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Re-examining the Northwest Superior Province Margin

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Manitoba
Energy and Mines

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Cover:
Staurolite-, cordierite-bearing metagreywacke on the Clay River near the southwest end of Assean Lake. These paragneisses contain a dominant population of 3.0 to 3.4 Ga detrital zircons with some as old as 3.8 Ga, the oldest in Manitoba and among the oldest in North America. The metagreywacke lies within the block of ancient crust flanking Assean Lake on the northwest.

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Re-examining the Northwest Superior Province Margin

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INTRODUCTION

As a result of integrated mapping and isotopic studies across the northwestern Superior craton margin over the past three years, a major re-interpretation of the location and nature of the boundary zone between Archean rocks of the Superior Province and Paleoproterozoic rocks in the Trans-Hudson Orogen is required in the region north-east of Thompson, Manitoba. The exact location of this boundary is now in question and a large region previously mapped as Proterozoic is now known to be Archean. In addition, evidence for ancient (pre-3.7 Ga) crust in the northwestern Superior Province has been identified in the Assean Lake area, providing enormous excitement for the possible preservation of some of the oldest rocks on Earth. In addition, this major re-interpretation of the geology along the northwestern Superior craton margin will have a significant impact on the mining community and exploration in the region as it could potentially delineate new zones that should have excellent potential for nickel mineralization. This report summarizes recent field work and isotopic results conducted in the Assean Lake and adjacent areas (Fig. 1) that have a bearing on the location and nature of the northwestern Superior Province margin.

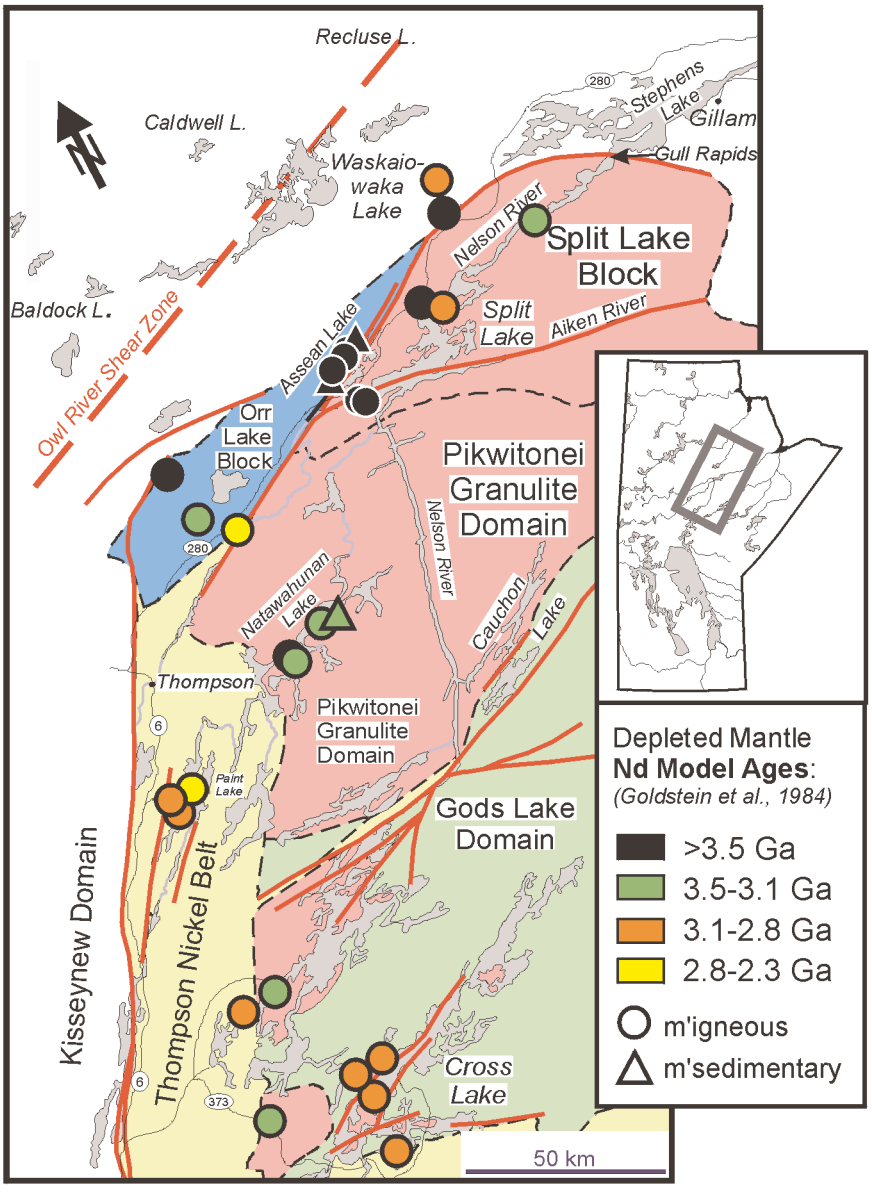

Figure 1: General geology and domain subdivisions in northwestern Superior Province with the sample locations.

