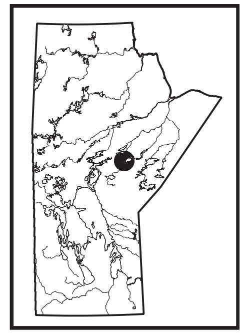
GS-1 Preliminary results of bedrock mapping at Oxford Lake, northwestern Superior Province, Manitoba (parts of NTS 53L12, 13, 63I9, 16)

by S.D. Anderson, P.D. Kremer and T. Martins



Anderson, S.D., Kremer, P.D. and Martins, T. 2012: Preliminary results of bedrock mapping at Oxford Lake, northwestern Superior Province, Manitoba (parts of NTS 53L12, 13, 63I9, 16); *in* Report of Activities 2012, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, p. 6–22.

Summary

As the largest contiguous greenstone belt in the northwestern Superior Province, the Oxford Lake–Knee Lake belt is central to understanding the stratigraphy, tectonic evolution and economic potential of a large and geologically diverse region that includes some of the most prospective yet underexplored greenstone belts in the Superior craton. In 2012, the Manitoba Geological Survey began a multiyear project to remap Oxford Lake in the western portion of this belt. Preliminary results from this mapping indicate that the supracrustal rocks are disposed in three fault-bounded structural panels and constitute four tectonostratigraphic assemblages, each of which is characterized by a distinct association of lithofacies and was likely deposited in a unique setting. Crosscutting relationships of intrusions suggest at least three broad ages of volcanism and sedimentation; however, absolute age constraints are presently lacking. Map patterns, mesoscopic deformation structures and overprinting relationships define at least three generations of ductile deformation structure, which include macroscopic isoclinal folds and a late network of dextral shear zones. Results from ongoing lithogeochemistry and U-Pb geochronology of samples collected in 2012 will be used to further constrain the stratigraphic and structural setting of base- and precious- metal occurrences at Oxford Lake, and to provide an up-to-date assessment of the economic potential.

Introduction

In 2012, the Manitoba Geological Survey (MGS) initiated a program of bedrock geological mapping at Oxford Lake. The study area is located 170 km southeast of Thompson, Manitoba, at the western end of the Oxford Lake–Knee Lake belt, which is the largest contiguous greenstone belt in the northwestern Superior Province. As such, this belt is central to understanding the stratigraphy, tectonic evolution and economic potential of a geologically diverse region that includes some of the most prospective yet underexplored greenstone belts in the Superior craton. By incorporating new bedrock mapping with modern techniques of structural analysis, lithogeochemistry, Nd-Sm isotope geochemistry, U-Pb geochronology and mineral-deposits studies, the Oxford Lake project is designed to complement investigations done in the Knee Lake area as part of the Western Superior NATMAP Project (Syme et al., 1997, 1998; Corkery et al., 2000). An important objective of this study is to provide up-to-date geoscience data to local stakeholders and the mineral-exploration industry.

Early work by the Geological Survey of Canada included route surveys of the Hayes River (e.g., Bell, 1879, 1881; Brock, 1911; McInnes, 1913; Bruce, 1920) and reconnaissance mapping of Oxford Lake at 1:126 720 scale (Wright, 1926, 1932). Subsequent investigations at Oxford Lake by the MGS involved systematic mapping of supracrustal rocks and surrounding plutonic complexes at 1:31 680 scale (Barry, 1959, 1960; Hubregtse, 1985); the latter study was part of the 'Greenstone Project' (1970–1973), which had the objective of improving the geological context for mineral exploration (Gilbert, 1985). Follow-up studies documented the distinctive chemistry and tectonic implications of shoshonitic volcanic rocks (e.g., Hubregtse, 1978; Brooks et al., 1982). Exploration activity at Oxford Lake has been intermittent following the initial discoveries of base-metal, gold and antimony mineralization in the early 1920s. Significant mineral occurrences were described by Wright (1926, 1932), Barry (1959, 1960), Haskins and Stephenson (1974), Haskins and Evans (1977) and Southard (1977). Exploration culminated in 1989–1990 with the delineation of the Rusty Zone gold deposit (Richardson and Ostry, 1996).

Fieldwork in 2012 involved six weeks of 1:20 000 scale bedrock mapping of the extensive shoreline exposures in western Oxford Lake. The study area covers approximately 200 km^2 and was selected for remapping in the inaugural field season because it includes several significant mineral occurrences. It also straddles the postulated trace of a major tectonic boundary in the western Superior Province (Stott et al., 2010) that exhibits potential as a significant gold metallotect. During the mapping, approximately 60 lithogeochemical samples were collected for analysis by high-precision, inductively coupled plasma–mass spectrometry (ICP-MS). Also collected were seven samples of key supracrustal and intrusive rock types for U-Pb geochronology; these will be analyzed by laser-ablation ICP-MS (detrital zircons) or thermal ionization mass spectrometry at the University of Alberta Radiogenic Isotope Facility. This report describes the preliminary results of the bedrock mapping component of the Oxford Lake project. The results of follow-up analytical work will be reported in subsequent years of what is designed as a three-year mapping project.

Regional setting

Oxford Lake is situated in the southwestern portion of the regionally extensive Oxford Lake–Knee Lake greenstone belt (Figure GS-1-1) in the Oxford–Stull Domain of the western Superior Province (Stott et al., 2010). Following the original scheme of Wright (1932), supracrustal rocks in the Manitoba segment of the Oxford–Stull Domain have traditionally been divided into two stratigraphic units: the older, basalt-dominated Hayes River Group (HRG) and the younger, more diverse Oxford Lake Group (OLG; e.g., Barry, 1960; Gilbert, 1985; Hubregtse, 1985). The HRG consists of pillowed and massive tholeiitic basalt flows and gabbro, with minor intermediate to felsic volcanic rocks and fine-grained sedimentary rocks (Hubregtse, 1978, 1985; Gilbert, 1985). At Oxford Lake, the HRG is described as consisting of three bimodal volcanic cycles, each of which consists of a thick mafic lower section and a thinner felsic upper section (Hubregtse, 1978). Felsic volcanic rocks in the HRG at Knee Lake range in age from ca. 2827 to ca. 2834 Ma (Corkery et al., 2000). The HRG has not been dated at Oxford Lake, and neither the stratigraphic base nor the top has been documented. The base is generally intruded by tonalite and granodiorite plutons or is cut by faults, whereas the top is defined by faults, younger plutons or the erosional unconformity at the base of the OLG.

Unconformably overlying rocks of the OLG are subdivided into lower volcanic and upper sedimentary

