DESCRIPTIVE NOTES

INTRODUCTION

This 1:250 000 compilation map is one of a series assembled as part of the Western Superior NATMAP project (Figure 1). It synthesizes new mapping, geochronological and geochemical information acquired during the course of the project with existing reconnaissance and detailed sources (*see* Figure 3). On the map face, an alphanumeric code is used to identify units and provide information on their age, assemblage name, and tectonic affinity. Colour is used on the map face to group rock units into eight basic subdivisions and to identify broad age groupings (*see* Figure 4). Generally, darker colours represent older rock units. Ages are based on U-Pb zircon dates at spot localities, extrapolated through lithological, geochemical or geophysical means. Supracrustal assemblages (*see* Figure 2) are defined principally by their rock types, depositional ages, and geochemical and geophysical characteristics, following the approach outlined in Geology of Ontario (Williams et al., 1992; OGS, 1992 a,b). Plutonic suites are the equivalent of supracrustal assemblages in this hierarchy, with designations based on mineralogy (e.g. biotite, hornblende, muscovite-bearing suites), composition (e.g. sanukitoid suite), or structure (e.g. gneissic suite)(Stone, 1998). The tectonic affinity of a supracrustal assemblage or plutonic rock suite (*see* tectonic affinity criteria listed in the legend key) may be assigned on the basis of its lithological character, stratigraphic context, whole-rock geochemical classification, and isotopic (Sm-Nd, U-Pb) signature, and is summarized in Figure 2.

Locations of samples used for magmatic or detrital U-Pb zircon dating and for Nd isotopic analysis are shown on the map face and listed in Tables 1 and 2, respectively. This map incorporates interpretation of the magmatic and depositional ages of many different rock types. Consequently, the ages assigned to large areas of the map have been inferred from along-strike lithological correlation, similarity to dated plutons, or crosscutting relationships between various rock types. Where there is a high level of confidence about the age, a small age range has been assigned to the rock unit, whereas with greater uncertainty, the assigned age range is broader. As well as indicating the confidence level, the width of the age range also serves to identify units and areas where the state of knowledge is less robust. A geochronological summary illustrating the age of major depositional, intrusive, and deformational events in the map sheet is shown in Table 3.

THE WESTERN WABIGOON SUBPROVINCE

The long-lived (ca. 2.92–2.70 Ga) western Wabigoon Subprovince of the Superior Province is an ideal setting in which to study Archean crustal evolution. It preserves vestiges of Mesoarchean cover sequences, and comprises voluminous ca. 2.74–2.72 Ga submarine volcano-sedimentary sequences, ca. 2.715–2.70 Ga clastic sediment-dominated cover, and widespread plutonic rocks of ca. 2.7 Ga age. It is situated south of a coherent ca. 3.6–3.0 Ga plutonic terrane, the Winnipeg River Subprovince, vestiges of which can be detected isotopically along its eastern margin (Central granitoid complex). Early quartzite sequences within the Wabigoon Subprovince indicate that its Mesoarchean strata were likely built unconformably on Winnipeg River continental basement. In contrast, its Neoarchean volcanic rocks, which are host to volcanogenic massive sulphide deposits (i.e. the Sturgeon Lake camp), are largely isotopically juvenile and interpreted to have formed in an oceanic to transitional arc setting. A sequence of late- to post-volcanic clastic rocks (Warclub assemblage) is interpreted to demarcate the basin across which oceanic rocks of the western Wabigoon Subprovince were joined with ancient continental rocks of the Winnipeg River terrane. Late-stage clastic deposition in a proximal braided river environment is represented by crossbedded conglomerate and arenite of the Ament Bay assemblage.

PALEO- AND MESOARCHEAN SUPRACRUSTAL ASSEMBLAGES

Kashaweogama Lake assemblage ca. 3285 Ma

The oldest supracrustal rocks presently identified in the map area are on the north shore of central Kashaweogama Lake (U-Pb # 1 on map face; K in Fig. 2), where intermediate and quartz-phyric felsic rocks are infolded with mafic rocks. These rocks are believed to represent ancient volcanic substrate of the Winnipeg River terrane exposed in the core of a F_1 anticline, however, they were previously interpreted as a subvolcanic porphyry (Breaks et al., 1979).

Vanessa Lake assemblage ca. 2927 Ma

Mesoarchean supracrustal rocks form an approximate 200 m wide by >20 km long panel that corresponds to the eastern margin of the Sturgeon Lake greenstone belt. The Vanessa Lake assemblage, supracrustal substrate to the more voluminous Jutten assemblage (described below), includes a 3 m wide lens of tectonized dacite pyroclastic tuff, dated at 2925 $\pm$ 2 Ma (U-Pb # 24; Table 1), in contact with garnet amphibolite to the east.