GEOLOGICAL SETTING

The northwestern margin of the Superior craton consists of two high grade terrains (dominantly granulite facies lithologies) including the Pikwitonei Granulite Domain (e.g. Weber, 1983) and the Split Lake Block (e.g. Corkery, 1985; Böhm et al., 1999). These two regions are unique among high grade terrains worldwide for the abundance of well preserved granulite facies mineral assemblages that occur in a variety of lithologies (e.g. granodiorite, basalt). The dominant lithologies in both regions are Archean meta-igneous units (e.g. enderbites) with subordinate supracrustal rocks such as banded iron formation, pillow basalt and paragneiss. These lithologies have been intruded by a small amount of Paleoproterozoic intrusions (e.g. 1825 Ma Fox Lake granite; Heaman and Corkery, 1996).

Based on field relationships, petrography and U-Pb geochronology, there is a similarity in the tectonic and metamorphic evolution of both the Pikwitonei Granulite Domain and the Split Lake Block. These two regions will be considered together for the remainder of this report. In general, these high grade domains along the Superior craton margin contain evidence for pre-2.8 Ga protoliths, 2708 Ma granodiorite magmatism and at least two late-Archean high grade metamorphic events at ca. 2695 and 2640 Ma (Weber and Scoates, 1978; Corkery, 1985; Heaman et al., 1986b; Heaman and Corkery, 1996;

