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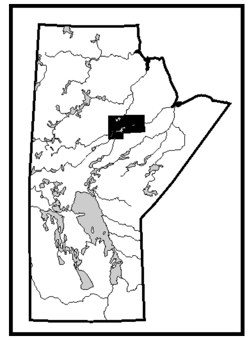
GS-12 Superior margin programs in the lower Nelson River region, Manitoba (parts of NTS 54D and 64A): year one



by C.O. Böhm, M.T. Corkery, M.S. Bowerman[1], M.W. Downey[2], R.P. Hartlaub[1], Y.D. Kuiper[2], L.M. Heaman[1] and S. Lin[2]

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Summary

A new collaborative program along the northern margin of the Superior Province started this summer. The project, set up for at least three years in collaboration with University of Alberta and Waterloo researchers, applies an integrated approach, including bedrock mapping, geochemistry, isotope geology, geochronology and structural studies, to specific areas in the region. Primary goals of the program are

- a series of modern, updated geological maps at regional and detailed scales, which will provide a new framework for the geology of the northern margin of the Superior Province in Manitoba;
- to improve the understanding of an economically important but insufficiently studied corridor between the exposed portions of the Thompson Nickel and Fox River belts; and
- to provide Manitoba Hydro with detailed geological information necessary for the bedrock assessment of a planned hydroelectric dam site at Gull Rapids, one of the main study areas of the program.

Introduction

The main impetus for undertaking a new generation of geological studies along the northern margin of the Superior Province is the currently insufficient understanding of the crustal architecture and evolution of the region. Past and current nickel, gold, platinum group element and, most recently, diamond exploration programs in areas along the northern Superior margin require an updated and improved geological framework. Based on these requirements and on decades of Manitoba Geological Survey bedrock mapping (e.g., Haugh, 1969; Corkery, 1985; Corkery and Lenton, 1990), rejuvenated by more recent, collaborative research (e.g., Heaman et al., 1986a, b, 1999; Böhm et al., 1999, 2000, 2003a; Lin and Jiang, 2001; Lin and Corfu, 2002), a new suite of projects has been initiated that takes an integrated, multidisciplinary approach to geological studies in the region. Primary products from these studies will include 1) updated 1:50 000-scale maps, 2) a revised 1:250 000-scale regional compilation map, and 3) focused structural, isotopic and geochronological studies within and adjacent to the main map areas (boxed areas in Fig. GS-12-1). A major part of the program will focus on the detailed examination of the Gull Rapids area, which may be affected in the near future by a hydroelectric power expansion program along part of the lower Nelson River between Birthday Rapids and Stephens Lake (Fig. GS-12-1). In response to this, the Manitoba Geological Survey and the Universities of Alberta and Waterloo are collaborating with Manitoba Hydro to extract as much geological information as possible from areas that may be affected by flooding and therefore inaccessible for direct future studies.

The three papers that follow this report in the volume (Böhm et al., GS-13; Kuiper et al., GS-14; Hartlaub et al., GS-15) summarize the preliminary outcomes from the field studies undertaken this year. The main aim of this report is to provide an updated geological framework for the program area.

Regional geology

The regional geology of the northwestern margin of the Superior Province is depicted in Figure GS-12-1. The main crustal terranes of the Superior Province are the Pikwitonei Granulite Domain and the associated Split Lake Block. The Superior Boundary Zone includes Archean rocks of the Superior Province, Paleoproterozoic rocks related to the Trans-Hudson Orogen, and Mesoarchean rocks of the Assean Lake crustal complex. The crustal terranes along the Superior margin are bounded by major deformation zones (Fig. GS-12-1) and have been subdivided, based primarily on differences in structural trends, metamorphic grade and, more recently, crustal nature and age. The Trans-Hudson Orogen flanks the area to the north and west.

