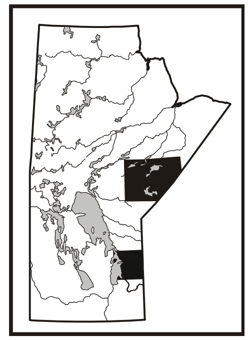
GS-17

WESTERN SUPERIOR NATMAP: EXPLORING THE EVOLUTION OF ARCHEAN CONTINENTAL AND OCEANIC DOMAINS



by J.A. Percival[1], J.L. Brown[2], M.T. Corkery, J. Devaney[4], B. Dubé[3], V. McNicoll[1], J.R. Parker[4], N. Rogers[1], M. Sanborn-Barrie[1], C. Sasseville[5], T. Skulski[1], D. Stone[4], G.M. Stott[4], E.C. Syme, P.C. Thurston[4], K.Y. Tomlinson[1] and J.B. Whalen[1]

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INTRODUCTION

Initiated in 1997, the Western Superior NATMAP project combines resources and expertise of the Geological Survey of Canada, Ontario Geological Survey and Manitoba Geological Services Branch, and capitalizes on the active research program of the Western Superior LITHOPROBE transect. Serving both the academic and exploration communities, the project aims to revise the tectonic framework for greenstone-granite subprovinces of the western Superior Province, through establishment of relationships between older (pre-2.8 Ga) continental fragments and younger (ca. 2.7 Ga) supracrustal assemblages. For decades, geologists have regarded the subprovinces of the western Superior as its fundamental tectonic building blocks, interpreted recently as accreted oceanic fragments at ca. 2.7 Ga (e.g., Williams et al., 1992). However, the model of primitive terrane accretion does not adequately account for the presence of widespread 3.0-2.8 Ga crust throughout the western Superior. For example, the Wabigoon subprovince has been considered as a single entity despite the presence of greenstones and granites with ages ranging from ca. 3.0 to 2.7 Ga (Williams et al., 1992). Similarly, the North Caribou terrane (Thurston et al., 1991) houses an extended record of crustal growth. Supracrustal rocks adjacent to these regions form the main focus of the project because they provide information on the tectonic environment during their deposition at ca. 2.75-2.70 Ga. Relationships are being elucidated through examination of the age, geochemistry and structural history of regions shown on Figure GS-17-1:

1) greenstone belts adjoining known old crustal blocks, such as the Sturgeon-Savant (Sanborn-Barrie and Skulski, 1999), Obonga (Tomlinson et al., 1996; Percival and Stott, in press) and Onaman-Tashota (Stott and Staub, 1999) belts of the Wabigoon Subprovince; Confederation (Rogers et al., in press; Devaney, in press), Red (Sanborn-Barrie et al., in press) and Wallace Lake (Sasseville and Tomlinson, 1999; in press) belts of the western Uchi Subprovince; and Island Lake (Lin et al., 1998), Stull Lake (Stone et al., 1998; Corkery et al., 1997), Knee Lake (Syme et al., 1998) and Gods Lake belts (Corkery et al., GS-18 this volume) on the northern margin of the North Caribou terrane;

2) granitoid regions of the central Wabigoon Subprovince (Percival et al., 1999; Stone and Halle, 1999a) and northern flank of the North Caribou terrane (Stone et al., 1999); and

3) two metallogenetically important deposit types: VMS and gold in old and young crustal blocks (Parker, 1999a,b).

Through these diverse approaches, the NATMAP project intends to map the distribution of oceanic and continental crust at 2.7 Ga, thereby providing an enhanced framework that should serve to focus mineral exploration in terranes with highest potential.

WESTERN UCHI SUBPROVINCE

Confederation Lake Belt

The Confederation Lake belt has been divided into Balmer (ca. 2975 Ma), Woman (ca. 2840 Ma) and Confederation (ca. 2740 Ma) assemblages (e.g., Stott and Corfu, 1991; van Staal, 1998). Initial results from ongoing work suggest that the Woman assemblage may be absent, and that the different volcanic packages form a stratigraphic sequence, rather than having been tectonically accreted. Geochemical data indicate abundant andesite and basaltic andesite in the Balmer assemblage, rather than basalt, an observation supported by the absence of pillowed flows. Felsic volcaniclastic rocks, chemically arc-like, occur towards the structural base and top of this assemblage, with U-Pb zircon ages of 2989 ±2 Ma and 2975 ±1 Ma, respectively (V. McNicoll, unpublished data). Low εNd values indicate that these rocks formed in a continental setting (Tomlinson and Rogers, 1999).