Northeast Arm assemblage ca. 2880 Ma

On northeast Savant Lake, supracrustal substrate to the Jutten assemblage is represented by an approximate 100 m thick sequence (denoted N on map face and Fig. 2) of ultramafic schist, rhyodacitic lapilli tuff, and fuchsitic siltstone $\pm$ chert, capped by ultramafic-derived siltstone/ash. A maximum age of the rhyodacite tuff is 2881 $\pm$ 2 Ma (U-Pb # 8; Table 1).

Jutten assemblage ca. 2775–2880 Ma

Unconformably overlying the Vanessa Lake and Northeast Arm assemblages, the basalt-dominated Jutten assemblage is extensively exposed in the Savant Lake area, extends southward along the eastern margin of the Sturgeon Lake belt, and is interpreted to include the northern volcanic (Botham Bay) sequence in the Sioux Lookout region. Basal to the assemblage in northeastern Savant Lake is polymictic conglomerate that contains clasts of the Northeast Arm assemblage, some of which are previously deformed. Transitional with this basal conglomerate are fuchsitic, quartz-rich clastic rocks, recognized also in the Sturgeon and Sioux Lookout regions, from which detrital zircon studies (eg., U-Pb # 7, 25, Table 1 and unpublished data) indicate Paleo- to Mesoarchean-age (3.6 to 2.91 Ga) sources for the clastic sequence, and a maximum depositional age of ca. 2912 Ma. Overlying basaltic rocks are typically fine-grained, pillowed to massive flows that lack varioles or amygdules. They are tholeiitic in composition and show modest enrichment in Fe and low TiO_2 contents (<1.1 wt.%). Most show flat to slightly light rare earth element (LREE)-depleted primitive mantle-normalized profiles, with enrichment in Th and La relative to Nb. This is qualitatively consistent with crustal contamination by chemically-evolved sialic crust. Others show depletion in primitive-mantle-normalized LREE, Th and Nb, and appear to represent depleted mantle-derived magmas. Neodymium isotopic data on Jutten basalt yield Nd values of 1.9 to $+2.3$ (Sm-Nd #73–78, Table 2). The flows are interpreted to conformably (or disconformably) overlie the quartz-rich clastic rocks, described above, since pillowed flows face away from same-facing clastic units; fault zones are not recognized at the contact; and gabbroic dykes interpreted to be feeder dykes to the basaltic flows cut underlying clastic rocks at several localities. Minor components of the Jutten assemblage include oxide-facies ironstone with chert jasper and, north of Kashaweogama Lake, strongly foliated and schistose ultramafic rocks.

Paleo- and Mesoarchean supracrustal rocks of the Kashaweogama Lake, Vanessa Lake, Northeast Arm and Jutten assemblages in the Savant, Sturgeon, and Sioux Lookout regions are separated from largely juvenile Neoarchean volcanic assemblages (described below) by late- to post-volcanic (<2703 Ma) clastic rocks of the Warclub assemblage.

NEOARCHEAN SUPRACRUSTAL ASSEMBLAGES

Fourbay Lake assemblage ca. 2775 Ma

Volcanic rocks of the Fourbay Lake assemblage form an arcuate, 1–2 km thick exposure about the southeast margin of the Lewis Lake batholith. They consist mainly of moderately to strongly foliated and gneissic, massive to pillowed tholeiitic basalt with low-K (0.13–0.38 K_2O%) and low Ti (0.63–1.38 TiO_2%) contents. The basaltic rocks have flat to LREE-depleted rare earth element (REE) profiles, and show an up-section increase in primative mantle-normalized Th/Nb from <1 to >1. Associated calc-alkaline quartz-phyric felsic tuff, 1 to 30 m thick, are dated at 2775 Ma (U-Pb # 21, 22: Table 1). Fourbay Lake basalt and associated dacite lapilli tuff have typical ε_{Nd} values of $+2.0$ (Sm-Nd # 81–84: Table 2) interpreted to reflect primitive island arc, or oceanic plateau, crust. The Fourbay Lake assemblage is cut by numerous gabbroic intrusions, and by tonalitic to granodioritic rocks of the Lewis Lake batholith.