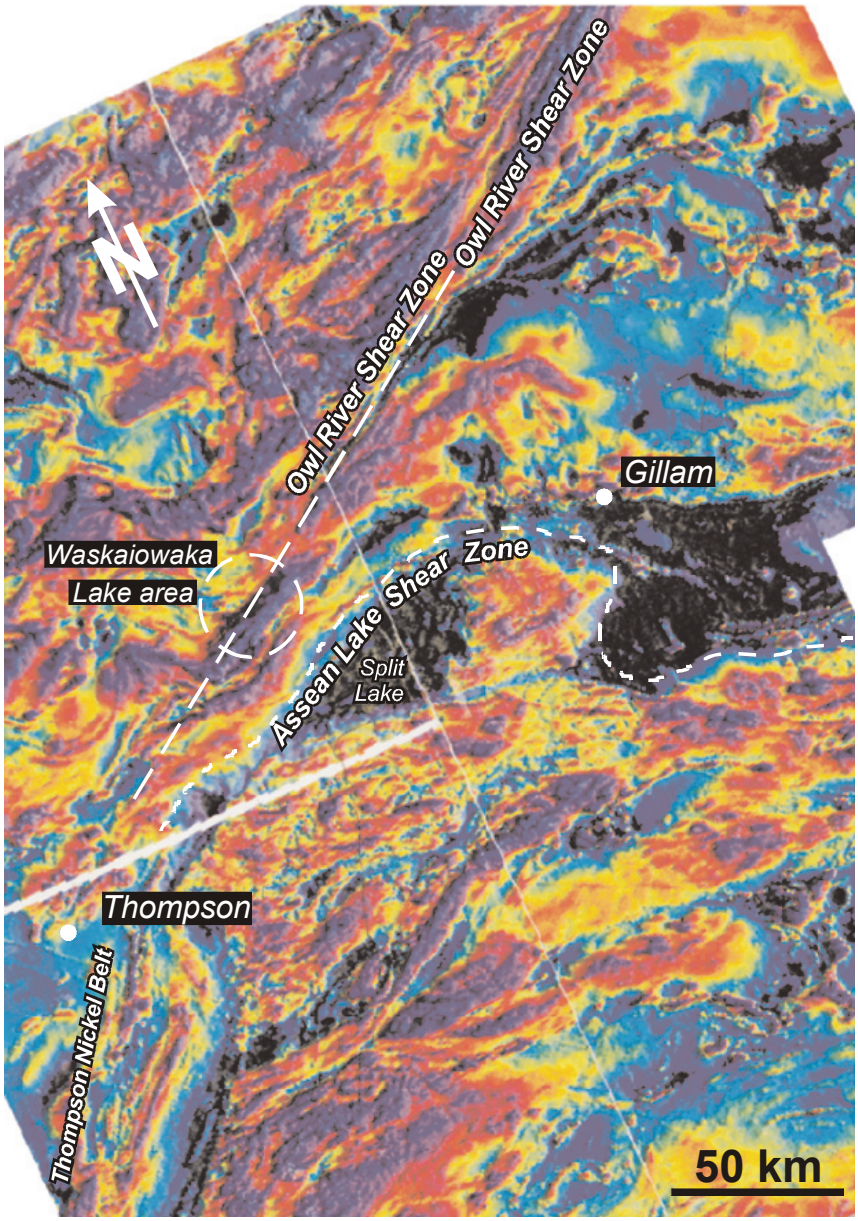

Figure 2: Pattern of magnetic trends in the region of Figure 1 with major structures indicated.

Böhm et al., 1998b and 1999). Estimates of peak pressure/temperature conditions during granulite facies metamorphism are about 830°C and 7.5-8.0 kbar in the Natawahunan Lake area (Mezger et al., 1990) with possibly somewhat lower P/T conditions (ca. 700°C and 6 kbar) in the eastern portions of the terrain (Pactunc and Baer, 1986). A prominent feature of the northwestern Superior margin is the preservation of discrete linear belts of cataclastic rocks, such as the Aiken River and Assean Lake deformation zones (Fig. 1). The tectonic significance, timing of deformation and movement along these deformation zones is poorly constrained.

Two distinct periods of Paleoproterozoic diabase dyke emplacement (ca. 2100-2070 and 1890-1860 Ma) have been obtained (Heaman et al., 1986a; Heaman and Corkery, 1996; Halls and Heaman, 1997) for the prominent northeast-trending dyke swarm in this region, previously referred to as the Molson dyke swarm (Scoates and Macek, 1978). This work indicates that there is a more complex dyke history than previously recognized. The younger dykes have well developed chilled margins (Scoates and Macek, 1978) and indicate that the majority of uplift that affected the northwestern margin of the Superior craton occurred prior to 1883 Ma.

In contrast, the crust north and northwest of the presumed margin of the Superior craton (i.e. north of the Assean Lake deformation zone in Fig. 1) preserves amphibolite grade metamorphic assemblages, with no indication of granulite grade assemblages common to the Superior Province rocks. Different lithologies (greywacke, arkose, granodiorite, basalt, etc.) that have been previously correlated with well-studied Paleoproterozoic units in the Trans-Hudson Orogen (e.g. Burntwood Formation metasediments, Ospwagan Group metavolcanics) are common. A belt-like pattern continuous with previously defined Trans-Hudson subdivisions was identified by Lenton and Corkery (1981) between Assean and Partridge Breast Lakes. The belts are defined by alternating east-west trending domains dominated by plutonic (e.g. Livingston, Baldock) and supracrustal (Kisseynew, Campbell–Waskaiowaka, and Partridge Breast–Northern Indian) lithologies. The northeast-trending dykes of the Molson swarm are not observed in this region.

Several geological anomalies northwest of Assean Lake noted by previous workers include: 1) the preservation of staurolite-bearing metagreywackes on Assean Lake in a region dominated by upper amphibolite facies metamorphism (Lenton and Corkery, 1981), and 2) the paucity of field evidence (Lenton and Corkery, 1981) for the "Owl River Shear Zone", a major deformation zone coinciding with a northeast-trending linear aeromagnetic anomaly (see Fig. 2). Discrete zones of high strain, such as the cataclastic and mylonitic deformation zones along Assean Lake and Aiken River, are not observed in the Waskaiowaka Lake area. Instead, a 060° trending gneissic zone occurs from the southwest end of Waskaiowaka Lake to Hale Lake. At present there is very little information on the nature of this potentially important deformation zone (see below).

The rocks in the Waskaiowaka Lake area can be subdivided into three main groups: 1) mafic to intermediate gneiss and associated migmatite of unknown age and origin, 2) granodiorite and gneissic granodiorite, and 3) late granite and quartz monzonite (Corkery and Lenton, 1990). The older gneisses represent variably migmatized para- and orthogneisses. Northwest of Waskaiowaka Lake, paragneiss derived mainly from greywacke and foliated tonalite to granodiorite intrusions are abundant. From northern Baldock Lake, eastward to Caldwell and Recluse lakes, an east-west trending zone of presumably Proterozoic megacrystic granite (Chipewyan batholith?) intrudes older orthogneisses. A Paleoproterozoic age for some of this magmatism northwest of Assean Lake is supported by Rb-Sr whole-rock isochron studies by Clark (1981) on the Baldock batholith (1747 Ma), Thorsteinson granite (1740 Ma), and Chipewyan batholith (1760 Ma).

