure GS-26-6: Photographs of rocks in the Point Gray sequence: a) pillowed basalt (unit 9) with D_1 flattening of pillows to left of person; b) contact between mafic tectonite and pillowed flow; c) quartz-carbonate vein stockworks in D_1 shear zone; d) interflow chert between two massive flows (unit 10); e) plagioclase megacrysts in massive basalt flow (unit 10); f) pegmatitic pod in massive gabbroic-textured flow (unit 10) prepared for collection of U-Pb radiometric dating sample.

variations in grain size that may be a consequence of incomplete cooling and amalgamation of flow units. Measured flows vary in thickness from 13 m to more than 60 m.

Most flows are pyroxene and pyroxene-plagioclase phyric, with up to 40% phenocrysts ranging from 2 to 8 mm in size (subunit 10a). Pyroxene phenocrysts in subunit 10a flows are often oikocrystic. Less common, but still abundant, are plagioclase megacrystic (subunit 10b) and pyroxene glomerocrystic (subunit 10c) flows. The plagioclase megacrysts that make up less than 7% of plagioclase-pyroxene–phyric flows of unit 10 are typically 1 to 5 cm in size, but locally up to 12 cm, and display local zoning and resorbed margins (Fig. GS-26-6e). Pyroxene glomerocrysts in subunit 10d are up to 4 cm in diameter. Thicker flows are locally gabbroic textured (subunit 10c) and include rare irregular pegmatitic domains up to 50 cm in diameter (Fig. GS-26-6f). A pegmatite pod from one thick flow was collected for U-Pb zircon dating in order to establish the age of the Gray Point sequence.

Intermediate to Felsic Volcaniclastic Rocks (Unit 11)

The base of the Drumming Point sequence is marked by an 80 to 120 m thick unit composed of bedded, intermediate to felsic volcaniclastic rocks. This unit is dominated by intermediate volcaniclastic rocks rich in plagioclase phenoclasts, but also contains chert, siliceous sedimentary rocks and heterolithic intermediate to felsic volcanic conglomerate, as well as rare rhyolite breccia and pillowed plagioclase-phyric basaltic andesite flows.

Intermediate volcaniclastic rocks (subunit 11a) are composed of 10 to 100 cm thick beds that display normal size-grading, basal scours, Bouma AB bed zoning, and rare flame structures and rip-ups (Fig. GS-26-7a). They are typically composed of texturally immature sand and grit that is geochemically similar to the stratigraphically overlying Drumming Point andesite and basaltic andesite (unit 12). They most likely represent locally derived, unconsolidated volcanic detritus that slumped and was deposited subaqueously by turbidity currents.

Intercalated with the intermediate volcaniclastic turbidites are beds of volcanic conglomerate and breccia (subunit 11b). They form beds that range from 1 m to more than 4 m in thckness, vary widely in composition and texture, contain a heterolithic clast population including intrusive rocks, are matrix-supported, and locally display both reverse and normal size-grading. Pebbles and cobbles in these beds are generally rounded to well rounded (Fig. GS-26-7b), in contrast to the detrital matrix, which normally is texturally immature. Many of the pebbles and cobbles are rhyolite and dacite, rock types not present in either the underlying (Gray Point) or overlying (Drumming Point) volcanic sequences. Rounding of pebbles and cobbles, heterolithic clast populations and presence of intrusive clasts suggest unroofing of the source terrane, possible subaerial transport of clasts, and mixing prior to their incorporation in the volcanic conglomerate beds. The texturally immature character of the detrital matrix indicates that it likely had a more local derivation and only limited, if any, subaerial transport.