The Aiken River deformation zone separates the Pikwitonei Granulite Domain and the Split Lake Block, which

[1] Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Alberta T6G 2E3
[2] Department of Earth Sciences, University of Waterloo, Waterloo, Ontario N2L 3G1

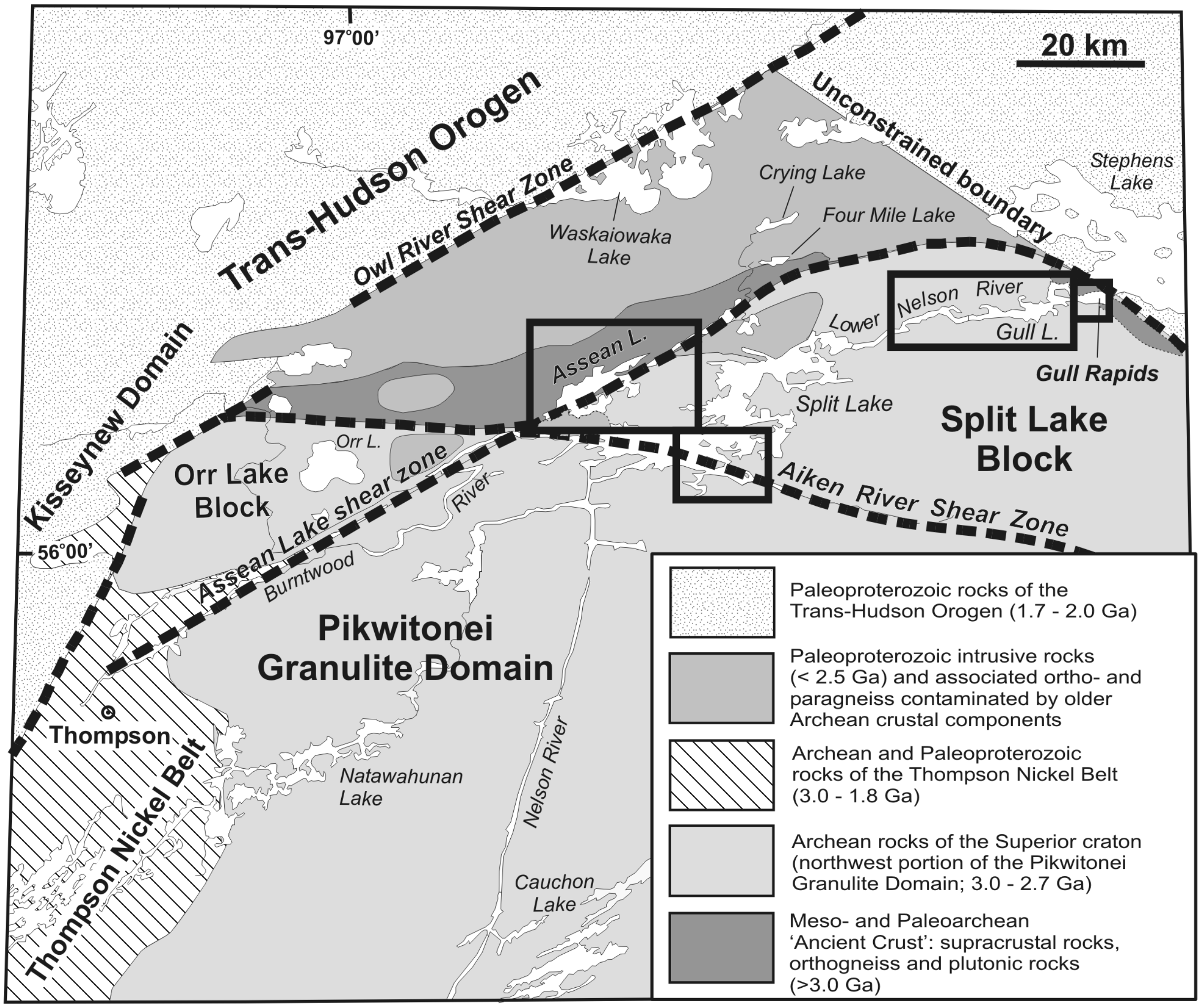

Figure GS-12-1: General geology of the northern margin of the Superior Province. Boxes encompass the 2003 study areas.

both consist predominantly of pristine and variably retrogressed granulite-facies assemblages. The two high-grade terranes are separated by the Assean Lake deformation zone from the Superior Boundary Zone. The latter represents a complex and heterogeneous zone that comprises the Superior-type Thompson Nickel Belt (Peredery et al., 1982; Bleeker, 1990; Machado et al., 1990) and Orr Lake Block (Lenton and Corkery, 1981), parts of the Trans-Hudson–type Kisseynew Domain, and exotic crustal segments including the Mesoarchean Assean Lake crustal complex (Böhm et al., 2000, 2003a).