Handy Lake assemblage ca. 2745 Ma

The Handy Lake assemblage conformably overlies the 2775 Ma Fourbay Lake assemblage in the Sturgeon Lake area and extends in an arcuate fashion throughout the Savant Lake area where it is cut by the Lewis Lake batholith. The northeastern Sioux Lookout belt may comprise correlative rocks that have been sinistrally displaced along the ca. 2690 Ma Miniss River fault (Fig. 2). The lower part of the Handy Lake assemblage consists of aphyric, non-vesicular, pillowed and massive, magnesian and Fe-rich tholeiitic basaltic rocks (Beggs, 1975) with flat to LREE-depleted mantle-normalized trace element profiles with depletion of Th- and Nb relative to other LREE. The middle part consists of a geochemically distinct sequence of tholeiitic and calc-alkaline basalt that is transitional with the lower unit and which has flat to LREE-enriched trace element profiles, marked by depletion in Nb relative to Th and La, and in Ti relative to the middle REE. Auriferous sulphidic-pyrrhotitic cherty horizons mark the contact between lower and middle Handy Lake rocks. The upper Handy Lake assemblage comprises calc-alkaline intermediate to felsic pyroclastic rocks with minor intercalated rhyolite and tholeiitic basalt flows. U-Pb zircon ages (U-Pb # 17,20,23: Table 1) allow correlation of the upper part of this assemblage in the Sturgeon and Savant areas. Intermediate to felsic rocks of the Handy Lake assemblage are enriched in LREE relative to heavy rare earth elements (HREE; normalized La/Yb 8–34) and in Th > La > > Nb. In contrast, thin tholeiitic basaltic units within the upper felsic sequence have flat to slightly LREE-enriched mantle-normalized profiles with depletion in Th relative to Nb.

The Handy Lake assemblage is cut by quartz-feldspar porphyritic intrusions, and by dykes and sills of plagioclase-porphyritic diorite and gabbro, melanocratic gabbro and tonalite.

South Sturgeon assemblage ca. 2735 Ma

Volcanic rocks that host Zn-Cu-Pb-Ag volcanogenic massive sulphide (VMS) deposits of the Sturgeon Lake belt constitute the poorly exposed ca. 2735 Ma South Sturgeon assemblage. This assemblage consists of a 9 km thick bimodal sequence of basalt-rhyolite which has been interpreted as a caldera complex (Morton et al., 1991). Pre-caldera strata include massive to pillowed basalt, scoria-tuff cone deposits, and debris flows with minor interstratified rhyolite. These rocks are overlain by a 4.5 km thick caldera-fill succession that was dated at 2735 Ma at several localities (U-Pb # 38–42, 44, 45: Table 1) thereby constraining the time of VMS formation. The mineralized caldera succession consists of numerous rhyolitic ash-flow units, dacitic domes, and andesitic flows, capped by epiclastic rocks. It contains at least five Cu-Zn VMS deposits: the Mattabi and F-Zone deposits are hosted near the middle of the felsic unit, whereas the Lyon Lake Zone, Creek Zone and Sturgeon Lake Mine deposits occur at, or near, its top (see Parker, in prep.).

In the Sioux Lookout area, the South Sturgeon assemblage is represented by 2733 Ma dacite tuff (U-Pb # 50: Table 1). In the Savant Lake area, ca. 2733 Ma porphyries (eg., U-Pb # 14: Table 1) are proximal to extensively hydrothermally altered volcanic rocks of the Handy Lake assemblage, highlighting the potential for VMS-prospective South Sturgeon strata in the central Savant Lake belt. Extensive plutonism at ca. 2735 Ma is recorded by voluminous tonalitic rocks of the Lewis Lake and Beidelman Bay intrusions, and the Pike Lake mafic intrusion (described below).

Quest Lake assemblage ca. 2718–2735 Ma

The Quest Lake metasedimentary assemblage in the southeastern map area consists of well-bedded, well-graded feldspathic wacke, and interbedded lithic wacke with minor siliceous siltstone, argillite and pebble conglomerate. Oxide facies (magnetite) ironstone southeast of Quest Lake (unit Uus6md) may be part of this assemblage, or part of a younger clastic succession. Feldspathic wacke from central Quest Lake yielded detrital zircons that show a range of ages from ca. 3275 to ca. 2720 Ma (U-Pb # 27; Table 1), indicating mixed provenance for these clastic rocks. A minimum depositional age for the sequence is 2718 $\pm$ 1 Ma, the age of a crosscutting, foliated porphyritic dyke (U-Pb # 28: Table 1). Rare metre wide dykes and sills of andesitic composition cut Quest Lake clastic rocks, and are likely feeders to the overlying Central Sturgeon assemblage (described below).

A horizon of graphitic shale, massive pyrrhotite-pyrite and siltstone extending southeast from Lyon Lake may be part of the Quest Lake assemblage and represent detritus accumulated during an interval of magmatic quiescence between 2735 Ma South Sturgeon and ca. 2720 Ma Central Sturgeon volcanism.