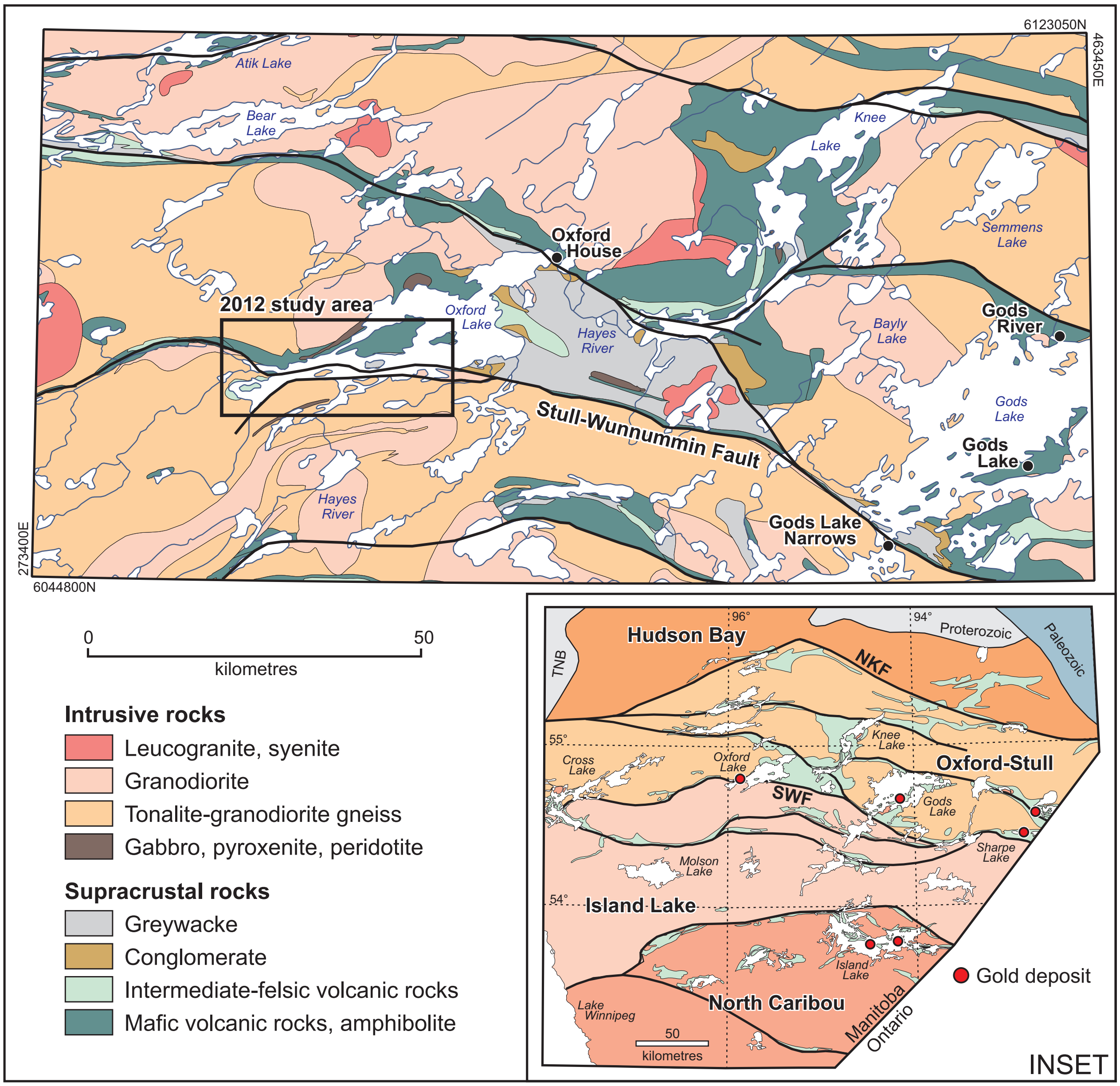


Figure GS-1-1: *Regional geological setting of the Oxford Lake–Knee Lake greenstone belt, showing the location of the 2012 study area. Inset map shows the major geological domains, greenstone belts and shear zones in the Manitoba segment of the northwestern Superior Province. Abbreviations: NKF, North Knife Fault; SWF, Stull-Wunnummin Fault.*

subgroups, and locally include polymictic conglomerate that contains clasts derived from the HRG and tonalite–granodiorite intrusions (Gilbert, 1985). The volcanic subgroup consists of porphyritic volcanic rocks of high-K calcalkalic to shoshonitic affinity that range in composition from basalt to rhyolite and are intercalated with locally derived, coarse epiclastic rocks (Hubregtse, 1978, 1985; Brooks et al., 1982; Gilbert, 1985). Felsic volcaniclastic rocks assigned to the volcanic subgroup of the OLG have ages of 2722 ±3 Ma at Knee Lake (Corkery et al., 2000) and 2705 ±2 Ma at Oxford Lake (Lin et al., 2006). The sedimentary subgroup consists of a thick succession of feldspathic greywacke-mudstone turbidite, iron formation, crossbedded quartz-lithic greywacke and polymictic conglomerate deposited in shallow-marine to subaerial settings. In southern Knee Lake, these rocks have a maximum depositional age of ca. 2707 Ma (Corkery et al., 2000). A minimum age is provided by the Magill Lake pluton, which intrudes the OLG south of Knee Lake and yielded a U-Pb monazite age of 2668 ±1 Ma (Lin et al., 2006).

Supracrustal rocks at Oxford Lake were overprinted by at least two generations of upright folds, intruded by granitoid plutons and tectonically segmented by greenschist-facies dextral shear zones. The latter structures are part of an anastomosed array of regional-scale shear zones that appear to merge toward the east into the crustal-scale Stull-Wunnummin Fault, which defines the south margin of the Oxford–Stull Domain in Ontario and is thought to represent a fundamental tectonic boundary in the northwestern Superior Province (e.g., Skulski et al., 2000; Stott et al., 2010). In Manitoba, the main strand of this fault trends in a westerly direction through Sharpe Lake (Beaumont-Smith et al., 2003) and bifurcates toward the west into a series of second-order splays (Figure GS-1-1, inset). The northernmost of these splays trends through the narrows in Gods Lake, where it is referred to as the 'Gods Lake Narrows shear zone' (Lin et al., 2006), and continues along strike to Oxford Lake, where it roughly coincides with the southern boundary of the Oxford Lake–Knee Lake belt. At Oxford Lake, this splay further bifurcates into a complex array of third- and fourth-order shear zones that segment the supracrustal rocks and likewise record dextral strike-slip shear under greenschist-facies metamorphic conditions. The main strand of this regional second-order splay is provisionally interpreted to coincide with the Hyers shear zone. As described below, rocks on either side of this structure at Oxford Lake are significantly different in several respects.

Provisional tectonostratigraphic framework

Supracrustal rocks in western Oxford Lake are here divided into four tectonostratigraphic assemblages that are characterized by distinctive associations of rock types and are inferred to reflect differences in depositional environment and possibly age. Pending the results of U-Pb geochronological analyses, and to avoid implied correlations with adjacent belts, the supracrustal assemblages at Oxford Lake have been assigned provisional names from geographic features at their local type localities. Previous nomenclature and possible correlations for each assemblage are described below.

The map area is also divided into three main structural panels, each of which is bounded by major (i.e., second- or third-order) greenschist-facies shear zones (Figure GS-1-2). The south panel contains the Cat Eye Bay and Hyers assemblages and is bounded to the north by the Hyers shear zone (HSZ), whereas the north panel contains the Carghill assemblage and is bounded to the south by the Carghill shear zone (CSZ). The central panel is confined by the HSZ and CSZ, and contains the Thomsen assemblage. The Carghill assemblage lies in tectonically modified intrusive contact to the north with massive to weakly foliated granodiorite of the Semple River pluton (Hubregtse, 1985). To the south, the Cat Eye Bay and Hyers assemblages lie in contact with strongly foliated and lineated biotite±hornblende tonalite of the Bayly Lake intrusive complex. The tonalite intrudes the Hyers assemblage and lies in tectonic contact with the Cat Eye Bay assemblage across the Lynx Bay shear zone. At the west end of Oxford Lake, all of these assemblages and major shear zones are stitched by gabbro dikes of the Molson (1883 Ma; Heaman et al., 1986) and Mackenzie (1267 Ma; LeCheminant and Heaman, 1989) swarms.

Despite the absence of U-Pb age constraints, crosscutting relationships of intrusions in each panel suggest different depositional ages and/or geological histories for the constituent supracrustal rocks. In the south panel, the widespread occurrence of demonstrably intratectonic tonalite, syenogranite and gabbro dikes (i.e., dikes that crosscut deformation fabrics and were later deformed) suggests a relatively protracted history of magmatism and deformation, and perhaps older relative ages for the Cat Eye Bay and Hyers assemblages. Intratectonic dikes are absent from the north panel, which is instead characterized by abundant subvolcanic dikes and sills (i.e., hypabyssal intrusions that texturally resemble overlying effusive rocks), indicating that the Carghill assemblage may have been deposited after an orogenic cycle recorded by the south panel. In the central panel, the Thomsen assemblage only contains rare hypabyssal intrusions and includes polymictic conglomerate with abundant detritus derived from granitoid plutons, which suggests a relatively young depositional age.