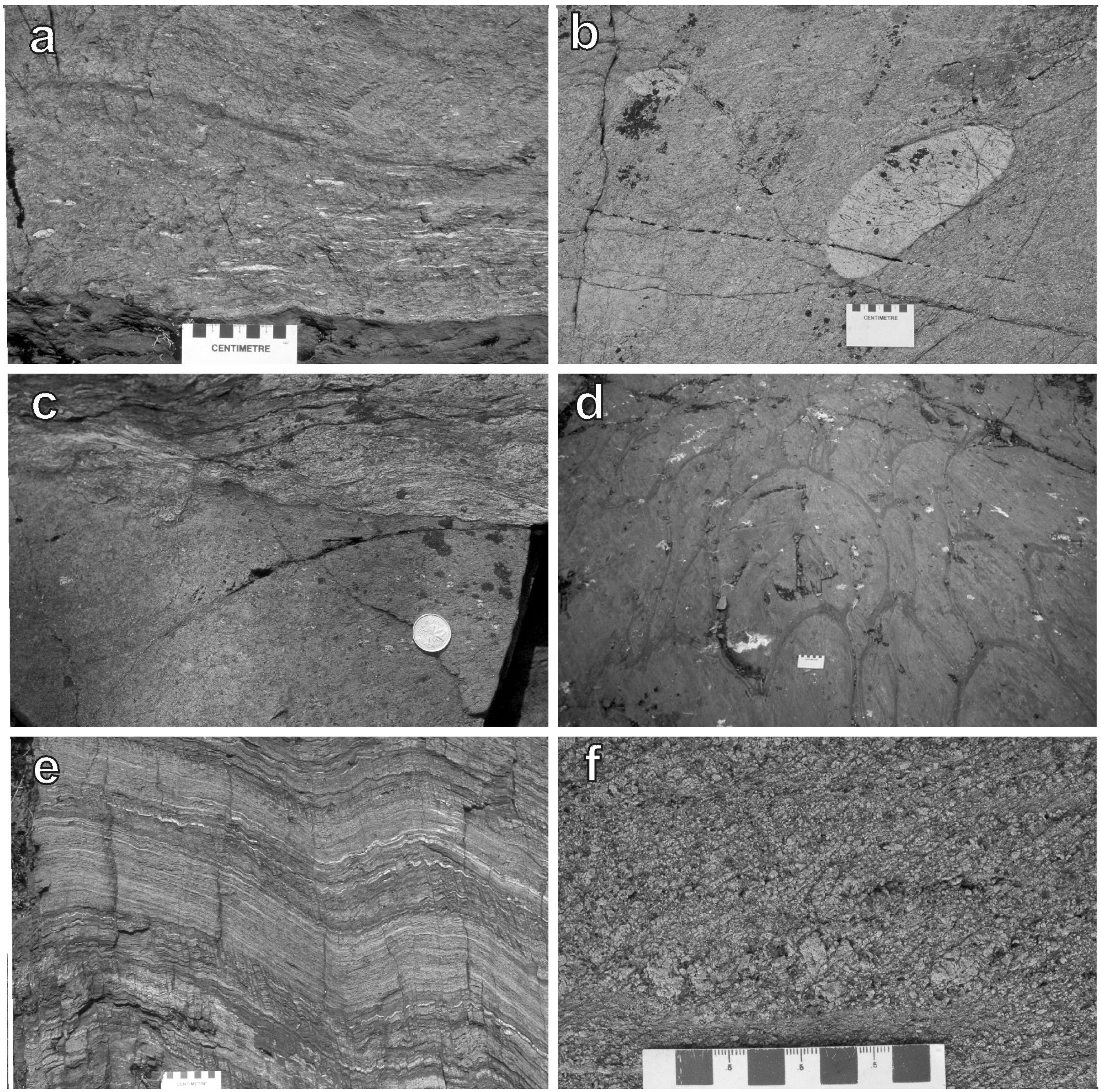

Figure GS-26-7: Photographs of rocks in the Drumming Point sequence: a) normal size-grading of rhyolite pebbles in bed of intermediate volcanic sandstone (unit 11); b) rounded rhyolite cobble supported in a matrix of texturally immature andesitic sandstone (unit 11); c) unfoliated dyke, texturally similar to Drumming Point andesite flows, cutting foliated Gray Point basalt (unit 9); d) pillowed Drumming Point andesite (unit 12); e) F_2-folded, delicately laminated siltstone and mudstone (unit 13c); f) coarse greywacke with angular lithic fragments (unit 13b).

Chert beds occur sporadically throughout unit 11, suggesting periodic sediment starvation of the depositional basin. The presence of soft-sediment slumping of chert in one locality suggests basin instability during lithification.

The presence of this basal volcaniclastic unit at the contact between two geochemically distinct volcanic sequences, the MORB-like Gray Point and the calc-alkaline Drumming Point, suggests that these units may be separated by an unconformity or disconformity. The presence of subaerially transported, rounded pebbles and cobbles in conglomerate beds of unit 11, and unfoliated basaltic dykes, petrographically similar to Drumming Point volcanic rocks and cutting foliated unit 9 basalt on Gray Point (Fig. GS-26-7c), is consistent with this interpretation.

Pillowed Basaltic Andesite and Andesite (Unit 12)

Aphyric (subunit 12a) and, less commonly, plagioclase-phyric (subunit 12b; <10% phenocrysts, 0.5–3 mm in size) basaltic andesite and andesite flows form a 350 to 1100 m thick sequence that directly overlies volcaniclastic rocks of unit 11. The flows are buff to buff-brown on weathered surfaces and medium to pale grey-green on fresh surfaces. They are least deformed (subunit 12a) on islands directly north of Black Island. Most of the flows are pillowed (Fig. GS-26-7d) and include only rare massive types (subunit 12c). Flow thicknesses are generally not well constrained due to incomplete exposure of flows on small islands. Pillow selvages are typically less than 1 cm and interpillow hyaloclastite is typically between 1 and 4 cm thick. The flows contain rare amygdales, radial pipe vesicles and synvolcanic dykes. Interflow sedimentary deposits, which are common between Gray Point massive flows (unit 10), are absent in unit 12 flows. Pillowed flows on islands east of Gray Point are commonly strongly foliated, and many of the flows have been tectonized (subunit 12d), with lensoid lithons in which strongly flattened pillow relicts are preserved.

Feldspathic Wacke and Related Volcaniclastic Rocks (Unit 13)

The Drumming Point sequence is topped by up to 1000 m of feldspathic wacke and associated volcaniclastic rocks (unit 13). The thickness of this unit is not well constrained, as its eastern contact is unexposed and may be a D_1 fault.

The sequence is dominated by feldspathic wacke (subunit 13a) and a massive, medium-grained, feldspathic volcaniclastic equivalent (subunit 13b). Both subunits 13a and 13b are characterized by buff to pale buff weathering and a medium grey-green fresh surface. Deformed equivalents are typically pale grey-green on both weathered and fresh surfaces. Orangy pink feldspars, likely saussuritized and hematized, usually form between 50 and 75% of both these subunits, with the remainder consisting of amphibole and 5 to 20% quartz. The feldspathic wacke (subunit 13a) is typically well laminated but, because of its very limited variation in grain size, rarely forms well defined beds. It locally displays normal size-grading, scours and flame structures, and contains rare fine-grained lithic pebbles. Locally, it is intercalated with fine-grained siltstone, chert and mafic mudstone (subunit 13c; Fig. GS-26-7e). Crystal-rich feldspathic volcaniclastic rocks (subunit 13b) are typically massive, without discernable layering or bedding. Subunit 13b does, however, display local bedding and rare normal size-grading, attesting to its clastic character (Fig. GS-26-7f). A decrease in grain size from northern exposures of coarser, feldspathic volcaniclastic rocks (subunit 13b) to southern exposures of finer-grained, bedded, felspathic wacke (subunit 13a) suggests that rocks to the north may be more proximal deposits.

Mafic Mudstone (Subunit 13d)

Mafic mudstone (subunit 13d) outcrops on two small islands at the top of the exposed Black Island assemblage. The mudstone is dark grey-green on both weathered and fresh surfaces and characterized by a well developed parting. The mudstone may indicate upward fining toward the top of unit 13, but this is very speculative because of the wide spacing of exposures.

Rhyolite Breccia (Unit 14)

Rhyolite tuff–lapilli tuff (subunit 14a) and heterolithic felsic breccia (subunit 14b) are exposed on a single outcrop on the south shore of Black Island. This unit is significant, as Ermanovics and Wanless (1983) reported a U-Pb zircon age of 2732 ± 10 Ma for this outcrop, and suggested that the Black Island assemblage is equivalent to the Bidou Lake subgroup of similar age, exposed 65 km to the east at Bissett. However, fieldwork this summer shows that the rhyolite (unit 14) is in fault contact and faces opposite to the remainder of the Black Island assemblage (units 9–13). Thus, the age of units 9 to 13 is not known, and the suggested age correlation with the Bidou Lake subgroup at Bissett should be regarded as tentative.