Central Sturgeon assemblage ca. 2720 Ma

The Central Sturgeon assemblage is a mixed tholeiitic and calc-alkaline sequence that extends across the southern map area (Figure 3). This assemblage apparently overlies the 2745 Ma Handy Lake assemblage on the north shore of Sturgeon Lake, and overlies 2735 Ma South Sturgeon volcanic rocks on the south shore of Sturgeon Lake and in the Sioux Lookout area. Its lower part comprises pillowed to massive basalt and andesite flows, pillow breccia, flow breccia and hyaloclastite. These are tholeiitic, high Ti (0.58–2.47% TiO_2) rocks with locally with up to 11.9% MgO. They are cut by gabbro and serpentinized peridotite, the latter possibly cogenetic with the high MgO basalts. The lower Central Sturgeon assemblage is characterized by LREE-enrichment with depletion of Th relative to Nb, similar to ocean island basalts. Overlying this are low Ti (0.2–1.4% TiO_2) calc-alkaline basalt and andesite and related felsic pyroclastic rocks, cut by associated hypabyssal intrusive rocks. U/Pb ages for the upper Central Sturgeon assemblage include ca. 2718 Ma for rhyolitic tuff (U-Pb # 43: Table 1), ca. 2720 Ma for a subvolcanic Cu-Mo porphyry (U-Pb # 46: Table 1), and 2718 $\pm$ 1 Ma for a porphyritic dyke (U-Pb # 28: Table 1) that cuts the Quest Lake assemblage, thereby providing a minimum age for sedimentation.

Warclub assemblage > ca. 2698 Ma < 2704 Ma

Late to post-volcanic clastic rocks of the Warclub assemblage (Blackburn et al., 1991) separate Paleo- and Mesoarchean strata from Neoarchean volcano-sedimentary rocks, and demarcate the basin between a Mesoarchean continental margin sequence and a juvenile oceanic to transitional arc setting (Sanborn-Barrie and Skulski, 1999). This clastic succession comprises lower polymictic conglomerate (Narrows formation, Savant Lake; Patara formation, Sioux Lookout) that marks a fundamental, belt-scale angular unconformity that extends from Sioux Lookout, through Savant Lake to northeastern Sturgeon Lake. Clasts within the conglomerate vary along its strike and generally reflect the composition of immediately underlying strata. A maximum age of ca. 2704 Ma is derived from the Savant Lake (U-Pb # 2: Table 1) and Sioux Lookout areas (OGS, 1992c).

Polymictic conglomerate grades transitionally into finer-grained turbiditic facies (West Shore formation, Savant Lake; Minnitaki and Abram groups, Sioux Lookout) consisting of feldspathic wacke and lithic wacke with interbeds of thinly bedded to thickly laminated magnetite-chert ironstone. The well-bedded, well-graded character of feldspathic wacke which regularly alternates with silt-size lithic wacke, and the prevalence of delicately laminated magnetite-chert ironstone, are interpreted to reflect turbiditic deposition in deep-water conditions, with intermittent quiescence and precipitation from iron- and silica-rich waters. Detrital zircon ages from feldspathic wacke (eg., U-Pb # 10,12,16,53: Table 1) show a range: the youngest dated zircons are 2703 Ma, with apparent age clusters at ca. 3060 Ma, ca. 2950–2920 Ma and ca. 2790–2770 Ma (Davis, 1996). This data indicates that variable-age source materials contributed to this clastic sequence which was deposited after 2703 Ma, the youngest detrital zircon analysed. West of this map sheet, turbiditic metasedimentary rocks of the Warclub assemblage are interpreted to be interstratified at their base with ca. 2712–2709 Ma rhyolitic tuff indicating that deposition of the Warclub assemblage was diachronous and began in the west as early as 2716 Ma (Davis, 1996). The accumulation of ca. 3.0–2.7 Ga detritus from 2716 to 2700 Ma is interpreted to reflect orogenic activity to the north (i.e. southern Uchi Subprovince) in advance of orogenic activity (D_1, D_2) which subsequently affected all supracrustal elements of this greenstone belt (discussed below).

Compositionally diverse volcanic rocks (Whimbrel Lake formation, Savant Lake; Daredevil formation, Sioux Lookout) represent a minor component of this group. These consist mainly of pyroclastic deposits, although intermediate to mafic porphyritic and amygdaloidal flows and associated fragmental rocks are exposed on Whimbrel Lake. Dacite tuff and lapilli tuff interbedded with clastic and chemical metasedimentary rocks on Savant Lake have ages of ca. 2701–2704 Ma (U-Pb # 6,11,15; Table 1) while those interstratified with the Minnitaki group have an age of 2704 $\pm$ 3 Ma (OGS, 1992c). Gabbroic and feldspar porphyritic sills that cut the Warclub assemblage are likely hypabyssal phases of the Whimbrel Lake and Daredevil formations.