Local geology

Supracrustal assemblages and intrusive rocks in the southwestern portion of Oxford Lake are described below in order of decreasing apparent age. Unit codes in the text correspond to those of Anderson et al. (2012a, b); a simplified version of these maps is included herein as Figure

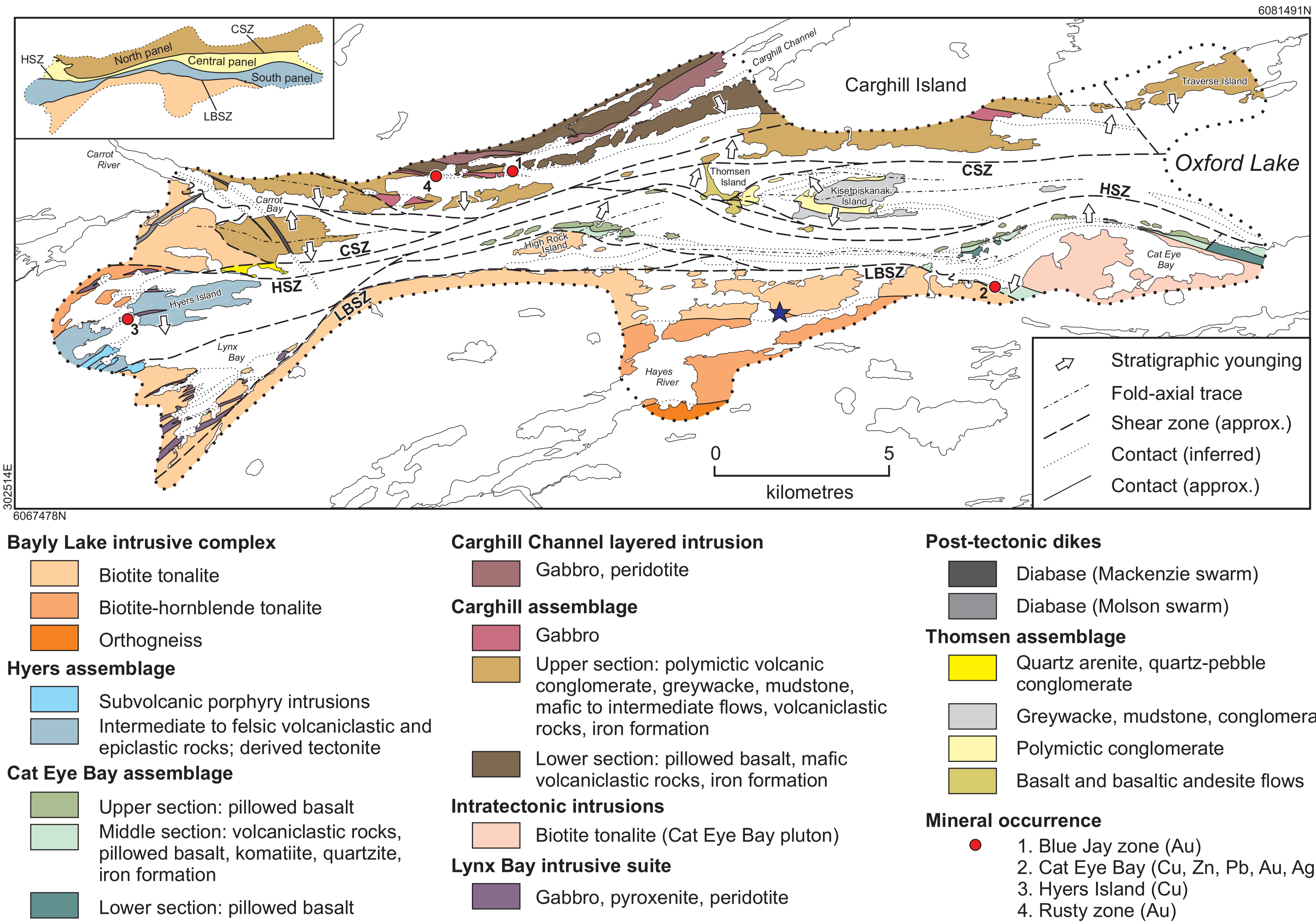


Figure GS-1-2: *Simplified geology of western Oxford Lake, showing the main components of the various supracrustal assemblages, major structural features and significant mineral occurrences. Inset diagram shows the three main structural panels and the star indicates the location of the possible carbonatite dike (see text for discussion). Abbreviations: CSZ, Carghill shear zone; HSZ, Hyers shear zone; LBSZ, Lynx Bay shear zone.*

GS-1-2. The arrangement of map units in the legend is based on composition (mafic to felsic), grain size (coarse to fine) and rock type (volcanic to volcaniclastic to sedimentary to intrusive), and is not intended to indicate stratigraphic order.

Supracrustal and intrusive rocks in the study area are variably metamorphosed and deformed. Metamorphic grade varies from amphibolite facies (hornblende±garnet, cordierite) along the margins of the belt to greenschist facies (chlorite±biotite, actinolite, sericite) in the interior. In the interest of brevity, however, the prefix 'meta' is not used in this report and the rocks are described in terms of their protoliths.

South panel

As indicated above, the south panel of the Oxford Lake belt is bounded to the north by the Hyers shear zone and to the south by strongly deformed tonalite of the Bayly Lake complex. This panel contains two distinct assemblages of supracrustal rocks: the mafic flow–dominated Cat Eye Bay assemblage and the felsic volcaniclastic–dominated Hyers assemblage.

Cat Eye Bay assemblage (units Cb1–Cb6)

The Cat Eye Bay assemblage crops out along the southern shoreline of Oxford Lake and is discontinuously exposed over a strike length of approximately 24 km, from the westernmost island in the chain that includes High Rock Island to the east end of the peninsula that defines the northeast shoreline of Cat Eye Bay. It consists mostly of basalt flows, with minor ultramafic flows, felsic volcaniclastic rocks, iron formation and quartzite. These rocks were assigned to the HRG by Barry (1960) and Hubregtse (1985), and the authors found no evidence to refute this correlation. Map patterns, younging criteria and industry high-resolution aeromagnetic data indicate that the assemblage at Cat Eye Bay defines a macroscopic anticline that trends parallel and adjacent to the south shoreline of Oxford Lake, and is bounded by the Hyers and Lynx Bay shear zones. At its type locality, the assemblage is intruded by intratectonic tonalite of the Cat Eye Bay pluton, which defines the core of the macroscopic anticline. It is also intruded by minor gabbro sills or slightly discordant dikes that may correlate with the Lynx Bay intrusive suite. At High Rock Island, the anticline is transected at a low angle by the Lynx Bay shear zone and the north limb is juxtaposed against biotite tonalite of the Bayly Lake complex.

The Cat Eye Bay assemblage appears to be truncated to the east by the Hyers shear zone and Cay Eye Bay pluton. Toward the west, aeromagnetic trends indicate that the assemblage may extend to the eastern tip of Hyers Island, for a total strike length of approximately 28.6 km. However, due to the absence of exposure in this area, it is provisionally interpreted to be truncated by a splay of the Lynx Bay shear zone. At the type locality in Cat Eye Bay, distinctive lower, middle and upper sections appear to define a mappable stratigraphy and suggest an analogy to Archean rift sequences (i.e., basalt, komatiite, quartzite, iron formation) documented elsewhere in the Superior Province.

The lower section consists of pillowed basalt flows (unit Cb2) and is poorly exposed along the western margin of the Cat Eye Bay pluton, where it appears to be at least 500 m thick. The basalt is typically aphyric, very sparsely amygdaloidal and forms strongly flattened, bun-shaped to amoeboid pillows with very minor interpillow hyaloclastite. Patchy to fracture-controlled to pervasive epidote-silica and garnet alteration are characteristic features of this basalt (subunit Cb2a; Figure GS-1-3a). This alteration appears to be semiconformable and is nowhere observed in superficially similar basalt in the upper section, suggesting that it may be syngenetic; its significance is discussed below.

The middle section of the assemblage ranges from 200 to 300 m in thickness and coincides with a prominent linear aeromagnetic anomaly that can be traced along the entire length of the assemblage, on both limbs of the macroscopic anticline. Considerable lateral variability of rock types and depositional facies suggests a relatively dynamic depositional setting. At Cat Eye Bay, the middle section comprises a heterogeneous association of basalt flows (unit Cb2) and volcaniclastic rocks (unit Cb3), with minor quartzite (unit Cb4) and iron formation (unit Cb5). The basalt is aphyric, contains sparse quartz amygdules and varies from pillowed to massive, with semipervasive garnetization (subunit Cb2a). The volcaniclastic rocks are best exposed along the north limb of the anticline and appear to consist mostly of interstratified felsic tuff and lapilli tuff (subunit Cb3a), heterolithic tuff breccia (subunit Cb3b; Figure GS-1-3b) and minor thin-bedded mafic tuff and chert (subunit Cb3c). Here, the volcaniclastic rocks are capped by a sulphide-facies iron formation that ranges up to 10 m thick and contains thin lenses of semi-solid pyrrhotite with minor chalcopyrite (subunit Cb5b; Figure GS-1-3c).