Volcanic rocks of the Balmer assemblage are disconformably to possibly unconformably overlain by a thick sequence of pillow basalts that are chemically divided into three conformable suites. They are typically primitive tholeiites, although Nd isotopes suggest some involvement of old crust in their petrogenesis (Tomlinson and Rogers, 1999). Felsic volcanic rocks have not been recognized within this sequence, precluding direct age control, but based on the age of a cross-cutting gabbro, they predate 2832 ±2 Ma (V. McNicoll, unpublished data, 1998). The structurally highest suite of pillow basalts is conformably to disconformably overlain by iron formation and wackes that contain ca. 2985 Ma and ca. 2880 Ma detrital zircons (V. McNicoll, unpublished data, 1998). These rocks were previously considered part of the Woman assemblage, however they are now tentatively correlated with the Bruce Channel assemblage of the Red Lake greenstone belt.

New results indicate that the ca. 2840 Ma Woman assemblage does not occur in the Confederation Lake belt. This assertion is based on a U-Pb zircon age of 2742 ±2 Ma (V. McNicoll, unpublished data, 1999) from a geochemically and petrographically similar, but isotopically different (Tomlinson and Rogers, 1999) sample along the strike extension of the Woman assemblage type locality. Similarly, detrital zircons of ca. 2840 Ma are absent from a wacke-conglomerate unit that conformably to unconformably overlies the type locality (V. McNicoll, unpublished data, 1999). Furthermore, felsic volcanic rocks typical of the Confederation assemblage occur between the Mainprize batholith and Swain Lake deformation zone, an area previously considered the northern extension of the Woman assemblage. Attempts to directly date the Woman assemblage at its type locality have so far been unsuccessful.

The Confederation assemblage is divided into three, north- to northeast-trending belts of distinct felsic volcanic rocks. The eastern and western panels contain arc-like andesites and dacites (F_1 rhyolites of Lesher et al., 1986), and are separated by a sequence of apparently rift-related dacites, rhyolites (F_3 rhyolites) and MORB-like tholeiitic basalts. This spatial configuration is interpreted to represent a rifted continental arc. Additional geochronology is required to constrain relationships between the different volcanic suites. The southeastern margin of the Confederation assemblage contains primitive ultramafic to gabbroic rocks that appear to tectonically overlie the arc-like sequence and may represent an obducted slice.

A sedimentary unit consisting of conglomerate and wacke along the east shore of Woman Lake was previously considered to mark the top of an east-facing Woman assemblage. However, its few top indications are to the west and it is likely of Confederation age or younger (V. McNicoll, unpublished data, 1999). South of the former South Bay Cu-Zn VMS deposit, units previously identified as tuffs include flow banded and spherulitic rhyolite lava flow facies, and a unit with mudstone intraclasts

[1] Continental Geoscience Division, Geological Survey of Canada, 601 Booth St., Ottawa, ON K1A 0E8
[2] Earth Sciences, University of Ottawa, P.O. Box 450, Stn. A, Ottawa, ON K1N 6N5
[3] Centre géoscientifique de Québec, Geological Survey of Canada, CP7500, Ste-Foy, QC G1V4C7.
[4] Ontario Geological Survey, 933 Ramsey Lake Road, Sudbury, ON P3E 6B5
[5] Earth and Planetary Sciences, McGill University, 3450 University St., Montreal, QC H3A 2A7