Pikwitonei Granulite Domain

The Archean Pikwitonei Granulite Domain borders the northwestern and western sectors of the Superior Province in Manitoba. Along the northern margin of the Pikwitonei lies the Split Lake Block. To the west and northwest, it is bordered by the Thompson Nickel Belt, where Pikwitonei Granulite Domain rocks were reworked in the Paleoproterozoic during collision with the Trans-Hudson Orogen at about 1.8 Ga (e.g., Bleeker, 1990). The Pikwitonei Granulite Domain is interpreted to represent the deep crustal levels of an Archean granite-greenstone terrane (Green et al., 1985) and is dominated by orthopyroxene-bearing tonalite and granodiorite (TTG suite), with vestiges of supracrustal belts (basalt, greywacke, iron formation; e.g., Weber, 1978, 1983; Böhm, 1998). Some of these tonalite gneisses are as old as 3.0 Ga, but most have emplacement ages that cluster around 2.7 Ga (Heaman et al., 1986a; Böhm et al., 1998, 1999 and unpublished data, 1999).

Based on field relationships, petrography and U-Pb geochronology, there is an indication of at least two high-grade Archean deformational and metamorphic episodes in the Pikwitonei Granulite Domain (Weber and Scoates, 1978;

Hubregtse, 1980; Heaman et al., 1986a). Geochronological studies, however, indicate that these events may be diachronous across the region. For example, at least two distinct metamorphic zircon growth events, at ca. 2685 and 2640 Ma, are recorded in the Cauchon Lake area (Heaman et al., 1986a; Mezger et al., 1990), with initiation of granulite conditions possibly occurring as early as 2695 ±2 Ma, the age of an orthopyroxene-bearing granitic dike. In comparison, metamorphic zircons from felsic and mafic granulite samples from Natawahunan Lake suggest amphibolite-grade metamorphism at ca. 2705 to 2692 Ma, followed by granulite-grade metamorphism from 2683 to 2665 Ma and possibly also at ca. 2657 Ma, and local amphibolite-facies retrogression at ca. 2636 Ma (Böhm et al., unpublished data, 1999). Estimates of peak pressure and temperature conditions during granulite-facies metamorphism are approximately 6.7 to 7.3 kbar and 730 to 770ºC in the Cauchon Lake area and approximately 7.0 to 7.8 kbar and 780 to 840ºC in the Natawahunan Lake area (Mezger et al., 1990). Uranium-lead zircon ages of ca. 2629 and 2598 Ma from post-granulite pegmatite in the Cauchon Lake area (K. Mezger, unpublished data, 1990) indicate that metamorphic conditions reached amphibolite grade shortly after granulite facies. The presence of orthopyroxene-sillimanite– and sapphirine-bearing rocks in central Sipiwesk Lake indicates that high-grade metamorphism reached maximum intensity at this location (Arima and Barnett, 1984; Macek, 1989).

The youngest igneous activity in the Pikwitonei Granulite Domain is the intrusion of Paleoproterozoic mafic dikes (formerly known as the Molson dike swarm; e.g., Scoates and Macek, 1978). At least two ages of mafic dike emplacement, at 2092 Ma (Halls and Heaman, 1997) and 1883 Ma (Heaman et al., 1986b), are currently recognized in the Pikwitonei Granulite Domain.