On the south limb of the anticline, the corresponding interval is represented by strongly layered mafic and felsic tectonite and phyllonite (unit Cb6) that crop out along the south shoreline of the lake. This interval includes cordierite-anthophyllite (Hubregtse, 1985) and quartz-sericite-pyrite schist, minor oxide- and sulphide-facies iron formation (subunits Cb5a and 5b, respectively), and several occurrences of base and precious metals hosted by thin zones of solid to semi-solid sulphide mineralization (chalcopyrite, sphalerite, pyrite±galena). These collectively comprise the 'Cat Eye Bay' occurrence of Haskins and Evans (1977). Coupled with the presence of the semiconformable alteration in the lower section, these features are indicative of an exhalative base-metal sulphide system. In this context, the sulphide-facies iron formation

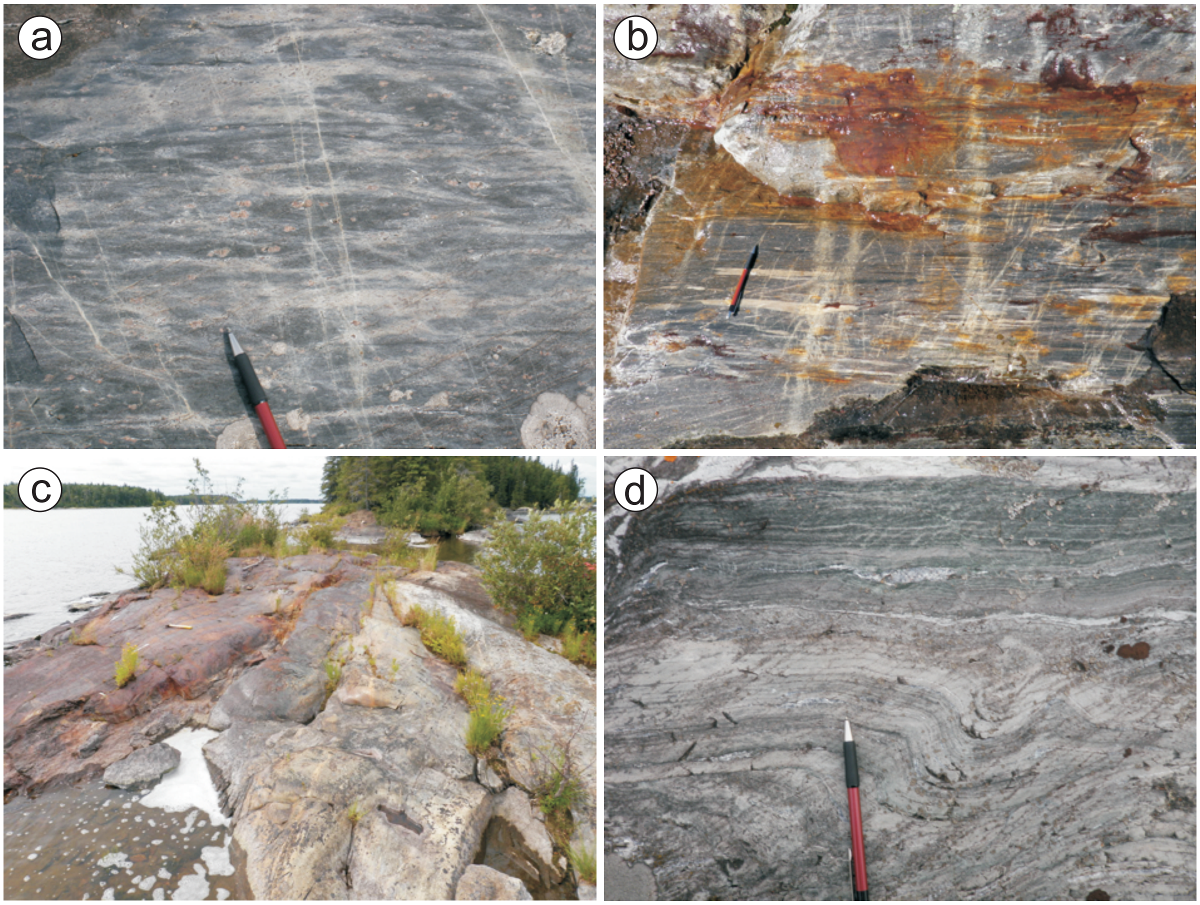


***Figure GS-1-3:** Outcrop photographs of characteristic rocks in the Cat Eye Bay assemblage from the type locality: **a)** fracture-controlled silicification and pervasive garnetization in pillowed basalt of the lower section (subunit Cb2a), western Cat Eye Bay; **b)** heterolithic tuff breccia near the base of the middle section (subunit Cb3b), northern Cat Eye Bay; **c)** sulphide-facies iron formation in tectonized felsic volcaniclastic rocks at the top of the middle section (subunit Cb5b), northern Cat Eye Bay; **d)** thin-layered quartzite and sericite-fuchsite schist near the base of the middle section (unit Cb4), western Cat Eye Bay.*

that defines the top of the middle section on the north limb of the anticline in Cat Eye Bay may represent an important exhalite marker horizon for base-metal exploration.

Quartzite (unit Cb4) is exposed in three widely separated localities near the base of the middle section on the south limb of the anticline in Cat Eye Bay and appears to define a single stratigraphic unit. In two of these localities, the unit includes two discrete quartzite horizons separated by garnetiferous basalt and minor sulphide-facies iron formation. The quartzite varies from 3 to 5 m in thickness and comprises thin (<30 cm) alternating layers of fine-grained, recrystallized quartz and sericite-fuchsite schist (Figure GS-1-3d). A sample of this material was collected for U-Pb geochronological analysis of detrital zircon to constrain the maximum depositional age.

At High Rock Island, the middle section is defined by pillowed basalt flows, sulphide- and oxide-facies iron formations, and spinifex or cumulate-textured ultramafic rocks (subunits Cb1a and 1b, respectively) that are interpreted to represent komatiite flows. Here, and at Cat Eye Bay, the middle section is overlain by a monotonous succession of pillowed aphyric basalt flows that lack semi-conformable garnetization (subunit Cb2b) and define the upper section of the assemblage. These flows are locally variolitic, which distinguishes them from basalt flows in the lower section.

Hyers assemblage (units Hi1–Hi5)

The Hyers assemblage crops out on Hyers Island, and along the southwestern shoreline of Lynx Bay and on adjacent islands. It consists mostly of intermediate to felsic volcaniclastic rocks, subvolcanic intrusions and derived epiclastic rocks, and is characterized by the widespread occurrence of volcanogenic alteration and sulphide mineralization. It is intruded by tonalite of the Bayly Lake complex, and both are cut by mafic to ultramafic intrusive rocks of the Lynx Bay intrusive suite. The Hyers assemblage was previously assigned to the OLG by Barry (1960) and was considered an extrusive equivalent of the Bayly Lake complex (termed the ‘Lynx Bay assemblage’) by Hubregtse (1985). However, based on the widespread occurrence of intratectonic gabbro dikes, these rocks are herein considered too old to be correlated with the OLG. The possibility of a magmatic association with the Bayly Lake complex remains feasible and will be further evaluated using lithogeochemistry and geochronology.

The Hyers assemblage is characterized by regionally pervasive hydrothermal alteration and is almost everywhere strongly deformed. The eastern portion of the assemblage is dominated by intensely foliated, fine-grained, sericitic or chloritic phyllonite (subunits Hi5a and 5b, respectively), which contain patchy to locally pervasive disseminated pyrite. These rocks are particularly extensive on either side of the channel north of Hyers Island along the trace of Hyers shear zone. Primary textures become better preserved toward the west, and clearly indicate that the precursor rocks were mostly intermediate to felsic volcaniclastic rocks (unit Hi1), with lesser epiclastic rocks (unit Hi2) and subvolcanic porphyry intrusions (unit Hi4). The volcaniclastic rocks consist mostly of homogeneous crystal tuff (subunit Hi1a) and crudely stratified lapilli tuff, tuff breccia and breccia (subunit Hi1b; Figure GS-1-4a). The latter rocks vary from aphyric to sparsely quartz and/or plagioclase phyric, and contain minor clasts of mafic volcanic material. Rare bedforms indicate that the stratigraphy trends toward the west and is subvertical. Minor interlayers of volcanic conglomerate vary from oligomictic (subunit Hi2a) to polymictic (subunit Hi2b) and contain a significant proportion of distinctly rounded clasts up to 50 cm in diameter, with minor interlayers of bedded volcanic sandstone; mudstone beds are conspicuously absent. Normally graded beds and possible scours in three locations indicate tops to the south (Figure GS-1-4b). A sample of volcanic sandstone from the southwest tip of Hyers Island has been submitted for U-Pb geochronological analysis of detrital zircon.