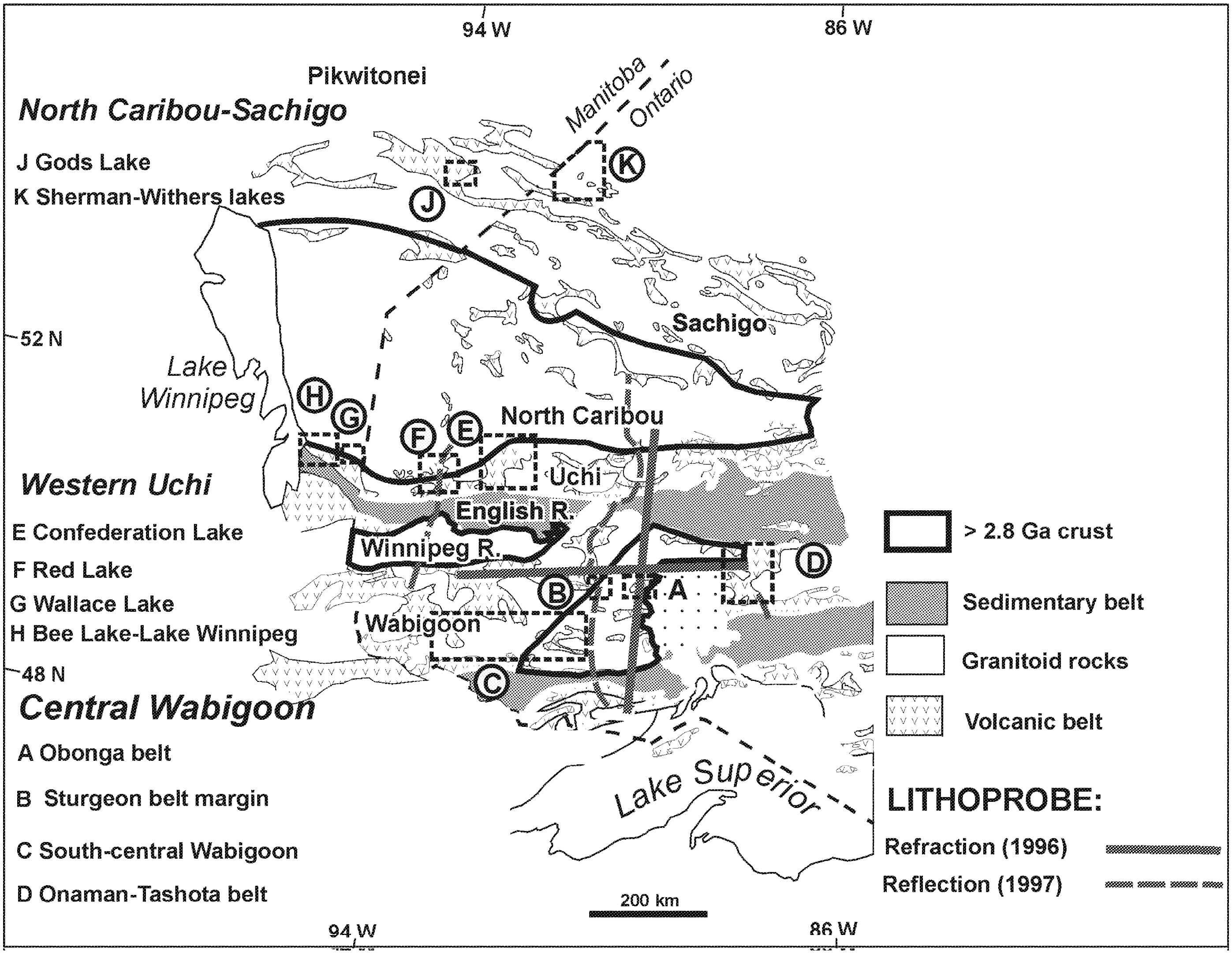

Figure GS-17-1: Generalized geological map of the western Superior Province showing locations of projects described in the text.

that may correlate with mudstone facies present within the ore horizon.

Volcaniclastic facies in the Lost Bay area represent a deep water turbiditic succession, but the pyroclastic-sedimentary distinction is problematic. Common graded sandstone or tuffaceous beds, interbedded with conglomerate or lapillistone having moderately well-sorted frameworks of small clasts, suggest significant sedimentary transport. There is no evidence of hot emplacement or direct volcanic deposition, but the sporadic presence of rare features such as pumice beds, lava flow facies, and chert-magnetite exhalite facies, suggest that the Lost Bay succession may be a complex mix of sedimentary, reworked volcaniclastic, and minor pyroclastic facies. At Sundown Lake, a 4-km-long conglomeratic unit with fluvial and resedimented facies is very similar to units to the northeast in the Birch Lake area, previously interpreted as late orogenic pull-apart basins. Newly identified features include top indications to the west, and common spherulitic clasts derived from the adjacent volcanic unit.

Red Lake belt

The Red Lake gold camp is characterized by a diverse supracrustal stratigraphy that spans some 300 m.y., a polyphase tectonometamorphic history, and a rich mineral endowment. Field investigations as part of the Western Superior NATMAP project (Sanborn-Barrie, et al., in press) will provide: 1) the mineral industry with a geological synthesis of an important gold mining camp; 2) a high resolution view of surface geology, geochronology and geochemistry along the northern segment of a LITHOPROBE seismic reflection line; and, 3) structural linkage between ongoing NATMAP investigations to the west (Rice-Wallace Lake belt) and east (Confederation Lake belt), thereby completing an overview of ca. 3.0-2.7 Ga tectonomagmatic processes that operated along the southern margin of the North Caribou terrane.

The Mesoarchean stratigraphy of the Red Lake greenstone belt includes at least three assemblages whose boundaries have been postulated to be tectonic (Stott and Corfu, 1991): the ca. 2.99-2.96 Ga Balmer assemblage; the 2.94-2.92 Ga Ball assemblage; and the ca. 2.89 Ga Bruce Channel assemblage (Corfu and Wallace, 1986; Corfu and Andrews, 1987). Neoarchean volcanic rocks of the ca. 2.75-2.73 Ga Confederation assemblage predominate throughout the northeast and southeast part of the belt. The Balmer-Confederation assemblage contact represents a time gap of some 200 m.y., and extends across the southeast part of the belt from the Chukuni River, through Madsen and the past-producing Starratt-Olsen Mine. The structural, petrological and isotopic character of rocks that straddle this interface, stitched by the 2718±1 Ma Dome Stock, are important in understanding gold mineralization (Madsen, Starratt-Olsen, Hasaga and Howey gold mines) localized along this interface.