Rhyolite tuff–lapilli tuff (subunit 14a), which forms the north side of the single outcrop of unit 14, is light grey to light buff-grey on weathered surfaces and pale grey on fresh surfaces. This greater than 5 m thick unit of aphyric, unbedded, massive rhyolite breccia mainly comprises a mixture of pale to medium grey-weathering, angular, fine-grained (?glassy) clasts and red-brown–weathering, subrounded, finely vesicular aphyric clasts. The presence in this mainly monolithic rhyolite breccia of possible shards and flattened pumiceous clasts indicates that it may have been a pyroclastic or secondary (resedimented) pyroclastic deposit.

Rhyolite cobble conglomerate (subunit 14b), which forms the south side of the outcrop, is well bedded and composed of a heterolithic mixture of subangular to rounded, matrix-supported felsic clasts. Beds vary in thickness from 30 cm to more than 100 cm, and one displays well defined normal size-grading of both matrix and larger clasts (Fig. GS-26-8a). A block of rhyolite tuff breccia in this conglomerate contains shards and welded pumice clasts (Fig. GS-26-8b), suggesting that at least part of the source volcanic terrane may have been subaerial. Rounded clasts and a heterolithic clast population are consistent with subaerial transport and mixing.

Gabbro, Quartz Diorite (Unit 15)

Quartz diorite to gabbro (unit 15) are exposed on a number of small islands to the south and east of Deer Island. Krogh et al. (1974) reported a 2715 ± 10 Ma U-Pb zircon age on a quartz diorite from this unit. The diorite and quartz diorite comprise fine- to medium-grained, multiphase intrusions (dyke complexes) that are overprinted by a weak (?S_1) foliation. Chilled margins and rare quartz amygdales in some dykes suggest intrusion at shallow levels and possible subvolcanic character. Two samples of unit 15 gabbro have chemical signatures identical to those of the Drumming Point basaltic andesite and andesite (unit 12).

GEOCHEMISTRY OF VOLCANIC ROCKS, BLACK ISLAND ASSEMBLAGE

Sampling of the Black Island assemblage volcanic rocks was undertaken in 1999 and 2000 as part of a broader program to provide high-precision geochemical analyses (ICP–MS) for volcanic rocks of the Rice Lake greenstone belt. The purpose is to characterize the trace-element and rare-earth element geochemistry of volcanic rocks in order to identify the tectonomagmatic environment of volcanism and to aid correlation between volcanic sequences throughout the belt (Bailes, 1998, 1999).

Samples were collected from all major units in the Black Island assemblage. They were taken from rocks that appeared mesoscopically least altered. Samples were trimmed to remove fractures, veins and weathered surfaces, and to avoid visible alteration or significant amygdale populations.

When this report was written, the only analyses available were

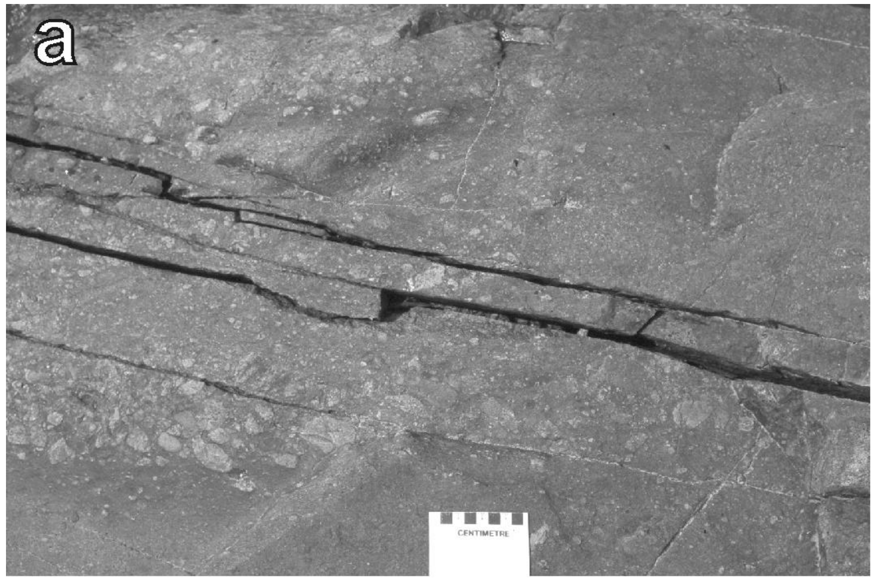

Figure GS-26-8: Photographs of rhyolite breccia (unit 14): a) normal size-grading at base of rhyolite pebble conglomerate (subunit 14a); b) rhyolite fragment containing flattened pumice and shards (subunit 14b).

those from the 1999 season, four from the Gray Point sequence and ten from the Drumming Point sequence. The stratigraphic positions of these sample sites are plotted for reference in Figure GS-26-5.

Major-element and immobile trace-element discrimination diagrams indicate that the Gray Point sequence (Fig. GS-26-9, a, c and e) is composed of basalt and basaltic andesite (46–54% SiO_2), whereas the Drumming Point sequence (Fig. GS-26-9, b, d and f) is slightly more felsic and composed of basaltic andesite and andesite (55–63% SiO_2). Both sequences are subalkaline (Fig. GS-26-9).

Gray Point basalt and basaltic andesite display many of the geochemical characteristics of ocean-floor basalt. They plot in the field of modern ocean-floor basalt on a diagram of Cr versus Ti (Fig. GS-26-10a) and in the N-MORB field using the trace elements Th, Zr and Nb (Fig. GS-26-10c). However, on diagrams using Th values or Th//Nb ratios (e.g., Fig. GS-26-11a, b), they plot within the arc field, slightly outside the ocean-floor/N-MORB field. Multi-element N-MORB–normalized plots (Fig. GS-26-12a) show that the basalt has elevated Th and slightly negative Nb values, but typical N-MORB geochemistry in all other respects. The elevated Th could be a result of crustal contamination, or the result of a slight subduction signature. Absence of negative values of Zr, Hf and Ti, which characterize subduction-arc–produced basalt in modern tectonic settings, suggests that the elevated Th may reflect contamination rather than a subduction component. An alternative interpretation, proposed for the geochemically similar Big Island basalts at Wallace Lake, is that this type of basalt was deposited in an oceanic plateau environment (Sasseville and Tomlinson, 2000). On primitive-mantle–normalized multi-element plots, the Gray Point basalt (Fig. GS-26-13a) displays slightly negative Nb and Th values and is geochemically similar to the Unnamed, Tinney, and Gunnar basalt units of the eastern Rice Lake greenstone belt. These outcrop 80 km to the east, where they form a basaltic ‘platform’ at the base of the Bidou Lake subgroup.