The porphyry intrusions (unit Hi4) contain variable proportions of euhedral to subhedral phenocrysts

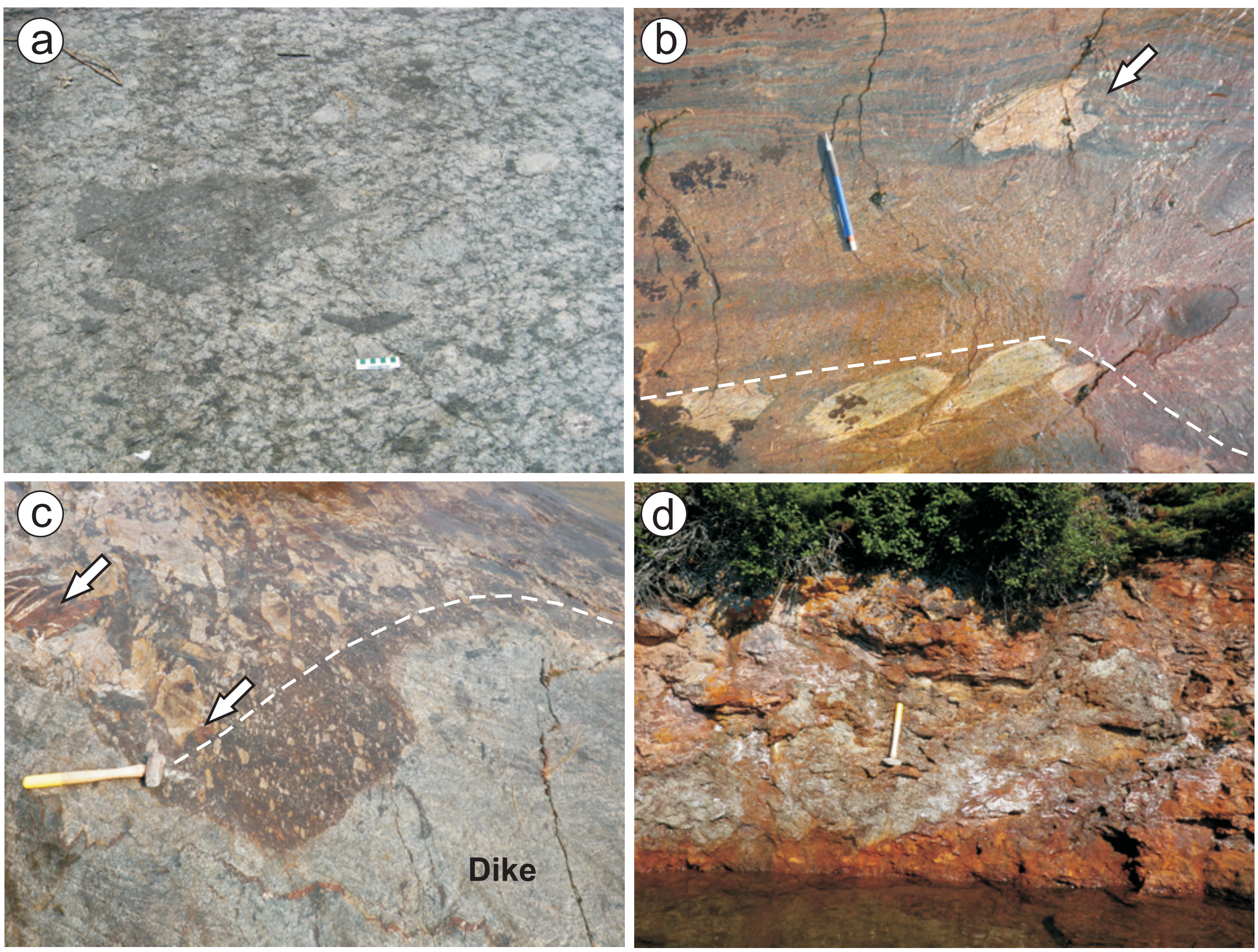


***Figure GS-1-4:** Outcrop photographs of characteristic rocks in the Hyers assemblage: **a)** heterolithic tuff breccia (subunit Hi1b), southwest shoreline of Lynx Bay; **b)** bedded volcanic sandstone and conglomerate from the southwest tip of Hyers Island (subunit Hi2b); normally graded beds, scour-and-fill structure (dashed line) and possible sag structure (arrow) indicate tops to the south (pencil points north); **c)** stratified heterolithic lapilli tuff and tuff breccia discordantly cut by irregular dike of plagioclase-quartz porphyry (subunit Hi4a), south shoreline of Hyers Island; dashed line indicates bedding; note large clasts of massive ankerite (arrows); **d)** massive ankerite alteration with stringer pyrite (subunit Hi3b), northwest tip of Hyers Island.*

of quartz or plagioclase in a very fine grained siliceous matrix. Contacts are rarely exposed but are sharp, irregular and discordant to bedding in one location (Figure GS-1-4c). The intrusions are voluminous along the southwestern shoreline of Lynx Bay, where they contain abundant coarse phenocrysts of plagioclase (20–30%; up to 2 cm) with lesser and smaller quartz phenocrysts. Some of these bodies texturally resemble clasts in the adjacent volcaniclastic country rocks and may thus represent extrusive flows. They also locally resemble porphyritic phases of the adjacent Bayly Lake complex, which prompted Hubregtse (1985) to suggest a comagmatic relationship. This hypothesis will be evaluated using new geochemical and geochronological data from samples collected during the 2012 field season; a sample of quartz porphyry from the southwestern shoreline of Lynx Bay has been submitted for U-Pb geochronological analysis.

Discrete zones of alteration and sulphide mineralization (unit Hi3) are exposed in four locations along the western shoreline of Hyers Island. Each zone trends roughly east and appears to be broadly stratiform. They are stacked roughly parallel to the shoreline along a southwesterly trend; it is presently unclear whether they represent four distinct horizons or a single horizon that has been repeated by folding or faulting. Both northern and southern zones show clear southward progressions from quartz-sericite schist with stringer-style ankerite veins to massive replacement-style ankerite (subunit Hi3a) and finally to stringer or massive, near-solid to solid sulphide mineralization (pyrite±chalcopyrite; subunit Hi3b; Figure GS-1-4d). These progressions are taken to indicate the local stratigraphic younging direction. Massive ankerite ranges up to 30 m thick in continuous exposures and is found as clasts in overlying volcaniclastic rocks (Figure GS-1-4c), indicating its syngenetic nature; all of these zones are cut by less-altered diabase dikes. The southern zone hosts the Hyers Island deposit, for which a small resource of 317 500 tonnes (350,000 tons) grading 2.5% copper has been calculated (Assessment File 72236, Manitoba Innovation, Energy and Mines, Winnipeg). The stratiform nature, styles and patterns of alteration and mineralization, geological setting and field relationships of these zones all support a subaqueous exhalative origin, likely in a shallow marine setting.

Bayly Lake intrusive complex (units Bl1–Bl3)

The Bayly Lake intrusive complex was examined along the southern shoreline of Oxford Lake, including Lynx Bay, and along the Hayes River south of Oxford Lake. Extensive shoreline exposures in the latter locality provide a roughly 4 km transect across the marginal zone of the complex. From south to north along this transect, the complex includes gabbroic–tonalitic orthogneiss (unit Bl1), biotite-hornblende tonalite (unit Bl2) and biotite tonalite–granodiorite (unit Bl3). Crosscutting relationships in outcrop and map patterns suggest that emplacement ages become progressively younger toward the north. The biotite tonalite intrudes the Hyers assemblage and lies in tectonic contact to the north with the Cat Eye Bay assemblage along the Lynx Bay shear zone.