ISOTOPIC STUDIES

Split Lake Block

U-Pb studies along the northwestern margin of the Superior Province were initiated in 1995 (see summary by Heaman and Corkery, 1996) with a reconnaissance sampling program in the Split Lake Block primarily focused on establishing the ages of Proterozoic mafic dyke emplacement and timing of Archean crustal development. This study demonstrated for the first time the presence of diabase dykes at the northwestern Superior margin as old as 2092 Ma that formed during the inception of Paleoproterozoic intra-continental rifting. The following year (1996) a larger initiative was put in place to study the nature of the Archean crust exposed in the Split Lake Block. U-Pb results for Archean basement samples collected during this field season provided the first evidence for pre-2.8 Ga protoliths of granodiorite and tonalite gneiss, 2708 Ma granitoid magmatism (Gull Lake granite) and at least two late-Archean high grade metamorphic events at ca. 2695 and 2620 Ma (Böhm et al., 1999). Interestingly, high grade metamorphism in the Split Lake Block is synchronous with the timing of two discrete high grade metamorphic events, not only in the southern Pikwitonei Granulite Domain (Heaman et al., 1986b), but in many Archean high grade terrains elsewhere in the Superior Province and worldwide.

Assean Lake

In addition to the collection of samples in the Split Lake and Nelson River areas for U-Pb geochronology, a detailed (1:50 000) mapping project was initiated in 1997 at Assean Lake in order to better understand the Assean Lake deformation zone and the geologic nature, kinematics and changes across the presumed Churchill-Superior boundary (Böhm, 1997a). This study applied integrated mapping, geochronology and isotope tracing across the presumed Archean-Paleoproterozoic boundary.

The Sm-Nd isotopic system is one of the more robust tracers of geological processes because both Sm and Nd are rare earth elements and tend to be relatively immobile during crustal processes, such as metamorphism. It has been shown in other Superior Province margin studies (e.g. Dickin, 1998), that the Nd isotope signature of orthogneiss samples is an effective reconnaissance tool for discriminating between Archean versus Proterozoic crust.

The Nd isotopic signature of samples from the Split Lake Block, Pikwitonei Granulite Domain and adjacent areas are shown on Figure 1. If the Assean Lake deformation zone represents a boundary between the Archean Superior craton to the southeast and Paleoproterozoic crust of the Trans-Hudson Orogen to the northwest, then we would anticipate a dramatic decrease in Nd model ages on the northwest side of this boundary. However, as can been seen from Figure 1 the Nd model age pattern is the reverse, with the oldest known model ages (3.85-3.55 Ga) preserved in the Assean Lake area. These ancient model ages are clearly older than those obtained for the Pikwitonei Granulite Domain or Split Lake Block and are the oldest so far recorded anywhere in the Superior craton.

Three samples from northwest Assean Lake with ancient model ages were selected for detailed U-Pb zircon geochronology: two greywacke samples and a granodiorite gneiss sample. The greywacke samples were selected in order to search for possible ancient provenance in the detritus. The majority of detrital zircon U-Pb ages obtained from these two greywacke samples indicate pre-3.2 Ga provenance with detritus as old as 3.75 Ga. The granodiorite gneiss sample from Assean Lake has an upper intercept U-Pb zircon age of 3.54 Ga making this the oldest known granodiorite in the entire Superior craton.

SUMMARY

The most exciting result from the Assean Lake project so far has been the discovery of ancient (pre-3.7 Ga) Archean crust northwest of the previously defined Superior Boundary Zone. This result has called into question the exact location of the Superior craton–Trans-Hudson Orogen boundary northeast of Thompson and opens the door for a major re-interpretation of the tectonic affiliation of the Orr Lake Block and a large tract of land north of the Assean Lake deformation zone. Our current interpretation is that the Assean Lake deformation zone (in the Assean Lake area) represents a cryptic suture between typical Superior margin high grade gneisses, such as those exposed in the Pikwitonei Granulite Domain and Split Lake Block, and a piece of exotic, ancient Archean crust (e.g. Böhm et al., 1998b). If correct, then the exact location of the Archean (Superior craton and the ancient crustal segment)–Proterozoic (Trans-Hudson Orogen) boundary is unknown. The most striking aeromagnetic anomaly north of the Assean Lake deformation zone is the Owl River lineament (Fig. 2) which projects through to Waskaiowaka Lake. Our current and future research program will involve further characterization of the newly discovered ancient crust between Assean and Waskaiowaka lakes and additional reconnaissance Nd isotope tracing in an attempt to locate the northwestern margin of the Superior craton.

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