Ament Bay assemblage < ca. 2698 Ma

Conglomeratic rocks and associated crossbedded arkosic wacke unconformably overlie the Central Sturgeon assemblage on Sturgeon Lake and unconformably overlie the Warclub assemblage (Patara formation) near Sioux Lookout. On south Sturgeon Lake, poorly stratified, clast-supported conglomerate dominated by basaltic and gabbroic clasts, grades upwards into increasingly polymictic conglomerate containing fine-grained intermediate to felsic volcanic, chert, sulphide, and metasedimentary clasts. Associated arenite, exposed on Sturgeons Narrows and Post Lake, are white-weathering rocks with crossbeds with foresets up to 1 m wide, and containing basal pebbly layers (Sanborn-Barrie et al., 1998). Crossbedded wacke from Post Lake (U-Pb # 29: Table 1) contains a restricted range of detrital zircon with ages between 2742 and 2716 $\pm$ 14 Ma (n = 16, GSC SHRIMP II) suggesting locally derived provenance. Mafic volcanic- and gabbro-derived conglomerate in the Princess Lake area (Sanborn-Barrie et al., 1998) is texturally and compositionally similar to that on south Sturgeon Lake and is interpreted to be correlative. In a similar setting, conglomerate, white-weathering arenitic sandstone and minor banded iron-formation in eastern Minnitaki Lake unconformably overlies ca. 2713 Ma quartz feldspar porphyry of the Central Sturgeon assemblage located along strike to the east.

The type locality of the Ament Bay assemblage is located south of Sioux Lookout where conglomerate with cross-bedded sandstone interbeds and scour-based sandstone lenses unconformably overlies the ca. 2703 Ma Warclub assemblage. A massive granodiorite clast from the Ament Bay assemblage (U-Pb # 51; Table 1) has an age of 2698 $\pm$ 4 Ma (Davis et al., 1988), providing a maximum age of deposition of the Ament Bay molasse assemblage in a proximal braided river environment (Devaney, 2000).

UNCONFORMABLE CONTACTS

Three unconformities are recognized in the stratigraphic record of this area. The oldest is represented by the Jutten sedimentary sequence which marks a period of erosion and deposition between Mesoarchean magmatism (tonalite gneiss and supracrustal substrate) and deposition of undated submarine tholeiites of the Jutten Group. Polymictic conglomerate of the basal Warclub assemblage (Savant Narrows and Patara formations) demarcates a regionally extensive unconformity that separates the Jutten assemblage, interpreted as part of a Mesoarchean continental margin sequence, from Neoarchean volcanic rocks, interpreted to represent an oceanic to transitional arc complex. Lastly, conglomerate and crossbedded arkosic wacke of the Ament Bay assemblage unconformably overlie the Central Sturgeon and Warclub assemblages and are interpreted to represent proximally derived detritus deposited in a braided fluvial system incised into this tectonically uplifted terrane.

PLUTONIC ROCKS OF THE WESTERN WABIGOON SUBPROVINCE

Central to the map area, the 1500 km^2 Lewis Lake batholith is intrusive into Neoarchean volcanic rocks of the Savant–Sturgeon greenstone belt except on its western side, where it is in fault contact (Miniss River fault zone) with ca. 3046 Ma tonalite and tonalitic gneiss of the Winnipeg River Subprovince. New isotopic data from multiple phases of this batholith indicate it was emplaced at ca. 2735 Ma (U-Pb #18,55: Table 1; Sm-Nd #104–111; 114–116: Table 2), essentially contemporaneous with the VMS-related South Sturgeon caldera complex. The batholith consists of foliated hornblende-biotite tonalite with biotite leucotonalite to granodiorite and hornblende-biotite quartz diorite phases. Pillowed and disaggregated diorite to quartz diorite dykes/sheets and tonalite gneiss rafts occur within the main tonalite phase. On its eastern side, dykes and stockwork veins of pink granitic aplite-pegmatite are locally abundant. Foliated, quartz-porphyritic hornblende-biotite granodiorite to tonalite forms a volumetrically significant phase at its northwestern margin (Yett Lake stock; Sm-Nd #115: Table 2) and its southwestern margins (U-Pb #55: Table 1). Leucocratic biotite (K-feldspar phenocrysts muscovite garnet) trondhjemite to granodiorite of the Robinson pluton is intrusive into the central part of the Lewis Lake batholith and yields a slightly younger age of ca. 2730 Ma (U-Pb #19, Table 1).