The orthogneiss (unit Bl1) consists of strongly layered and recrystallized gabbroic and tonalitic components that preserve evidence of an early phase of ductile deformation (Figure GS-1-5a). The biotite-hornblende tonalite varies from equigranular to plagioclase phyric (subunits Bl2a and 2b, respectively) and is also strongly recrystallized, with a penetrative L>S shape fabric defined by mineral aggregates. Aside from minor inclusions of orthogneiss and amphibolite, it tends to be very homogeneous; dikes of this tonalite discordantly cut the orthogneiss. The biotite tonalite and granodiorite are texturally similar to the biotite-hornblende tonalite; along the northern margin of the complex, however, they locally include a distinctive porphyritic phase (subunit Bl3b) that contains coarse (up to 10 mm) subhedral phenocrysts of blue-grey quartz (2–10%) in a fine-grained matrix of feldspar, quartz and biotite.

Lynx Bay intrusive suite (units Lb1–Lb3)

The Lynx Bay intrusive suite is best exposed and most extensive in southern Lynx Bay, where each of the different components is present in outcrop. It includes serpentinized peridotite (unit Lb1) and gabbro (unit Lb3), with minor pyroxenite (unit Lb2). The peridotite is only observed in the type locality, whereas the gabbro is much more widespread and forms abundant thick dikes in the Hyers assemblage and Bayly Lake complex; it may also correlate with gabbro sills and dikes in the Cat Eye Bay assemblage.

Unit Lb1 defines an irregular sill-like intrusion that is traced along strike for approximately 4 km and is bounded by gabbro and pyroxenite. The peridotite is typically bluish green and massive, with locally well-preserved cumulate texture defined by closely packed euhedral crystals of serpentinized olivine up to 2 cm in size (subunit Lb1a; Figure GS-1-5b). Some outcrops are vaguely layered or contain irregular networks of fibrous serpentine veins. Spectacular examples of glacially sculpted and polished outcrops in two locations suggest that this material might be suitable for carving. Rare outcrops of breccia (subunit Lb1b) consist of large blocks of cumulate-textured peridotite in a matrix of talc-serpentine schist.

The gabbro (unit Lb3) and lesser pyroxenite (unit Lb2) form sill-like intrusions and dikes that range up to 200 m in thickness. The gabbro is typically fine to medium grained, equigranular and mesocratic (subunit Lb3a), with a weak to moderate foliation. It is variably recrystallized and locally contains sparse plagioclase phenocrysts up to 1.5 cm in size (subunit Lb3b). Contacts are sharp and planar, with thick (3–10 cm) chilled margins. Within the Bayly Lake complex at Lynx Bay and

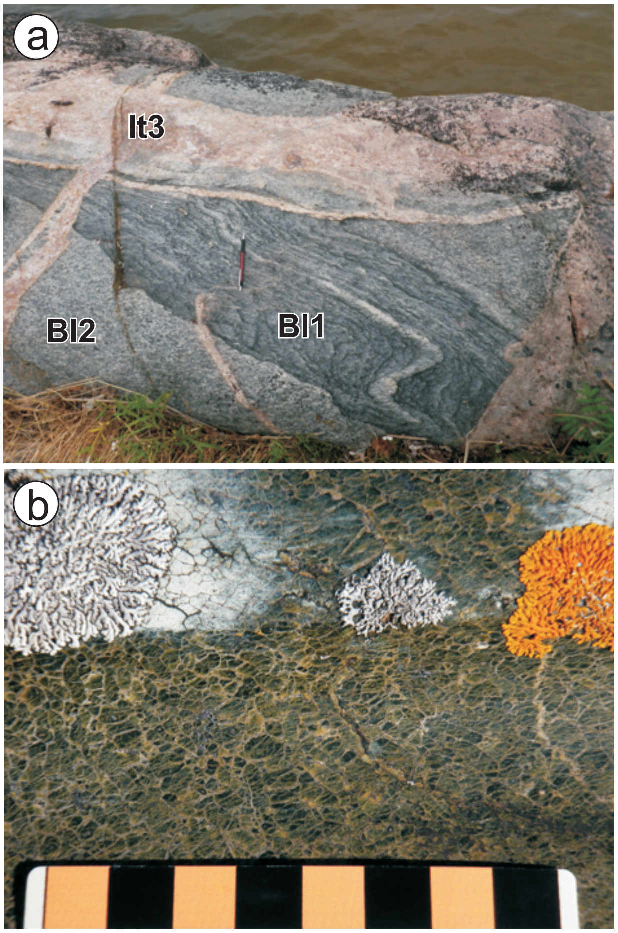


Figure GS-1-5: *Outcrop photographs of key rocks in the Bayly Lake intrusive complex and Lynx Bay intrusive suite:* ***a)*** *layered and folded orthogneiss (unit Bl1) crosscut by dikes of biotite-hornblende tonalite (unit Bl2) and syenogranite (unit It3), eastern shoreline of the Hayes River, south of Oxford Lake;* ***b)*** *serpentinized peridotite (subunit Lb1a), small island adjacent to southeast shoreline of Lynx Bay; cumulate texture is defined by closely packed euhedral crystals of serpentinized olivine.*

along the Hayes River, the gabbro contains inclusions and large rafts of tonalite but is nowhere cut by tonalite; most outcrops are very homogeneous.

Intratectonic intrusive rocks (units It1–It4)

With the exception of the Cat Eye Bay pluton, the intratectonic intrusive rocks identified in the study area occur as dikes that are too small to map at 1:20 000 scale. The term ‘intratectonic’ refers to the fact that the dikes discordantly cut at least one generation of ductile deformation fabric in the country rock but were overprinted by later ductile or brittle-ductile deformation and are also recrystallized. Their presence in only the south panel indicates a distinct magmatic and deformational history, and possibly older depositional age, for the supracrustal country rocks.

Diabase dikes of unit It1 intrude the Hyers assemblage and discordantly cut plutonic rocks of the Bayly Lake complex and Lynx Bay intrusive suite. The diabase is fine grained, equigranular and homogeneous, and weathers a distinctive dark emerald green. It forms narrow (<50 cm) planar dikes with well-developed chilled margins. At the east end of Hyers Island, they clearly postdate at least two earlier generations of mafic intrusion and brittle-ductile deformation but are themselves tightly folded.

Biotite tonalite dikes of unit It2 intrude the lower and middle sections of the Cat Eye Bay assemblage at the type locality in western Cat Eye Bay. This tonalite is light grey, homogeneous and contains blocky phenocrysts of plagioclase (20–30%; 1–4 mm) in a fine-grained groundmass of plagioclase, quartz and biotite, with accessory epidote and pyrite. The dikes are typically 1–2 m in thickness and have sharp planar contacts. They crosscut the tectonite fabric in the country rocks at shallow angles but also contain a weak to moderate foliation. A sample of this tonalite has been submitted for U-Pb geochronology to constrain the minimum depositional age of the Cat Eye Bay assemblage.

Syenogranite dikes of unit It3 are abundant in the northern portion of the Bayly Lake complex along the Hayes River. They discordantly cut gabbro dikes of the Lynx Bay intrusive suite, as well as the intense regional L>S shape fabric, and are not observed north of the Lynx Bay shear zone in the Cat Eye Bay assemblage. The syenogranite is light pink, aplitic to pegmatitic and consists of equigranular K-feldspar and quartz, with minor plagioclase and biotite, and rare accessory garnet. These dikes are typically less than 1 m thick and have sharp planar contacts (Figure GS-1-5a). Along the southern margin of the Lynx Bay shear zone, they crosscut greenschist-facies dextral mylonite but are offset in a right-lateral sense by discrete brittle-ductile shear zones, perhaps indicating that they were emplaced during the later increments of dextral transcurrent shearing. The apparent absence of these dikes north of the Lynx Bay shear zone might indicate that the Cat Eye Bay assemblage was juxtaposed with the Bayly Lake complex later in the tectonic evolution of the belt.