Initial results of stratigraphic-structural mapping suggest that the ca. 2.894 Ga Bruce Channel volcano-sedimentary assemblage, spatially associated with gold mineralization near Cochenour and Balmertown, may be much more extensive than previously recognized. Correlative rocks appear to extend from western (Wolf Bay) to northeastern (McCuaig Island) Red Lake, thereby extending units prospective for Au mineralization. Two phases of folding (F_1, F_2), previously recognized in the east (Zhang et al., 1997; Menard et al., 1999), have affected much of the

Red Lake belt and control the present distribution of map units. Pre-D_1 deformation is reflected by an angular unconformity between the Balmer and Confederation assemblage, documented at several localities, whereas the Balmer-Ball contact is tectonic, and the Balmer-Bruce Channel contact disconformable.

The Madsen gold deposit is a disseminated stratabound deposit of replacement style located at the Balmer-Confederation interface. It comprises two main ore horizons, mainly hosted by altered mafic volcaniclastics and by massive and pillowed basalts of the Balmer assemblage, respectively known as the Austin and McVeigh "tuffs". Study of the upper to middle sections of the deposit indicates two alteration facies (Dubé et al., in press): 1) a banded-laminated inner (higher temperature?) core of hornblende-actinolite, biotite, quartz, calcite, +/- K-feldspar, pyrrhotite, pyrite and arsenopyrite alteration assemblages hosting the ore; surrounded by 2) an aluminous and calc-silicate dominated outer alteration zone characterized by andalusite-cordierite, garnet, biotite and amphibole. The association of alteration and mineralization with the Balmer-Confederation unconformity suggests that mineralized fluids were channelized along this permeable horizon. Strain is highly heterogeneous but generally low to moderate, with local cm- to m-scale higher strain zones. Two main generations of structures are present: 1) D_1, characterized by a bedding-parallel (S_0-S_1) north-northeast-trending, southeast-dipping foliation; and 2) main phase D_2, comprising east-northeast-trending, southeast-dipping, S_2 foliation, moderately east-plunging F_2 "S" folds, and local cm-to m-wide sinistral zones of higher strain. The alteration and mineralization are folded and partly transposed by D_2 deformation that consequently controls the geometry of the ore.

The Madsen deposit shares many characteristics with gold deposits formed at lower- to middle-amphibolite facies (500 to 600°C) in greenstone belts elsewhere. However, it is possible that the deposit formed at moderate to shallow depth and was metamorphosed to amphibolite facies during subsequent deformation and contact metamorphism. Alternatively, the alteration assemblages may be the result of two distinct hydrothermal events: an early syn-volcanic (VMS?) large scale aluminous/calc-silicate alteration event, followed by a pre-D_2 gold-mineralizing event.

The volcanogenic massive sulphide (VMS) potential of the Confederation and Balmer assemblages is also being assessed in the Red Lake belt, as are the characteristics of gold mineralization in the western part of the belt (Parker, 1999a,b). The Confederation assemblage (2744-2733 Ma) consists of thick sequences of massive and lobe-hyaloclastite rhyolite flows, interlayered with associated pyroclastic rocks and mafic to andesitic flows. The majority of metavolcanic rocks are interpreted to have formed in subaqueous, proximal, volcanic environments. Almost all of the felsic metavolcanic rocks have the trace element geochemistry of FIIIa and FIIIb metavolcanic rocks which are known to occur in VMS-productive metavolcanic successions throughout the Superior Province (Lesher et al., 1986; Parker, 1998; 1999a). The Type FIII metavolcanic rocks extend from Upper Medicine Stone Lake in the extreme southwest corner of the belt, through Baird and Heyson townships, to Gullrock Lake at the east end of the belt. Several previously unknown sulphidic, exhalative, chert/argillite horizons hosting anomalous zinc and copper mineralization were identified, as well as localized synvolcanic alteration. These observations suggest that the Confederation assemblage in the Red Lake greenstone belt has considerable potential to host volcanogenic massive sulphide deposits.

In the western Red Lake belt, gold mineralization occurs in the Ball assemblage, within polymetallic quartz veins associated with east-striking D_2 structures that are axial planar to regional folds. Most of the gold deposits are hosted within intensely sericitized felsic metavolcanic rocks, iron carbonatized ultramafic flows and intrusive rocks, and intermediate to mafic intrusive rocks. Gold-bearing sulphide zones north of the Mount Jamie gold mine are hosted by pillowed mafic metavolcanic flows that have been affected by synvolcanic alteration consisting of pervasive biotitization overprinted by an aluminous mineral assemblage of disseminated andalusite and garnet porphyroblasts. This alteration style is remarkably similar to that associated with gold mineralization at the Madsen mine in the Balmer assemblage.