Split Lake Block

The Split Lake Block forms a lensoid tectonic slice of reworked Superior craton margin that is bounded by the Assean Lake and Aiken River deformation zones (Fig. GS-12-1), which likely represent Neoarchean structures that have been locally reactivated during Paleoproterozoic tectonism (Böhm et al., 2000, 2003a and unpublished data, 2001). Based on field evidence (Haugh, 1969; Corkery, 1985), the Split Lake Block consists dominantly of meta-igneous protoliths that have a range in composition from gabbro to granite, but tonalite and granodiorite predominate. Böhm et al. (1999) reported three periods of Archean magmatism in the Split Lake Block: 1) pre–2.9 Ga granodiorite to tonalite magmatism considered part of the basement, 2) 2841 ±2 Ma tonalite magmatism, and 3) intrusion of the Gull Lake granite at 2708.2 ±2.5 Ma.

The Split Lake Block is one of the few regions along the craton margin where a detailed record of the Archean tectonometamorphic history is well preserved and only affected in a minor way by Paleoproterozoic collisional events related to the Trans-Hudson orogeny. Three high-grade metamorphic events are recognized in the Split Lake Block (Corkery, 1985). Two of these events occurred within a short time span of about 10 m.y (Böhm et al., 1999). The older event resulted in hornblende granulite–grade metamorphism at 2705 ±2 Ma, based on metamorphic zircon overgrowth ages obtained from enderbite. This event is closely linked to the emplacement of the youngest granite magmatism (Gull Lake granite). The younger pyroxene granulite–grade event is constrained at 2695 +4/–1 Ma, based on the formation age for orthopyroxene-bearing leucosome isolated from a mafic gneiss. The youngest dated metamorphic event occurred at ca. 2620 Ma and locally was responsible for retrogression to amphibolite-grade mineralogy and growth of zircon (Corkery, 1985; Böhm et al., 1999). There are currently no pressure-temperature estimates for high-grade metamorphic conditions in the Split Lake Block. The Split Lake Block is dominated, however, by medium- to coarse-grained granoblastic gneisses containing both hypersthene and diopside and retrograde equivalents, similar in character to rocks documented in the Pikwitonei Granulite Domain (Corkery, 1985).

Assean Lake ancient crust and associated terranes

The crustal configuration of the Superior Province margin shown in Figure GS-12-1 has been modified over the past five years with the recent recognition that a zone between the Assean Lake and Owl River deformation zones is largely Archean and contains a component of ancient, pre–3.0 Ga crust (Böhm et al., 2000, 2003a). The Assean Lake crustal complex contains abundant amphibolite-grade supracrustal rocks. Paragneiss and metavolcanic rocks form a migmatitic supracrustal assembly in the southwest (Clay River) and a volcanosedimentary assembly of lower to medium amphibolite metamorphic grade in the northeast (Lindal Bay; *see* Figure GS-14-1b in GS-14, this volume). The Clay River and Lindal Bay supracrustal domains are separated and intruded by dominantly orthogneiss, ranging in composition from tonalite to granite.

The majority of current knowledge about these ancient crustal rocks is based on integrated mapping, petrography, isotopic and geochronological study of rocks in the Assean Lake area (Böhm, 1997; Böhm et al., 2000, 2003a), where the existence of ancient crust was first detected through Nd isotopic studies. At Assean Lake, all analyzed rocks have model Nd dates older than 3.5 Ga. Model Nd dates older than 4.0 Ga and U-Pb single detrital zircon dates as old as 3.9 Ga have been recorded in at least one sample so far (Böhm et al., 2003a). The difficulty in defining the nature and extent of the ancient Assean Lake crust is that the region has been subjected to multiple deformation and high-grade metamorphic events in the Neoarchean (ca. 2.7–2.6 Ga) and Paleoproterozoic (ca. 1.8 Ga). Many of these ancient rocks are highly deformed because they occur within or near the Assean Lake deformation zones at the northwestern margin of the Superior craton, a site of multiple Precambrian continental collision events. Because of limited surface exposure, the extent of this ancient crust is currently unknown. In the Assean Lake area, this ancient crust displays a magnetic high, which can be traced northeastward along the Assean Lake deformation zone, providing some evidence that it extends beyond the well-studied Assean Lake area.