Biotite tonalite of the Cat Eye Bay pluton (unit It4) is well exposed in extensive clean shoreline outcrops in the central and eastern portions of its namesake bay. The tonalite is light grey, medium grained and equigranular, and is very homogeneous in most locations. It consists of plagioclase and quartz, with minor biotite and K-feldspar, and accessory epidote, magnetite and titanite. The titanite forms particularly coarse (1–3 mm) euhedral crystals that are characteristic features of this tonalite. The tonalite contains very minor quartz veins, aplite dikes and small inclusions of fine-grained quartzofeldspathic material, and typically contains a weak to moderate foliation defined by biotite. In one location near the northern margin, it contains large rafts of tectonized basalt. Although Hubregtse (1985) included this pluton in the Bayly Lake complex, the distinctive field characteristics of these units indicate that they are unrelated.

North panel

As indicated above, the north panel of the Oxford Lake belt contains the Carghill assemblage and is bounded to the north by granodiorite of the Semple River pluton and to the south by the CSZ. This panel appears to continue along strike to the east and west, beyond the limits of the 2012 map area, and may be contiguous with the narrow septa of supracrustal rocks that define the Carrot River greenstone belt west of Oxford Lake.

Carghill assemblage (units Ci1–Ci9)

The Carghill assemblage crops out along the northern shoreline of Oxford Lake and adjacent islands, and is interpreted to underlie all of Carghill Island. The lower section of the assemblage consists of pillowed basalt, with minor gabbro and mafic volcaniclastic rocks, whereas the upper section is considerably more diverse, with mafic to felsic flows, subvolcanic intrusions, proximal volcaniclastic rocks and derived epiclastic rocks, and minor iron formation. Barry (1960) assigned these sections to lower and upper 'units' of the HRG, and described the contact as "conformable or gradational", whereas Hubregtse (1985) assigned the lower section to the HRG and the upper section to the volcanic subgroup of the OLG and argued, on the basis of map patterns and structural trends, for an unconformable contact relationship. Using the available age constraints from Knee Lake (Corkery et al., 2000), the latter interpretation would require a depositional gap of approximately 100 m.y. at this contact and would thus be incompatible with a single tectonostratigraphic assemblage.

Observations made during the 2012 field season do not shed substantial new light on the nature of this contact. Younging criteria indicate a tightly folded but generally south-younging stratigraphy. Bedding orientations above and below the contact are generally concordant, except where obviously folded, and the field characteristics of subvolcanic intrusions in the lower section and effusive volcanic rocks in the upper section strongly suggest a primary depositional relationship. In the area west of Carghill Island, the contact appears to coincide with a distinctive interval of thin-bedded sulphidic mudstone, oxide-facies iron formation and greywacke, with minor lenses of polymictic conglomerate and pillowed basalt, indicating that deposition occurred in a relatively quiescent marine setting. However, in the absence of absolute age constraints, it would be premature to assign special significance to this interval. A sample of greywacke from the upper section, above the purported unconformity, has been submitted for U-Pb dating of detrital zircons to constrain the maximum depositional age. One of the goals for the 2013 field season will be to establish similar constraints for the lower section.

As noted above, the lower section of the assemblage is dominated by basalt or basaltic andesite flows (unit Ci1) with minor mafic volcaniclastic rocks (unit Ci3), gabbro (unit Ci8) and iron formation (unit Ci7). The basalt is typically dark green, aphyric and sparsely amygdaloidal, and forms thick homogeneous flows composed of small (<50 cm) bun-shaped pillows with very minor interpillow hyaloclastite (subunit Ci1a). Subordinate flows of massive or brecciated basalt are typically less than 5 m thick. Near the base of the section, some of these flows are plagioclase phyric (subunit Ci1b) and, along the margin of the Semple River pluton, are converted to a strongly foliated garnet amphibolite (subunit Ci1c). Interlayers of mafic volcaniclastic rocks consist of well-stratified intervals of heterolithic tuff breccia and lapilli tuff (subunit Ci3a). Near the top of the section, the basalt flows contain thin (<1 m) layers of oxide-facies iron formation (subunit Ci7a; Figure GS-1-6a). Younging criteria everywhere indicate tops to the south. Subvolcanic intrusions are ubiquitous (unit Ci9) and typically form narrow (<1 m) dikes with sharp contacts and well-developed chilled margins. Various types are distinguished on the basis of composition and phenocryst populations (subunits Ci9a–e), and are generally representative of effusive rocks in the upper section of the assemblage.

The upper section of the assemblage consists of a very diverse association of rock types that, for the sake of brevity, will not be described in detail here. Mesoscopic deformation structures and abundant younging criteria indicate two generations of tight to isoclinal folding and associated transposition, followed by dextral transcurrent shearing and crossfolding; consequently, the stratigraphy of the upper section is poorly understood. West of Carghill Island, the base of the section is defined by a 200–300 m thick interval of thin-bedded greywacke, sulphidic mudstone, oxide-facies iron formation and conglomerate (unit Ci6). This interval includes minor pillowed basalt flows (unit Ci1), gabbro (unit Ci8) and intermediate to felsic volcaniclastic rocks (unit Ci4), and is traced on the basis of its distinctive aeromagnetic signature to Carghill Island, where it appears to be truncated by a fault. It is overlain by a thick succession of interlayered volcanic conglomerate (unit Ci5; Figure GS-1-6b) and thin-bedded greywacke-mudstone turbidites (subunit Ci6a), which are the characteristic rock types of the upper section. These rocks are discontinuously exposed from the southern shoreline of Carrot Bay to Traverse Island. Several distinct subunits of volcanic conglomerate (subunits Ci5a–c) are recognized on the basis of clast populations. Unit Ci5 is interstratified north of Thomsen Island with massive or brecciated flows of porphyritic (plagioclase and/or pyroxene) basaltic andesite and andesite (unit Ci2). On Traverse Island, it includes thick intervals of intermediate to felsic volcaniclastic rocks (unit Ci4) that locally contain

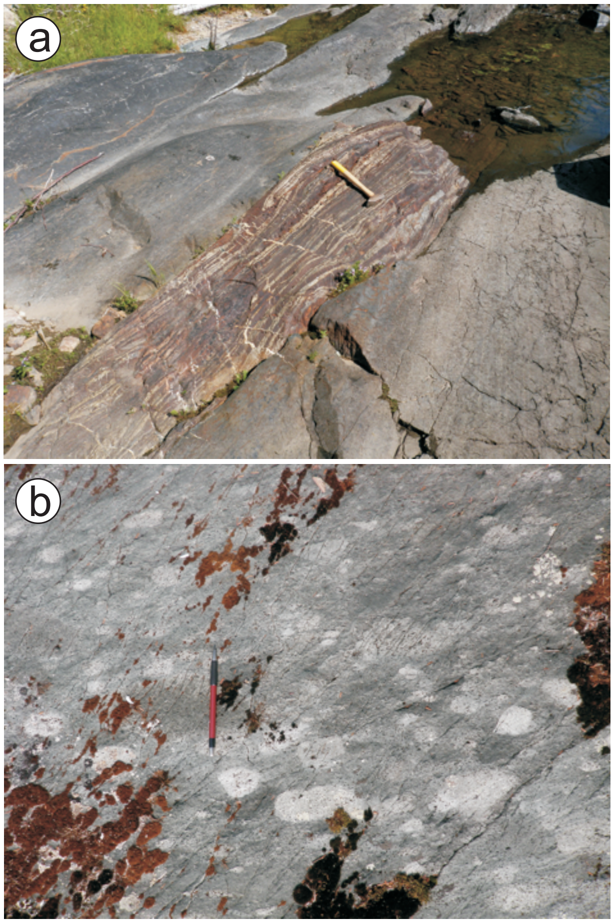


***Figure GS-1-6:** Outcrop photographs of representative rocks in the Carghill assemblage: **a)** thin layer of oxide-facies iron formation (subunit Ci7a) in pillowed aphyric basalt (subunit Ci1a) near the top of the lower section, southern shoreline of the large island at the southwest end of Carghill Channel; **b)** polymictic volcanic conglomerate (subunit Ci5a) composed of subangular to rounded clasts of plagioclase (±pyroxene)–phyric andesite, southern shoreline of Traverse Island.*

collapsed pumice and likely represent pyroclastic deposits. Although geochemical data from samples collected in 2012 are pending, the field characteristics of these volcanic rocks indicate a probable correlation with ca. 2705 Ma (Lin et al., 2006) shoshonite to high-K andesite–dacite–rhyolite series volcanic rocks farther to the east in the Oxford Lake belt (Hubregtse, 1978, 1985; Brooks et al., 1982).