Bee Lake-Lake Winnipeg Corridor

Several projects are active in this corridor. In the Bee Lake belt, a coarsening-upward clastic sequence capped by conglomerate with leucogranite boulders appears to represent Timiskaming-type sedimentary rocks. It is bound at its structural base by an early high-strain zone and by a ductile reverse fault at the northern belt margin. To the northwest in the Garner-Gem lakes area of the Rice Lake belt, a project is underway to define the relationship between dominantly komatiitic sequences of Mesoarchean age and supracrustal rocks of the Bidou Lake Subgroup (ca. 2.73 Ga). The Gem Lake Subgroup, originally thought to be younger, has a range of ages from 2.72 to 2.87 Ga (Gem, Garner lakes respectively), and the Conley Formation of the Wallace Lake belt is >2.92 Ga. Structural studies indicate major dislocations and possible bounding faults between the Bidou Lake and Gem Lake subgroups; however, the relationship between volcanic units of similar age in the two subgroups is under current investigation. At Garner Lake, east-trending ductile shear zones may separate felsic volcanic and sedimentary units of the Gem Lake subgroup from a mafic volcanic - sedimentary rock sequence. The north-trending Moore Lake-Beresford Lake deformation zone appears to truncate the east-west structures.

In the Wallace Lake belt, the Conley (>2.92 Ga), Big Island and Siderock Lake formations consist respectively of a platformal sedimentary sequence, mafic volcanic rocks and volcanogenic polymictic conglomerates (Sasseville and Tomlinson, in press). They are separated by layer-parallel D_1 high-strain zones which are folded by northwest and west-trending close and reclined D_2 folds. Dextral shearing and east-northeast-trending folds represent a D_3 event, and D_4 produced S-shaped kink bands within older high-strain zones. Ultramafic volcanic rocks are recognized at three distinct stratigraphic levels within the belt: as lenses within the Conley Formation; in the uppermost Conly, and within the Big Island Formation. Structural repetition is possible, as the Big Island Formation appears to consist of three superposed tectonic slivers.

Reconnaissance-scale investigations were made along the southern margin of the North Caribou terrane to the west (Percival and Whalen, in press). In eastern Lake Winnipeg, supracrustal rocks of the Black Island volcanic (2732 Ma; Krogh et al., 1974) and Hole River sedimentary units have been correlated with units of the Rice Lake belt 65 km to the east (Ermanovics, 1981). Lewis and Storey islands in the east expose magnetic rocks including spinifex-textured komatiite and iron formation, which together with non-magnetic arkosic sandstone, resemble the Conley formation of the Wallace Lake belt. This package and adjacent Black Island sequence carry an early north-trending high-strain S_1 foliation that is isoclinally folded about moderately west-northwest-plunging F_2 hinges, subsequently crenulated by west-southwest-striking F_3 folds and axial planar foliation. The structural sequence and trends correspond closely to those of the Rice Lake belt (Poulsen et al., 1996). The low-grade supracrustal rocks are bound to the east by the broad, north-trending East Shore shear zone that consists of amphibolite-facies mylonite with gently southeast-plunging lineation and dextral kinematic sense. These tonalitic to quartz dioritic rocks contain zircons in excess of 2.9 Ga (Krogh et al., 1974), suggesting that the rotolith constitutes part of the North Caribou terrane. Because it lacks the east-west D_3 crenular overprint, latest movement on the ductile shear zone (D_4) is inferred to post-date the Hole River sediments. To the south across the dextral, greenschist-facies cataclastic Wanipigow fault zone (D_5) are 3.0 Ga tonalites (Krogh et al., 1974).

Parts of the North Caribou terrane are also present in the English Lake magmatic complex to the east (Weber, 1991). This body consists mainly of tonalite (3003 Ma; Turek and Weber, 1994) and granodiorite in the east, and grades to layered diorite, gabbro, hornblendite and pyroxenite toward the west, as the degree of metamorphism and migmatization increases. It is bound to the east by the north-northeast-trending English Lake shear zone, a 1-km-wide, west-dipping ductile shear with down-dip stretching lineation and west-side down (normal) movement sense. This area is interpreted to expose a cross-section to mid-crustal depths through an evolved plutonic arc, exhumed along an extensional detachment. Northeast of Wanipigow Lake to the east, the Little Beaver belt (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 pre-2.8 Ga history. It is cut by the weakly foliated Clinton-Poundmaker quartz-porphyritic biotite tonalite on the west and by late biotite and muscovite leucogranites on the east. The tonalite contains large xenoliths of sheared tonalite and quartz-vein-riddled mafic schist with sinistral shear sense indicators, possibly preserved samples of an early phase of movement on the Wanipigow fault. 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. The East Shore shear zone could align with the Garner Lake shear, and the D_1 high-strain zone in Lake Winnipeg, with the Beresford Lake shear (Poulsen et al., 1996).