The Drumming Point basaltic andesite and andesite straddle the ocean-floor and island-arc fields of modern volcanic rocks on the Cr versus Ti diagram (Fig. GS-26-10b), but clearly fall in the arc field on the plot of Th, Zr and Nb (Fig. GS-26-10d) and on all discriminant plots shown in Figure GS-26-11. On multi-element N-MORB–normalized (Fig. GS-26-12b) and primitive-mantle–normalized (Fig. GS-26-13c, -13d) plots, the Drumming Point sequence displays negative Nb relative to Th, La and Ce, a feature that is typically attributed to subduction processes in modern volcanic regimes (Pearce and Peate, 1995). However, the positive normalized values of Zr and Hf on these plots are not typical of magmas in modern arc environments.

Elevated light rare-earth elements (LREE) and depleted heavy rare-earth elements (HREE) on the N-MORB– and primitive-mantle–normalized multi-element plots (Fig. GS-26-12b, GS-26-13c, -13d, -13e)

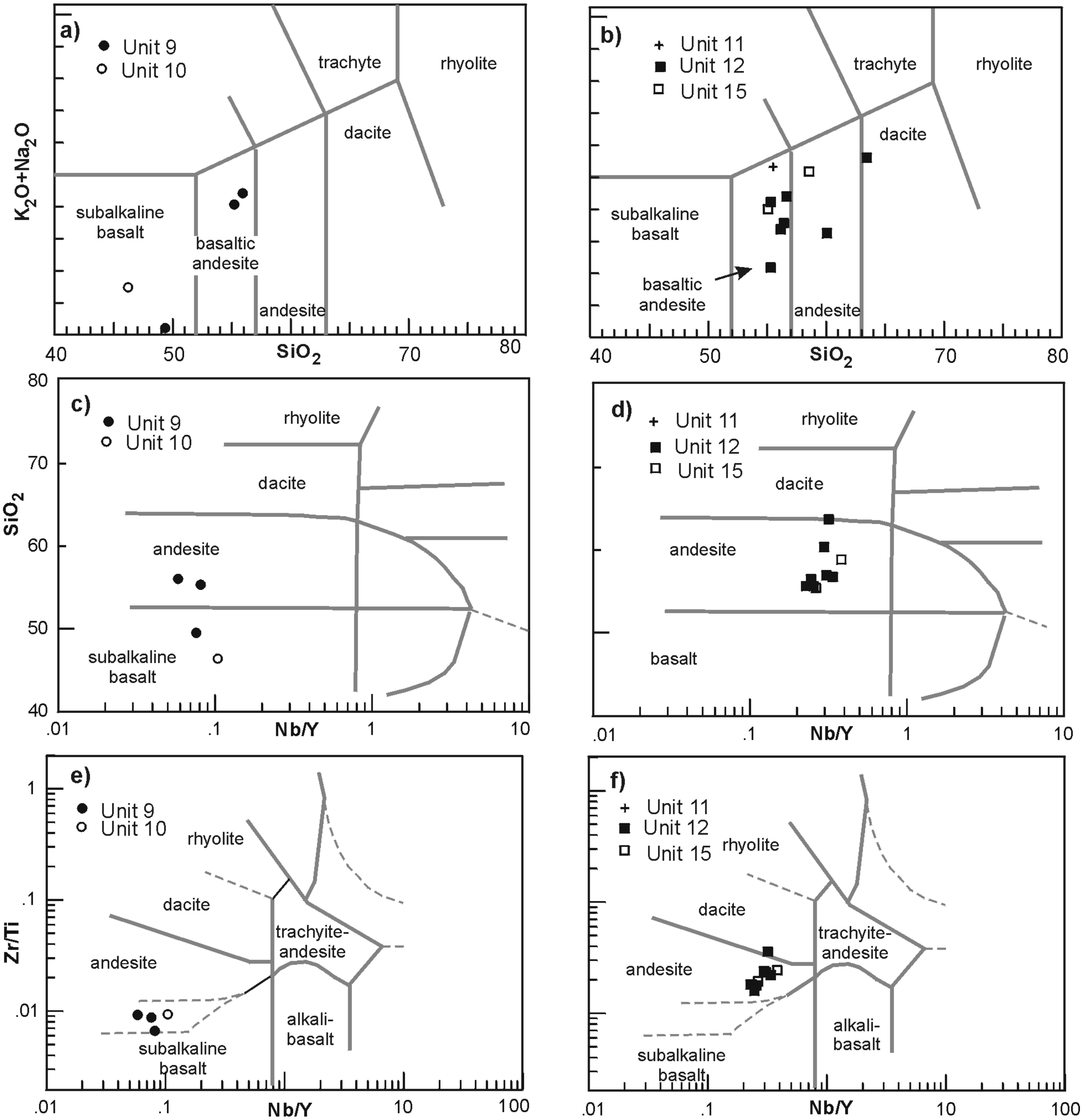

Figure GS-26-9: Black Island assemblage volcanic rocks plotted on geochemical discrimination diagrams for rock type and major chemical affinities: SiO_2 vs. K_2O+Na_2O (a and b); Nb/Y vs. SiO_2 (c and d); and Nb/Y vs. Zr/Ti (e and f).

suggest a calc-alkalic affinity for the Drumming Point sequence. Drumming Point volcanic rocks also fall in the calc-alkalic field on the Jensen cation plot (Fig. GS-26-14b) and display Hf/Th ratios between 1.3 and 2.4. The latter is significant, as Wood (1980) has shown that modern tholeiitic and calc-alkalic volcanic suites have Hf/Th ratios of greater than 3 and less than 3, respectively. The Drumming Point sequence is geochemically similar to basaltic andesite and andesite that comprise part of the upper Bidou Lake subgroup at Bissett and Wanipigow Lake (Fig. GS-26-13f).