South Sturgeon plutonic suites also include the synvolcanic Beidelman Bay intrusion (U-Pb #47: Table 1; Sm-Nd #118–119: Table 2)), dominated by texturally variable leucotonalite phases with older quartz diorite and xenolithic tonalite phases (Galley et al., 2000) and the Pike Lake gabbroic intrusion (U-Pb #48: Table 1) a layered complex consisting of melagabbro to quartz gabbro and granophyre phases. These are, in turn, cut by a swarm of porphyritic felsic dykes, one of which yielded a ca. 2720 Ma age (U-Pb #46; Table 1; Sm-Nd #120: Table 2).

Deformed and metamorphosed intrusions in the Savant Lake belt include the pre-2704 Ma Fairchild Lake intrusion, Jutten batholith, tonalitic Patterson Lake stock, and the ca. 2703 Ma Heron Lake stock.

Late- to post-tectonic alkalic to subalkalic potassic intrusive rocks cut the Sturgeon Lake belt. These include late-tectonic, coarse-grained nepheline syenite of the Sturgeon Narrows alkalic complex and medium- to coarse-grained syenite, nepheline syenite and monzonite with associated pegmatite of the Squaw Lake and Bell Lake complexes. Foliated, pink, medium- to coarse-grained, equigranular to K-feldspar porphyritic, hornblende-biotite quartz monzonite to monzosyenite of the Vista Lake complex has a sanukitoid geochemical affinity (Stern et al., 1989) and is interpreted to be ca. 2690 Ma, the age of chemically similar quartz diorite to the east (U-Pb # 36: Table 1; Sm-Nd #133: Table 2).

Numerous post-tectonic plutons of granitic composition intrude the supracrustal belt including the ca. 2696 Ma Grebe Lake stock (U-Pb #13, Table 1). Unfoliated granodiorite containing xenoliths of foliated (S_1) quartzose wacke on the east shore of Vista Lake has an age 2685 $\pm$ 3 Ma (U-Pb # 26; Table 1) providing a minimum age of penetrative D_1 deformation in this area.

CENTRAL GRANITOID COMPLEX

The Savant–Sturgeon greenstone belt is bound to the east by a plutonic complex (Percival et al., 1999; Percival et al., 2002), that is dominated by Neoarchean-age granitoid and volcanic rocks but which also includes scattered remnants of Mesoarchean crust as old as 3075 Ma, likely part of the Winnipeg River terrane (Tomlinson and Percival, 2000). Within the map area, Neoarchean plutonic rocks are mainly tonalite and granodiorite with lesser amounts of granite and hornblende diorite-monzonite. Generally all units have calc-alkaline compositions, pronounced negative Nb anomalies and plot within the volcanic-arc granite field in tectonomagmatic classification diagrams (Whalen et al., in press). These characteristics suggest that these rocks formed at a destructive plate margin setting or were derived from crustal sources with arc affinities.

WINNIPEG RIVER SUBPROVINCE

A coherent domain of foliated to gneissic Paleo- to Meso-Archean plutonic rocks across the northwest map area constitute the foundation of the Winnipeg River Subprovince. Major rock types include medium-grained, grey-weathering, foliated biotite-tonalite-trondhjemite and tonalite-trondhjemite gneiss with lesser foliated to gneissic granite and granodiorite. The gneissic suite typically contains inclusions and rafts of amphibolite which are generally of plutonic origin, but in some cases can be shown to be volcanic in origin. It is typically cut by a compositionally diverse suite of ca. 2710 to 2680 Ma plutonic rocks. Granitic pegmatite gneiss is a minor, yet widespread phase of the gneissic suite, whereas porphyroclastic mylonite gneiss (U-Pb #56: Table 1) typifies the Miniss River fault zone. Foliated to gneissic tonalitic rocks generally yield primary magmatic ages around 3 Ga (U-Pb #56, 58–59, 66: Table 1), but also include ca. 3.32 Ga, a revised age for tonalite at Tannis Lake, west of the map area, and ca. 2.97 Ga, (U-Pb #4; Table 1) for tonalite gneiss from north of the Savant Lake belt. The latter age determination provides a basis for extending the Winnipeg River Subprovince eastward to include the Caribou North assemblage (see Percival et al., 2002).