WABIGOON SUBPROVINCE

Located between the Sturgeon-Savant belt on the west and Onaman-Tashota belt on the east, the Obonga Lake greenstone belt hosts a variety of recently dated (K.Y. Tomlinson and D.W. Davis, unpublished) volcanic, sedimentary and intrusive units, which provide potential linkages with adjacent belts (Percival and Stott, in press). Previous structural models of the belt as a synform are no longer sustainable in light of age differences between northern and southern structural panels. The northward-younging southern panel comprises volcanic and gabbroic rocks of 2733-2727 Ma age, and is similar to the south Sturgeon assemblage and Onaman-Metcalfe block. In contrast, the southward-younging northern panel contains sedimentary and volcanic rocks with ages of <2724 and 2703 Ma respectively, and could be equivalent to the central Sturgeon assemblage and Savant sedimentary group. Structurally beneath the northern panel is the dismembered Awkward Lake greywacke-argillite unit of unknown age and tectonic significance. Northern components of the belt, including the Puddy Lake serpentinite, are separated by east-striking dextral shear zones.

In the Brightsand Forest area, the eastern extension of the Sturgeon Lake belt is exposed as panels of supracrustal rock separated by granitoid sheets (Rogers, 1964). Stratigraphic correlations made on the basis of comparative trace-element geochemical profiles (cf. Sanborn-Barrie and Skulski, 1999; Brown and Percival, 1999) suggest extensions of Jutten, central Sturgeon and Beckington sequences into the area. Associated with Jutten-type amphibolites is a thin quartz-rich metasedimentary unit, a kilometre-thick felsic metavolcanic section, and a thin conglomeratic unit of unknown age or affinity (Brown et al., in press). Five kilometres across strike to the north, the Robert Lake amphibolite of unknown geochemical affinity is associated with greywacke, pelite, silicate facies iron formation and sulphidic pods localized along amphibolite-sedimentary rock contacts. Further north, the Stinson Lake amphibolite contains characteristic pyroxenite layers and pods. All units, including intervening tonalite and granodiorite sheets, are metamorphosed to the amphibolite facies and carry a penetrative S_3 (Percival et al., 1999) foliation, folded about east-southeast-trending F_4 folds. A 3-km-long pod of tonalitic gneiss occupying the core of an open, gently-plunging F_4 synform displays complex fold interference patterns involving early (S_1, F_2) generations of structures. The folded S_3 layering and foliation correlate with seismic reflections at depths of 5-10 km on LITHOPROBE line 1d. An open, steeply south-plunging fold of S_3 foliation dominates the map pattern in the Mountairy Lake area (Rogers, 1964). Its sheared eastern limb is a cataclastic zone, which along with parasitic folds, is crenulated by east-west folds and foliation consistent with D_4 structures regionally. The map-scale fold may have formed late during D_3 deformation.

Between the Sturgeon-Obonga corridor and Garden Lake belt to the south is a region dominated by granitoid rocks (Sage et al., 1973). Road-based reconnaissance during 1999 revealed continuity of major homogeneous, foliated tonalite and granodiorite bodies recognized to the north (Percival et al., 1999). These units are generally characterized by a single penetrative east-trending foliation, and locally by an older, north-trending fabric and easterly crenulation. Several mafic plutons (Sage et al., 1973) have similar structural character. North of the Empire Lake gabbro is a ca. 10 km-wide anorthositic body consisting mainly of foliated gabbroic anorthosite and minor gabbro hosting minor chalcopyrite occurrences. Enclaves of tonalitic gneiss carrying an early layering in addition to one or two sets of folds, occur sporadically through the northern part of the area. Although pegmatite and small bodies of leucogranite are ubiquitous, larger bodies are present in the south. They are generally massive and inferred to postdate penetrative regional deformation, however east- and southeast-striking ductile shear zones with dextral shear sense were observed in a few locations. The western limit of the central Wabigoon region, with its characteristic lithological heterogeneity, including tonalitic gneisses, may be marked by a prominent zone of north-striking, gently east-dipping foliation south of Shikag Lake (Rogers, 1964). Northerly foliation and gneissosity in the ca. 5 km-wide zone is crenulated by east-trending fold hinges. To the west, plutonic rocks take the form of large bodies of homogeneous tonalite and trondhjemite (Sage et al., 1973) characteristic of the western Wabigoon subprovince.

The Garden Lake greenstone belt, with a single age of 2709 Ma (Tomlinson et al., 1998), extends across the central Wabigoon subprovince, and may contain units of both Mesoarchean and Neoarchean age. Mapping at 1:20 000 (Hart, in press) indicates a generally east-west striking, south facing sequence dominated by pillowed mafic flows and tuffs, with subordinate intermediate tuffs, felsic volcaniclastic rocks and metasediments. Felsic units are most prominent on the northern and southern margins of the belt. An approximately 100-m-thick sequence of lapilli tuff and iron formation extends across the north-central length of the belt. Metasedimentary rocks include interflow oxide-facies iron formation and a sequence of conglomerate, with minor finer clastic and chemical sediments, located in the centre of the belt. The conglomerates contain mainly metavolcanic clasts, with variable amounts of well rounded granitic, chert, quartz, and rare sulphide clasts. Three late gabbro intrusions are distinguished by their lack of deformation and lower greenschist-facies metamorphism. Plutons of foliated to gneissic monzogranite and granodiorite bound the belt to the north and south and occur as plugs and dykes within the belt.