The dramatic geochemical differences between the Gray Point and Drumming Point sequences, N-MORB (?contaminated) versus calc-alkaline, indicate that the boundary between these two volcanic sequences, which appears to be marked by an unconformity, also marks a significant change in tectonic setting of volcanism. The geochemical similarity of Gray Point and Drumming Point volcanic rocks to the lower and upper portions of the Bidou Lake subgroup, respectively, suggests that this boundary could extend to the east into the Bissett and Beresford Lake areas.

ECONOMIC GEOLOGY

The Rice Lake greenstone belt has a long history as a lode gold producer. Shear zones and related quartz-carbonate vein stockworks, belonging to D_1, on the eastern shore of Black Island and on smaller islands to the east are considered to have potential to host gold, but assayed samples from two sites showed less than 8 ppb Au. However, very little exploration activity (trenches or sampling) was obvious on these zones, indicating that their potential has not been assessed.

The Rice Lake greenstone belt hosts no known economic base-metal volcanogenic massive sulphide (VMS) deposits. Rhyolite in the Rice Lake greenstone belt is typically F2 type, according to the classification system of Lesher et al. (1986), and therefore does not have a high potential for economic VMS deposits (Lesher et al., 1986). The absence

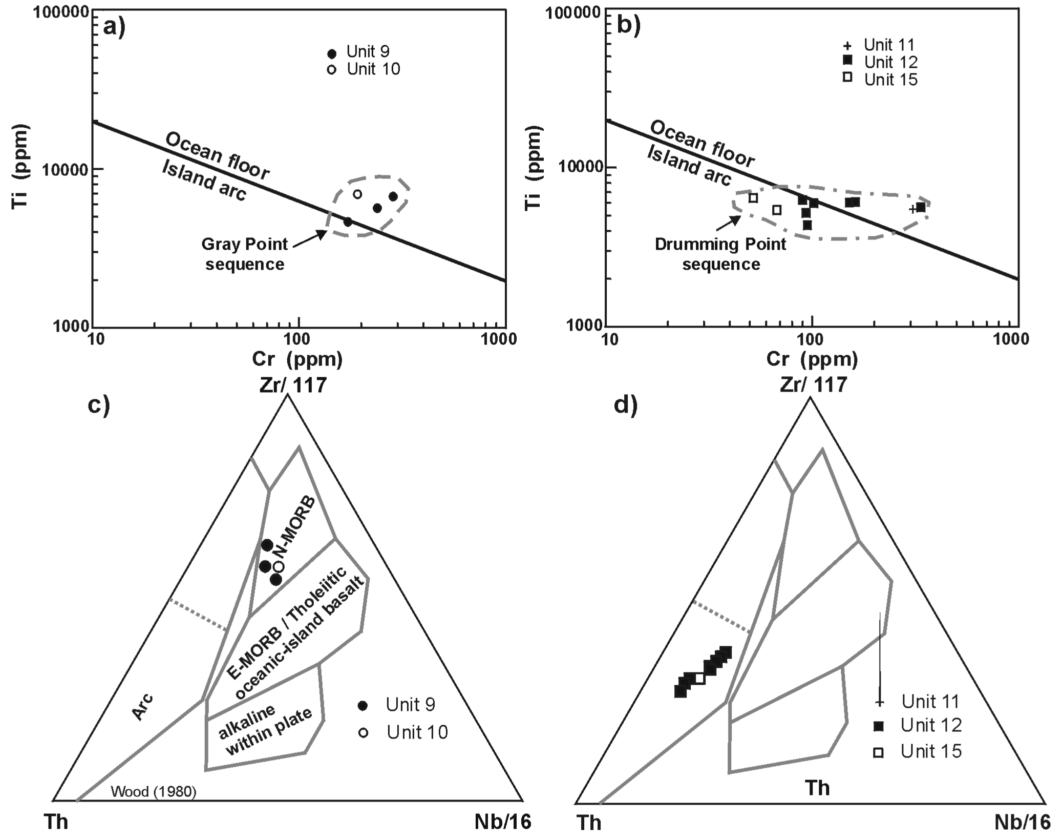

Figure GS-26-10: Black Island assemblage basalt, basaltic andesite and andesite plotted on tectonic discrimination diagrams: Cr vs. Ti (a and b); Th vs. Zr/117 vs. Nb/16 (c and d).