Kisseynew Domain in the Stephens Lake area

Bedrock mapping in the Stephens Lake area was conducted before and after flooding by Haugh and Elphick (1968) and Corkery (1985), respectively. Greywacke- and arkose-derived paragneiss of middle to upper amphibolite metamorphic grade form the principal rock types along the lower Nelson River from Gull Rapids downstream to the Kettle Rapids dam. The paragneiss contains minor amphibolite and quartzite and is intruded by tonalite to granite and derived migmatitic gneisses. Preliminary Nd isotope results from a metagreywacke sample from Moose Lake and a layered granodiorite gneiss from the Kettle Rapids dam (Nd model ages of 1.95 and 2.1 Ga, respectively; Böhm et al., unpublished data, 2000) suggest that both para- and orthogneiss are Paleoproterozoic. This is in agreement with Corkery (1985), who interpreted the greywacke- and arkose-derived paragneiss at Stephens Lake to be related to Burntwood Group and Sickle Group metasedimentary rocks of the Kisseynew Domain (e.g., Zwanzig, 1990). These results are in stark contrast, however, to a preliminary Nd model age of ca. 3.5 Ga for a turbiditic metagreywacke sample from Gull Rapids (Böhm et al., unpublished data, 2000), indicating that the Archean-Proterozoic boundary is located east of Gull Rapids, as outlined by the mapping of Haugh and Elphick (1968).

Projects

Gull Rapids bedrock investigations (GS-13, this volume)

During the 2003 field season, detailed (1:1000-scale) bedrock mapping was conducted in the entire 15 km^2 Gull Rapids mapping area, from the east end of Gull Lake to the west end of Stephens Lake (Fig. GS-12-1), by C. Böhm (Manitoba Geological Survey), M. Bowerman (M.Sc. student, University of Alberta) and M. Downey (M.Sc. student, University of Waterloo). The preliminary results of the Gull Rapids mapping program are summarized in Böhm et al. (GS-13, this volume) and published in a new 1:5000-scale preliminary map (Böhm et al., 2003b).

Structural studies along the Assean Lake and Aiken River shear zones (GS-14, this volume)

The aim of continued studies in the Assean Lake and Split Lake–Aiken River areas is to improve understanding of the timing and kinematics of deformational events along the regional Assean Lake and Aiken River shear zones. The new structural studies by Y. Kuiper (Postdoctoral research fellow, University of Waterloo), introduced in Kuiper et al. (GS-14, this volume), combine integrated mapping, detailed analysis of shear zones and other structures, and isotope and dating techniques to establish a kinematic and temporal framework for crustal boundaries along the northern Superior margin.

Nature and age of the Split Lake Block (GS-15, this volume)

New mapping, geochemical, isotope and geochronological studies by R. Hartlaub (Postdoctoral research fellow, University of Alberta) focus on the nature and age of the Split Lake Block and adjacent crustal terranes (GS-15, this volume). Based on studies by Corkery (1985) and Böhm et al. (1999, 2000), the emphasis of continued work along the Superior margin is to investigate the extent and nature of supracrustal rocks, including additional exposures of Assean Lake–type ancient crust.

Economic impacts

Providing detailed and regional bedrock maps and structural information of the northern Superior margin will 1) assist Manitoba Hydro in assessing the Gull Rapids site for potential hydroelectric power generation, and 2) guide exploration programs in the study areas. The current program along the northern Superior margin in Manitoba covers an economically important but insufficiently studied corridor between the exposed portions of the Thompson Nickel and the Fox River belts. The results of the studies will provide fundamental information outlining the extent and distribution of the various crustal segments along the Superior Boundary Zone. Based on present exploration programs in the Thompson Nickel and Fox River belts and at Assean Lake, the study area has potential for a variety of commodities along the Superior craton margin, including nickel, platinum group elements and shear-hosted gold. In addition, the preliminary results (e.g., Böhm et al., 2000, 2003a) indicate for the first time that a piece of ancient stable crust exists along the Superior Boundary Zone in the Assean Lake area, and that diamond potential could therefore be considerable in this region.

Acknowledgments

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