A northwest-trending deformation zone characterized by carbonatized rocks and minor gold occurrences passes through Garden Lake oblique to the strike. Lenses of massive pyrite and pyrrhotite associated with iron formation occur in mafic rocks north of Garden Lake.

The Entwine Lake and Bonheur areas (Stone and Halle, 1999) represent part of the south central Wabigoon Subprovince. The Entwine Lake area is underlain by complexly interleaved units of biotite tonalite, tonalite gneiss and thin greenstone slivers. These are intruded by oval to lobate bodies of hornblende granite and biotite granite and the Entwine stock, which varies compositionally from diorite/gabbro through monzodiorite to monzonite. Greenschist-altered diorite/gabbro contains up to 10% combined magnetite, pyrite and chalcopyrite with up to 0.95 g/t combined Au, Pt and Pd in sporadic mineral showings over a distance of 8 km in the western part of the stock. Massive biotite granite is extensive in the northern Bonheur area and gives way southward to foliated biotite tonalite, tonalite gneiss and greenstone slivers. The Marmion fault extends more than 80 km north-northeast from Atikokan through the Bonheur area and represents a major structure internal to the central Wabigoon Subprovince. Greenstone slivers in the Entwine Lake and Bonheur areas appear to be distal extensions of the post-2.75 Ga Kakagi Lake-Savant Lake greenstone belt. Based on crosscutting relationships, biotite tonalite locally postdates Neoarchean greenstone remnants, but elsewhere appears continuous with Mesoarchean tonalite and tonalite gneiss north of Atikokan. These observations probably indicate that there are multiple generations of tonalite and/or that mapped units of biotite tonalite, tonalite gneiss and greenstone slivers may contain unrecognised intrusive contacts and tectonic breaks or unconformities. Quartz-deficient intrusions of the sanukitoid suite including the Entwine stock comprise about 5% of the central Wabigoon Subprovince and are recommended as exploration targets for platinum-group-element mineralization.

In the eastern Wabigoon Subprovince, the northern margin of the Onaman-Tashota greenstone belt is marked by the Marshall assemblage, a large, caldera-like sequence of ca. 2739 Ma dacite (Stott and Straub, 1999). This obliquely-exposed section comprises tuff and minor lapilli tuff, overlain by interlayered massive to autobrecciated flows, tuff and a marker unit of iron formation and clastic sediment. The assemblage faces stratigraphically eastwards and is intruded by the trondhjemitic Summit Lake pluton of inferred synvolcanic age. The tuffaceous base of the Marshall assemblage is very thickly bedded and contains synvolcanic alteration zones including quartz-sericite, andalusite-quartz, and albite types that accompany volcanic-hosted massive sulphide deposits, explored since the 1950's. Kyanite occurs locally in the andalusite alteration zones. Alteration appears to be stratabound in some sections and was observed higher in the stratigraphic section (i.e., further east) than previously reported by exploration companies. Synvolcanic faults, notably one along Gripp River at Marshall Lake, are identified from indirect evidence, including a decrease in alteration intensity away from the faults, concentration of alteration on one side of a fault, and the presence of mafic dykes and massive dacite within the Gripp River fault zone. The stratigraphic framework of this assemblage appears to be a simple, east-facing volcanic pile, centred on the Summit Lake pluton. All rock units, with the exception of a late-tectonic gabbro intrusion on the north shore of Marshall Lake, have been tectonically deformed. The tectonic history involved: 1) D_1 flattening foliation parallel to bedding, likely a consequence of lithostatic loading; 2) D_2 deformation, characterized by east-striking, steeply south-dipping foliation and a shallow to moderate, east-plunging mineral and crenular lineation superimposed on the S_0-S_1 foliation. Narrow shear zones, parallel to S_2 are generally dextral. D_2 structures can be traced into the English River metasedimentary terrain north of the belt and are attributed to transpressive deformation that was focused along the Wabigoon-English River boundary during a distal collisional event to the south; 3) D_3 late tectonic, northwest-trending transcurrent faults and high strain zones.