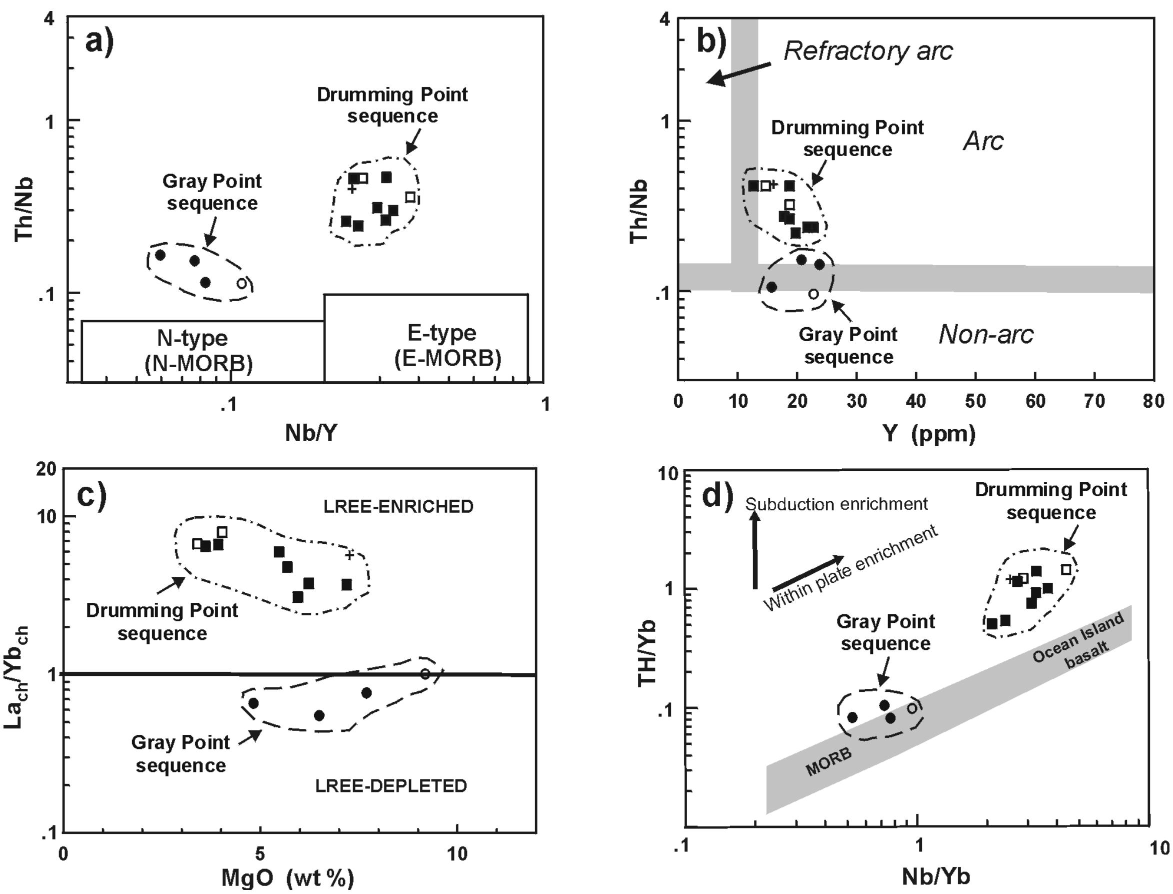

Figure GS-26-11: Black Island assemblage volcanic rocks plotted on various geochemical discrimination diagrams: a) Nb/Y vs. Th/Nb, b) Y vs. Th/Nb, c) MgO vs La_{ch}/Yb_{ch} and d) Nb/Yb vs. Th/Yb.

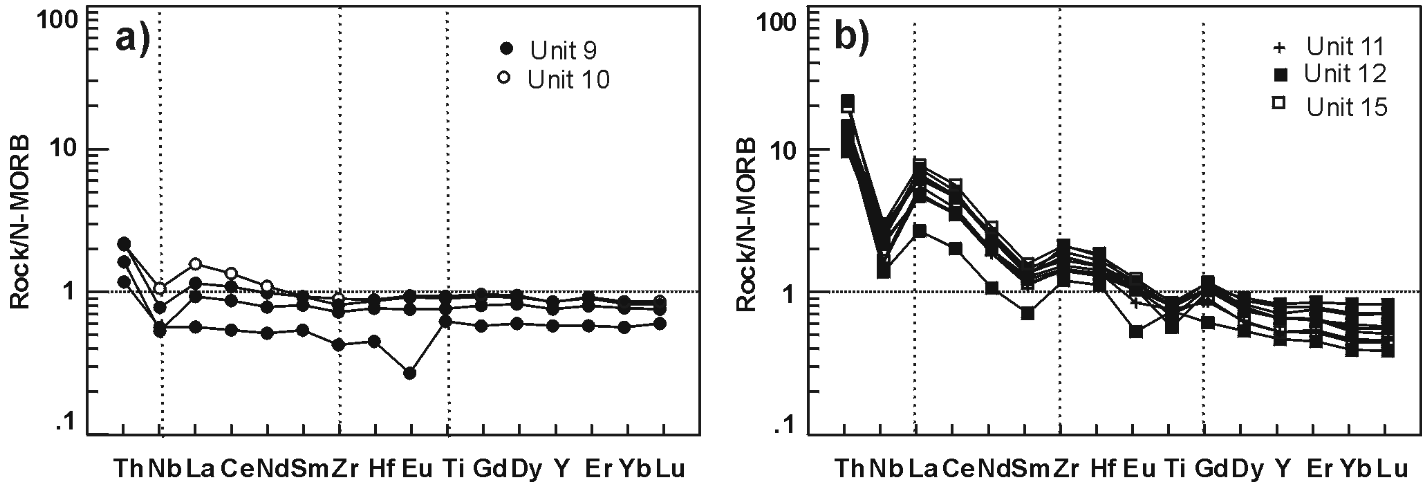

Figure GS-26-12: N-MORB–normalized multi-element plots of Black Island assemblage mafic volcanic rocks. Normalizing values and order adopted from Sun and McDonough (1989).