The Winnipeg River Subprovince is a distinctive block of continental crust in the western Superior Province, in that it preserves an ancestry revealed through isotopic systematics that extends back to ca. 3.6 Ga. This is documented through whole rock Sm-Nd data (eg., Sm-Nd #1; #139; Table 2), from which model ages >3.0 Ga are calculated, and single zircon Lu-Hf data (Davis et.al., 2000) that yield significantly enriched ε_{Hf} values of -2 to 0, significantly less than the estimated value of $\sim +5$ for mantle-derived rocks at this time. On this basis, 3.6–3.2 Ga detrital zircon from quartzite that is part of a Mesoarchean continental margin sequence can be traced to the Winnipeg River terrane.

ENGLISH RIVER SUBPROVINCE

Metamorphosed clastic sedimentary rocks, associated peraluminous granites and metaluminous plutons of the English River Subprovince underlie the northwestern corner of the map area. The metasedimentary rocks consist of quartzofeldspathic, pelitic, and migmatitic rocks that represent variably metamorphosed wackes and mudstones. Migmatitic rocks include metatexite (unit Feg6sm), having <10% melt segregations in pelitic layers; inhomogeneous diatexite, with 10–70% partial melt segregations (unit Gms65gg); and homogeneous diatexite (unit Gms65gr), consisting of more than 90% granitic leucosome. Homogeneous diatexite forms large garnet-bearing plutons and cordierite-biotite granitic bodies such as the 2200 km^2 Churchill Lake batholith. The metasedimentary rocks host a number of ca. 2698 Ma dioritic to granodioritic stocks and batholiths (U-Pb #69:Table 1) that have been affected by regional metamorphism and deformation, and are locally gneissic.

DEFORMATION

Western Wabigoon Subprovince

Supracrustal rocks of the western Wabigoon Subprovince have been affected by two penetrative regional deformation events (D_1 and D_2) and an early non-penetrative event. Early (pre-D_1) ductile deformation is recorded in granitoid, volcanic and possible sedimentary clasts in the basal conglomerate facies of the Jutten assemblage. These fabrics suggest that the supracrustal substrate unconformably below the Jutten assemblage may have been penetratively affected by a strain event prior to ca. 2.8 Ga. In the Sturgeon Lake belt, pre-D_1 folds are: 1) east southeast-trending, shallowly to moderately east- and west-plunging; 2) lack an associated axial planar cleavage; and 3) are identified on the basis of reversals in structural facing (younging in the direction of S_1). These Neoarchean structures may be related to thrust faulting proposed by Koopman (1993) to have affected the VMS-mineralized 2735 Ma South Sturgeon assemblage, and may reflect an initial stage of tectonic thickening resulting from non-penetrative north-south shortening across the Sturgeon Lake belt after 2735 Ma.

Penetrative ductile deformation after 2704 Ma is interpreted to record collision and convergence between the continental margin sequence and the diverse oceanic terrane. In the Savant Lake area, earliest penetrative deformation, D_1, involved north- to northwest-trending, shallow-plunging F_1 folds and development of an associated axial planar cleavage (S_1). This is overprinted by 050–070°-trending, steeply-plunging F_2 folds with an associated axial planar foliation, S_2. Zones of localized D_2 strain include the 070°-trending Kashaweogama Lake and Stillar Bay shear zones. In the Sturgeon Lake area, the dominant fabric is a northerly-striking, steeply-dipping penetrative ductile fabric which correlates with S_1 in the Savant Lake area. This fabric is axial planar to tight, moderate north-plunging folds, similar in style to F_1 to the north. It is recognized to extend east of the supracrustal belt where it is moderately to strongly developed within ca. 2710 Ma granitoid rocks (Percival et al., 1999). Fabric elements of southern Sturgeon Lake, in contrast, comprise southwest- to southeast-trending folds (F_1) and fabrics (S_1) which are at a high angle to those described above. Overprinting D_2 structures, geometrically consistent with those in the Savant Lake area, penetratively affect rocks in the northern Sturgeon Lake area, but are only locally developed throughout much of the Sturgeon Lake belt.

Winnipeg River Subprovince

The earliest structural element recognized in the Winnipeg River Subprovince is a strong to intense transposition fabric, generally S_1 gneissosity, that trends northerly to northeasterly with a moderate (10–40°) dip to the east and west (Sanborn-Barrie, 1988). This fabric has been tentatively attributed to large-scale horizontal tectonic structures, such as thrusts or nappes (Westerman, 1977), and its formation in the Kenora area is believed to be bracketed between ca. 3.1 Ga, the crystallization age of the tonalite gneiss suite and ca. 2.85 Ga, the age of tonalitic rocks that cut the gneissic fabrics (Melnyk et al., 2000). Subsequent deformation of the gneissic suite, into upright, east-trending, open, locally domical folds with an associated east-striking, steeply south-dipping foliation and shallow east-plunging lineation, took place at ca. 2.7 Ga, following intrusion and crystallization of the ca. 2.71 Ga tonalitic suite. Transcurrent faulting concentrated near the margin of the subprovince reflects northwesterly directed regional transpresssion that affected the entire western Superior Province. Subsequent brittle-ductile movement on faults locally corresponding to the subprovince boundary, such as the Miniss River fault zone, are likely related to final stabilization at ca. 2680 to 2670 Ma (Bethune et al., 2000).