SACHIGO SUBPROVINCE

In the far northern Superior Province of Manitoba and Ontario, Neoarchean shear zones isolate pre-3.3 Ga crust that once belonged to a larger, Northern Superior superterrane (NSS). In the Pikwitonei granulite domain and Split Lake block, recycled fragments of NSS orthogneiss are reported to contain 3.6 Ga inherited zircons and have 3.4-3.1 Ga Nd model ages (Skulski et al., 1999). In northern Ontario, 2.81 Ga NSS orthogneisses have 3.2-3.6 Nd model ages and contain 3.57-3.2 Ga inherited zircon cores (Skulski et al., 1999). The NSS was accreted to the northern margin of the 3.0-2.7 Ga Uchi-Sachigo-Goudalie superterrane (USG; Stott, 1997). Published tracer isotopic (Nd, Hf) and zircon U/Pb data show that prior to 2.71 Ga the northern USG was isolated from >3.3 Ga felsic crust. Accretion of diverse oceanic terranes to the northern USG margin preceded NSS collision. At Cross Lake, 2.76 Ga ocean floor basalts and gabbro were thrust onto the margin and intruded by ca. 2.75 Ga granite (Corkery et al., 1992; Parmenter et al., GS-19 this volume). At Knee Lake, faults that separate USG continental margin sequences from 2.83 Ga oceanic arc rocks and undated ocean floor basalts, pre-date early folding (<2.82 > ca. 2.73 Ga; Syme et al., 1999). Accretion of oceanic terranes was accompanied by 2.78-2.75 Ga arc magmatism on the USG margin. Post-accretionary, continental-derived sediments and banded iron formation were deposited between 2.76-2.73 Ga at Cross Lake and 2.82-2.73 Ga at Knee Lake. Renewed arc activity between 2.74-2.72 Ga terminated with USG-NSS collision and resulting deformation, uplift, and deposition of <2.71 Ga synorogenic continental sediments in the south, and 2.71-2.69 Ga synorogenic magmatism and accompanying high grade metamorphism in the north.

Examination of the North Kenyon, South Kenyon and Stull-Wunnummin faults in the Sherman-Withers lakes area reveals broad, steep mylonite zones with dominant subhorizontal lineations (Stone et al., 1999). They separate the narrow Ellard and Yelling lake greenstone belts, as well as plutonic domains comprising six suites: 1) tonalite gneiss; 2) biotite tonalite; 3) two-mica granite; 4) hornblende tonalite to granite; 5) biotite granite; and 6) clinopyroxene monzodiorite to granite. The Yelling Lake belt consists of mafic flows, argillaceous sediments and iron formation, whereas the synclinal Ellard Lake belt has marginal mafic flows and a central felsic-intermediate unit (2732 Ma). The mapping supports the interpretation of Skulski et al. (1999) that the faults mark boundaries of major crustal blocks possibly representative of accreted terranes such as are postulated for parts of the southern Superior Province.

The largest contiguous greenstone belt in the Sachigo Subprovince, the Knee Lake Belt, is being explored through stratigraphic, geochemical, structural and geochronological studies (Corkery et al., GS-18 this volume). Results of 1999 mapping in the Gods Lake Narrows area include: 1) identification of a regional angular unconformity between the ca. 2.84 Ga Hayes River Group metavolcanic rocks and the Oxford Lake sedimentary subgroup (ca. 2.73 Ga); 2) documentation of a D_1 shear zone at the boundary between the sedimentary and volcanic subgroups of the Oxford Lake Group; 3) observation that the D_1 shear zone is folded as a result deformation associated with a southern belt-bounding D_2 shear zone; and 4) documentation that the thin Munro Lake greenstone belt is separated from the Knee Lake Belt by both an older gneiss belt and the major Gods Lake Narrows shear zone.

DISCUSSION

Growing evidence suggests that pre-3.0 Ga continental crust was present throughout the ca. 300 m.y. magmatic history of the western Uchi Subprovince, although ancient vestiges have not been recognized. Some observations suggest that an early (pre-2.75 Ga) deformation event affected parts of the western Uchi belt, including an angular unconformity beneath the Confederation assemblage in the Red Lake belt, and structures predating Neoarchean magmatism in the English Lake magmatic complex. Whether this event relates to pre-2.87 Ga deformation in the northern North Caribou terrane (Thurston et al., 1991) remains unresolved.

Neoarchean D_1 deformation is evident as localized high-strain zones in the Bee Lake- Rice Lake- Wallace Lake- Black Island belts. Where constrained, these zones juxtapose sequences as old as Mesoarchean with sedimentary rocks as young as <2704 Ma. Because such structures are not recognized to the east in the Uchi Subprovince, the shear zones could root in the English River subprovince to the south. Further east, the oldest structures trend north-northwest and are overprinted by east-west-trending D_3 structures.

Similar features characterize the central Wabigoon subprovince, where Nd isotopes and zircon geochronology suggest involvement of pre-3.0 Ga crust in Neoarchean magmatism. A further similarity exists in the structural history, in which the oldest Neoarchean structures (D_1) postdate <2704 Ma sediments, and D_2 structures have easterly trends. However, the central Wabigoon Subprovince remained magmatically and tectonically active at least until ca. 2.68 Ga.

In the northern Sachigo Subprovince, the presence of ancient crust is evident in inherited zircons and low eNd values in Neoarchean plutons. Adjacent greenstone belts with juvenile isotopic characteristics may have been juxtaposed along accretionary boundaries, however present contacts are late shear zones.

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