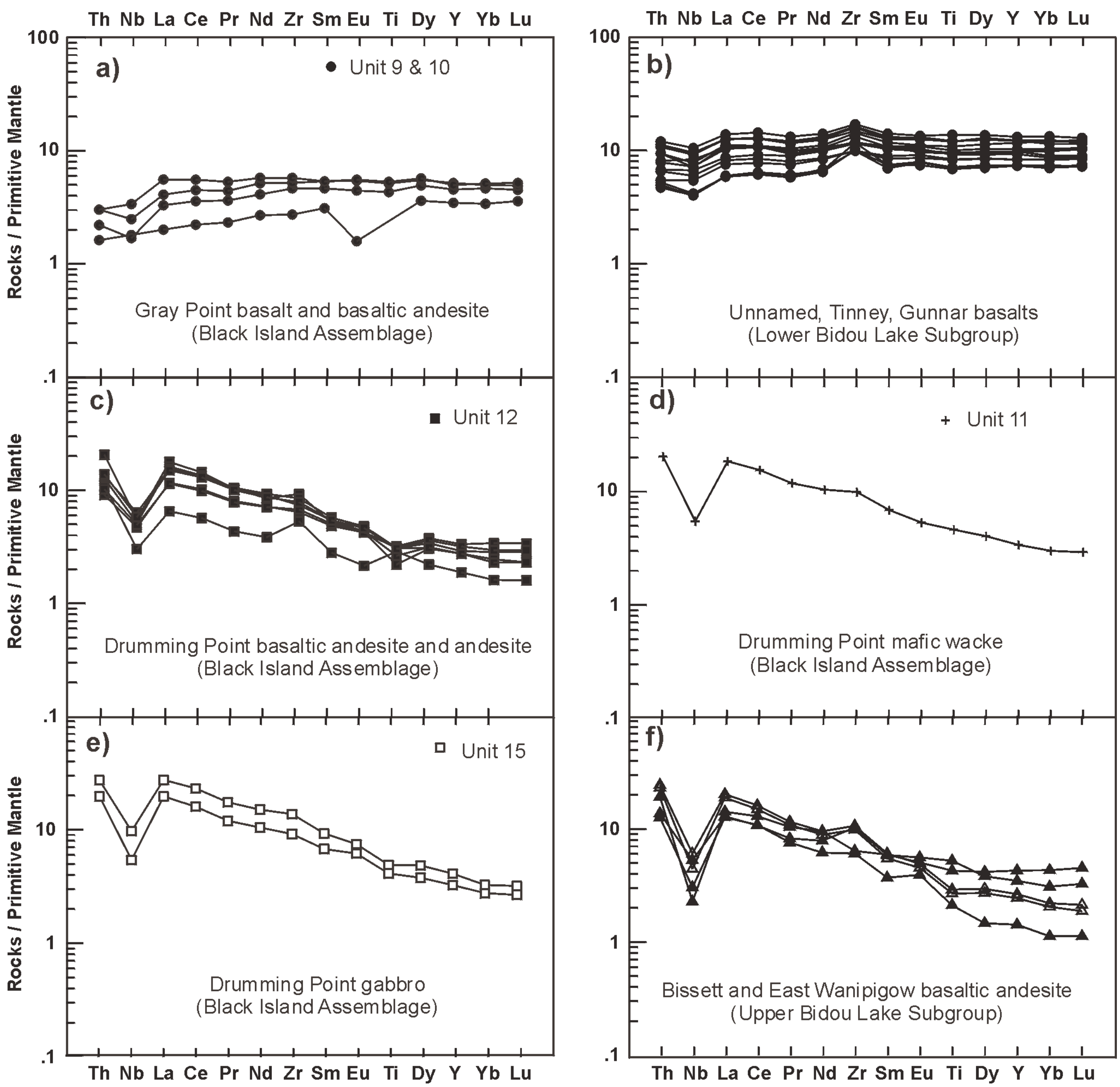

Figure GS-26-13: Primitive-mantle–normalized multi-element plots of Black Island assemblage and Bidou Lake subgroup mafic volcanic rocks. Normalizing values and order adopted from Sun and McDonough (1989).

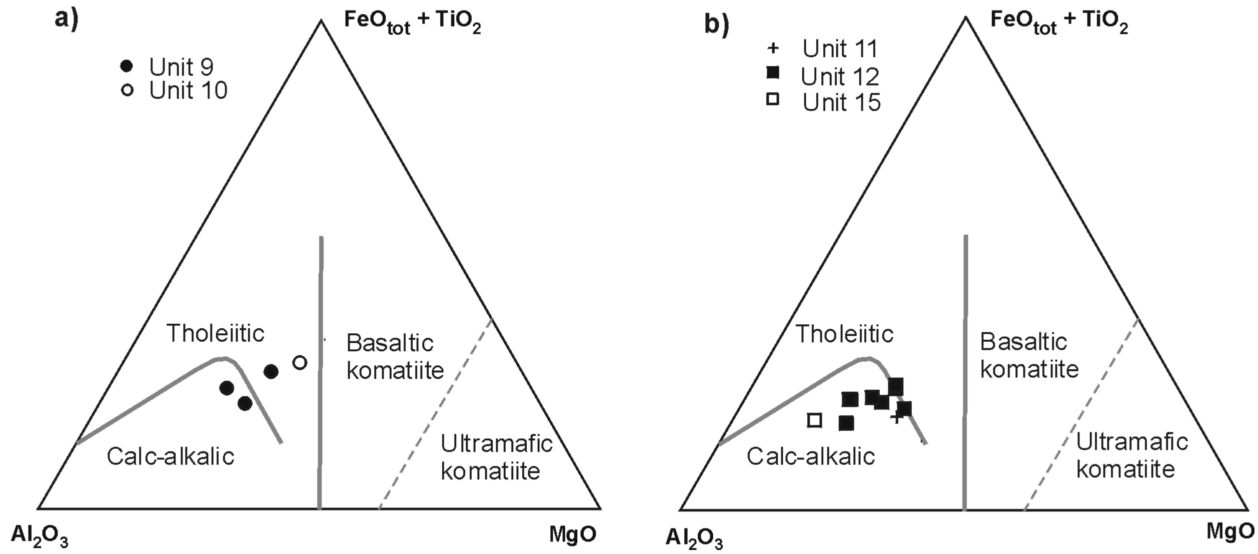

Figure GS-26-14: Black Island assemblage volcanic rocks plotted on Jensen cation plot (Al_2O_3 vs. FeO_{tot}+TiO_2 vs. MgO): a) Gray Point basalt and basaltic andesite; b) Drumming Point basaltic andesite and andesite.

of rhyolite in the Black Island assemblage (only two small exposures), combined with the F2 geochemical signature of rhyolite in the Rice Lake belt, suggests that copper-zinc VMS deposits are unlikely to be present in the Black Island assemblage.

The presence of ca 3.0 Ga crust (units 1 and 2) east of Lake Winnipeg and the unconformably overlying Lewis–Storey rift-platform sedimentary rocks (units 3–7) provides a previously unrecognized and unexplored succession. The ca. 3.0 Ga ([?] and older) crust is one that could have potential for diamond exploration, since old Archean crust can be bonded to stable refractory mantle lithosphere that includes the diamond stability field (Kerrich and Wyman, 1996). The economic potential of the Lewis–Storey rift-platform sequence is not known. However, rifted continental margins elsewhere are commonly areas with elevated levels of hydrothermal activity and ultramafic magmatism. Younger rift successions are known to host magmatic nickel and platinum-group elements (PGEs).

CONCLUSIONS

The succession of rocks exposed on Black Island and the adjacent east shore of Lake Winnipeg provides a unique opportunity to examine the tectonostratigraphic and structural relationships between the Uchi Subprovince (Black Island assemblage) and the older North Caribou Terrane. A working hypothesis for the tectonostratigraphic and structural evolution of the area involves deposition of the Lewis–Storey assemblage as a rift sequence on the western margin of ca. 3 Ga basement (East Shore plutonic complex), with subsequent spreading recorded by mafic sill emplacement. The deposition of the Black Island assemblage began in an ocean-floor–arc-rift environment (Gray Point sequence, N-MORB geochemistry) and abruptly switched ([?] at a disconformity) to an oceanic-arc–like environment (Drumming Point sequence, calc-alkalic). Juxtaposition of the Black Island assemblage and the North Caribou Terrane (at ca. 2.71–2.70 Ga) resulted in development of D_1 structures in a probable strike-slip (dextral) regime. The Hole River sedimentary rocks were deposited in strike-slip basins during continued D_1 oblique convergence. Waning deformation became focused in shear zones during D_2 and D_3 transcurrent shear events.