English River Subprovince

The main fabric forming event to affect the English River Subprovince took place at ca. 2691 Ma, during the main period of metamorphism and anatexis (U-Pb # 64,68,70: Table 1). The dominant fabric elements are east-trending, generally moderate to steep south-dipping foliation (S_2) and an associated moderately east-plunging mineral lineation (L_2). These structures, common to both the Winnipeg River and Wabigoon subprovinces, are interpreted to have formed in response to subhorizontal NW-directed compression. Unmetamorphosed pegmatite immediately north of the map area (Miniss Lake) cuts regional L_2/S_2 fabrics in migmatitic paragneiss, and provides a minimum age of 2688 $\pm$ 2 Ma (Corfu et al., 1995) for regionally significant deformation and anatexis of the English River Subprovince.

METAMORPHISM

Western Wabigoon Subprovince

Supracrustal rocks of the western Wabigoon Subprovince are characterized by mineral assemblages typical of greenschist facies regional metamorphism. Although there is little quantitative P-T data for these rocks, hydrothermally altered volcanic rocks with kyanite-andalusite-chloritoid assemblages from the Savant-Sturgeon area yield pressure estimates of 3–4 kb (Franklin et al., 1975). An increase in metamorphic grade to amphibolite facies toward the margins of the greenstone belt, reflected by the presence of garnet and staurolite in metasedimentary rocks and by hornblende clinopyroxene in mafic rocks, is attributed to contact metamorphism by bordering plutonic phases. Overgrowths of low Th/U zircon on detrital zircon from the Vista Lake quartzite (U-Pb # 25: Table 1) are dated at 2695 $\pm$ 6 Ma, indicating metamorphism at this time.

Winnipeg River Subprovince

Medium- to high-temperature, low-pressure metamorphism of the Winnipeg River Subprovince is reflected by widespread plagioclase-hornblende-quartz $\pm$ clinopyroxene $\pm$ orthopyroxene assemblages in mafic rocks and by textural evidence of in situ partial melting of a variety of rocks including amphibolite. Estimates of peak metamorphic conditions for the eastern Lac Seul region include 650°C to 750°C, at 3.5–6 kbar and 700°C to 750°C at 4–6 kbar (Beakhouse, 1992). Although multiple episodes of metamorphism have been proposed for the Winnipeg River Subprovince, the timing of mainstage regional Neoarchean metamorphism at ca. 2680 Ma is best constrained (Corfu, 1988; Corfu et al., 1995).

English River Subprovince

The English River Subprovince underwent a rapid evolution that saw deposition of turbiditic sedimentary sequences at ca. 2710–2695 Ma followed closely by compressional deformation, high-temperature metamorphism, anatexis and intrusion of peraluminous granites at ca. 2691 Ma. The 2691 Ma metamorphic and magmatic event took place at pressures of 3 to 6 kbar and temperatures of 500°C to 725°C. Achievement of paleodepths of 10–20 km and establishment of a high geothermal gradient over such a short interval suggests that the subprovince underwent considerable crustal shortening and tectonic imbrication, with significant input of heat from external (mantle?) sources from 2700–2690 Ma.

MINERAL DEPOSITS AND ALTERATION

A companion metallogenic map, Preliminary Map P.3454 (Parker, in prep.), shows the distribution and types of mineral deposits for the map area, where mineral exploration has been ongoing for more that a century in the search for gold, iron, and base metals. The Sturgeon Lake volcanogenic massive sulphide (Zn-Cu-Ag-Pb) camp comprises the past-producing Mattabi, F-Zone, Lyon Lake, Creek Zone and Sturgeon Lake deposits, hosted by the ca. 2735 Ma South Sturgeon assemblage. The Savant Lake area has had no mineral production to date, however, rocks of the Handy Lake assemblage are characterized by alumina enrichment and alkali depletion, reflected by the presence of staurolite, andalusite, kyanite, cordierite, and sillimanite. Their peraluminous nature is similar to that observed in footwall rocks beneath the massive sulphide deposits in the Sturgeon Lake camp (Franklin et al., 1975).

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