The new mapping and interpretation of rocks undertaken as part of this project provide a more complete geological context in which to undertake exploration at the west end of the Rice Lake greenstone belt. The unique rock formations and complex overprinting deformation provide the possibility of mineralization in stratigraphic and structural environments that have yet to be satisfactorily explored and investigated.

REFERENCES

Bailes, A.H. 1998: Geochemical sampling of the Bidou Lake Subgroup of the Rice Lake greenstone belt; *in* Report of Activities 1998, Manitoba Energy and Mines, Geological Services, p. 144–150.

Bailes, A.H. 1999: Geochemical sampling and geological reconnaissance of the western Rice Lake greenstone belt; *in* Report of Activities 1999, Manitoba Industry, Trade and Mines, Geological Services, p. 102–105.

Bailes, A.H. and Percival, J.A. 2000: Geology of the Black Island–Seymourville area; Manitoba Industry Trade and Mines, Manitoba Geological Survey, Preliminary Map R-1, 1:20 000 scale.

Ermanovics, I.F. 1970: Precambrian geology of the Hecla–Carroll Lake map area, Manitoba–Ontario (62P E1/2, 52M W1/2); Geological Survey of Canada, Paper 69-42, 33 p.

Ermanovics, I.F. 1981: Geology of the Manigotagan area, Manitoba; Geological Survey of Canada, Paper 80-26.

Ermanovics, I.F. and Wanless, R.K. 1983: Isotopic age studies and tectonic interpretation of Superior Province in Manitoba; Geological Survey of Canada, Paper 82-12, 17 p.

Kerrich, R. and Wyman, D.A. 1996: Trace element geochemistry of igneous rocks in mineral exploration: an overview; *in* Trace Element Geochemistry of Volcanic Rocks: Applications for Massive Sulphide Exploration, (ed.) D.A. Wyman; Geological Association of Canada, Short Course Notes, v. 12, p. 1–50.

Krogh, T.E., Ermanovics, I.F. and Davis, G.L. 1974: Two episodes of metamorphism and deformation in the Archean rocks of the Canadian shield; Carnegie Institution of Washington, Geophysical Laboratory Yearbook, p. 573–575.

Lesher, C.M., Goodwin, A.M., Campbell, I.H. and Gorton, M.P. 1986: Trace element geochemistry of ore-associated and barren felsic metavolcanic rocks in the Superior Province, Canada; Canadian Journal of Earth Sciences, v. 23, p. 222–237.

Pearce, J.A. and Peate, D.W. 1995: Tectonic implications of the composition of volcanic arc magmas; Annual Review of the Earth and Planetary Sciences, v. 23, p. 251–285.

Percival, J.A. and Bailes, A.H. 2000: Geology of the Pipestone Rock–Little Rice River area; Manitoba Industry, Trade and Mines, Manitoba Geological Survey, Preliminary Map R-2, 1:20 000 scale.

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:80/gsc/bookstore).

Percival, J.A., Whalen, J.B. and McNicoll, V. in press: Tectonic reconstruction of the western Uchi Subprovince; *in* 2000 Western Superior Transect Sixth Annual Workshop, (ed.) R.M. Harrap and H.H. Helmstaedt; LITHOPROBE Secretariat, University of British Columbia, LITHOPROBE Report.

Poulsen, K.H., Weber, W., Brommecker, R. and Seneshen, D.N. 1996: Lithostratigraphic assembly and structural setting of gold mineralization in the eastern Rice Lake greenstone belt, Manitoba; Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Field Trip Guidebook A4, 106 p.

Rainbird, R.H. and Ernst, R.E. in press: The sedimentary record of mantle plume uplift; Geological Society of America, Special Paper.

Rogers, N., McNicoll, V., van Staal, C.R. and Tomlinson, K.Y. 2000: Lithogeochemical studies in the Uchi–Confederation greenstone belt, northwestern Ontario: implications for Archean tectonics; Geological Survey of Canada, Current Research 2000-C16 (online; http://www.NRCan.gc.ca:80/gsc/bookstore).

Rogers, N., van Staal, C.R. and McNicoll, V. 1999: Recent advances in the geology and structure of the Confederation Lake region, northwestern Ontario; *in* Current Research 1999-C; Geological Survey of Canada, p. 187–195.

Sanborn-Barrie, M., Skulski, T., Parker, J., Dubé, B. and Balmer, W. 2000: Integrated regional analysis of the Red Lake greenstone belt and its mineral deposits, Ontario; Geological Survey of Canada, Current Research 2000-C18 (online; http://www.NRCan.gc.ca:80/gsc/bookstore).

Sasseville, C. and Tomlinson, K.Y. 2000: Tectonostratigraphy, structure and geochemistry of the Mesoarchean Wallace Lake greenstone belt, southeastern Manitoba; Geological Survey of Canada, Current Research 2000-C14, 9 p. (online; http://www.NRCan.gc.ca:80/gsc/bookstore).

Stott, G.M. and Corfu, F. 1991: Uchi subprovince; *in* Geology of Ontario, (ed.) P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott; Ontario Geological Survey, Special Volume 4, Pt. 1, p. 144–236.

Sun, S.S. and McDonough, W.F. 1989: Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes; Geological Society, Special Publications, v. 42, p. 313–345.

Thurston, P.C. and Chivers, K.M. 1990: Secular variation in greenstone sequence development, emphasising Superior Province, Canada; Precambrian Research, v. 46, p. 21–58.

Thurston, P.C., Osmani, I.A. and Stone, D. 1991: Northwestern Superior Province: review and terrane analysis; Chapter 5 *in* Geology of Ontario, (ed.) P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott; Ontario Geological Survey, Special Volume 4, Pt. 1, p. 81–144.

Turek, A. and Weber, W. 1994: The 3 Ga granitoid basement to the Rice Lake supracrustal rocks, southeast Manitoba; *in* Report of Activities 1994, Manitoba Energy and Mines, Geological Services, p. 167–169.

Weber, W. 1991: Geology of the English Brook area, southeastern Manitoba (NTS 62P/1); *in* Report of Activities 1990, Manitoba Energy and Mines, Geological Services, p. 49–52.

Wood, D.A. 1980: The application of Th-Hf-Ta diagram to problems of tectonomagmatic classification and to establishing the nature of crustal contamination of basaltic lavas of the British Tertiary Volcanic Province; Earth and Planetary Science Letters, v. 50, p. 11–30.