Carghill Channel layered intrusion (units Cc1 and Cc2)

This intrusion is exposed along the northern shoreline of Carghill Channel near its southwest end. It is traced along strike for 7 km and varies from 100 m thick in the west to more than 800 m thick in the east; it is open in both directions. The intrusion consists mostly of gabbro (unit Cc2) with minor peridotite (unit Cc1) and contains thin enclaves of sedimentary rock (subunits Ci5b and 6c). The gabbro is typically mesocratic, equigranular and homogeneous (subunit Cc2b) but locally contains pegmatitic phases (subunit Cc2d) and thick layers of melanocratic gabbro (subunit Cc2a) and porphyritic gabbro (subunit Cc2c). The peridotite is exposed on a small island near the base of the intrusion at its southwest end and exhibits a fine-grained cumulate texture defined by tightly packed equant crystals (1–2 mm) of serpentinized olivine.

Central panel

The central panel of the Oxford Lake belt contains the Thomsen assemblage and is bounded to the north and south by the CSZ and HSZ, respectively. This panel is clearly identified by high-resolution aeromagnetic survey data, and coincides with a prominent linear magnetic trough that extends along the axis of the Oxford Lake belt.

Thomsen assemblage (units Ti1–Ti4)

The Thomsen assemblage crops out on islands in widely separated locations in western and central Oxford Lake, and is defined to include four distinct map units. The most extensive exposures occur east of Thomsen Island and consist mostly of greywacke (unit Ti3) and polymictic conglomerate (unit Ti2) that were assigned to the OLG by Barry (1960) and Hubregtse (1985). Also included in this assemblage is a distinctive unit of quartz arenite (unit Ti4) 600 m northeast of Hyers Island that was assigned to the OLG by Barry (1960) and to the Lynx Bay assemblage of the Bayly Lake complex by Hubregtse (1985). For the reasons described below, the assemblage is also thought to include basaltic flows west of Thomsen Island (unit Ti1), which were assigned to the HRG by Barry (1960) and Hubregtse (1985).

As described by these workers, a contact between 'HRG' basalt and 'OLG' conglomerate is exposed on the southeastern shoreline of Thomsen Island (Figure GS-1-7). The outcrop at this locality shows massive basalt in sharp contact to the east with polymictic conglomerate. Flow contacts and pillow tops in the basalt indicate it is part of a north-younging subvertical homocline, whereas bedforms in the conglomerate indicate it is disposed in an upright, tight, macroscopic fold that trends east from the contact (the contact locality is situated in the hinge of this fold). Bedforms in conglomerate just east of the contact dip steeply west, roughly concordant with the contact, and are nearly orthogonal to an exposed flow contact 40 m to the west in the basalt. On this basis, Barry (1960) and Hubregtse (1985) described this locality as a folded angular unconformity across which north-younging HRG basalt is overlain by east-younging OLG conglomerate.

Although appealing many respects, this interpretation is difficult to reconcile with the field relationships observed by the present authors along the southeastern

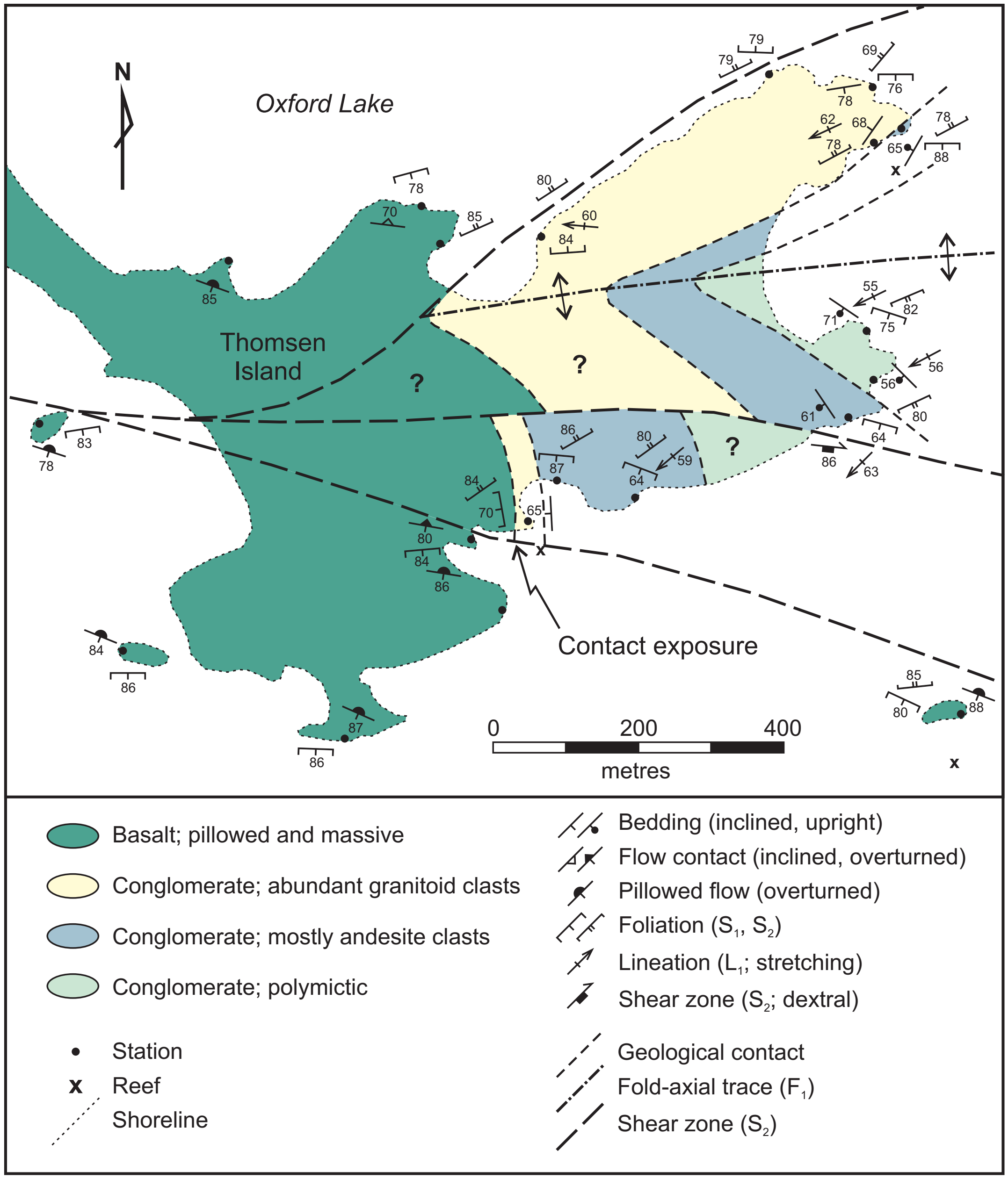


Figure GS-1-7: *Sketch map of the geology and structure of southern Thomsen Island, showing an interpretation of the stratigraphy and structure that is compatible with observed field relationships and does not require the presence of an angular unconformity (see text for discussion).*

shoreline of Thomsen Island. Of particular concern are unambiguous younging criteria (i.e., crossbeds and scours) in the conglomerate, which consistently indicate that it becomes younger toward the basalt, in a direction opposite to that predicted by the unconformity model (Figures GS-1-7, -8a). Moving across strike toward the contact, consistent bedding-cleavage (S_0-S_1) angular relationships are also observed in the conglomerate; hence, the presence of an early generation of refolded isoclinal fold—as postulated by Hubregtse (1985, Figure 34), apparently as a means to explain the incompatible younging directions—is considered unlikely. Furthermore, our examination of the contact revealed that the basalt is chilled and amygdaloidal, and penetrates several centimetres into the conglomerate to envelop rounded 'exotic' (i.e., nonbasaltic) clasts (Figure GS-1-8b). Coupled with the younging criteria, this indicates that the basalt overlies, or perhaps intruded, the conglomerate; hence, it is assigned to the Thomsen assemblage and the apparent angular discordance is attributed to later deformation (Figure GS-1-7).

Basalt and basaltic andesite (unit Ti1) of the Thomsen assemblage are exposed along the southwestern shoreline

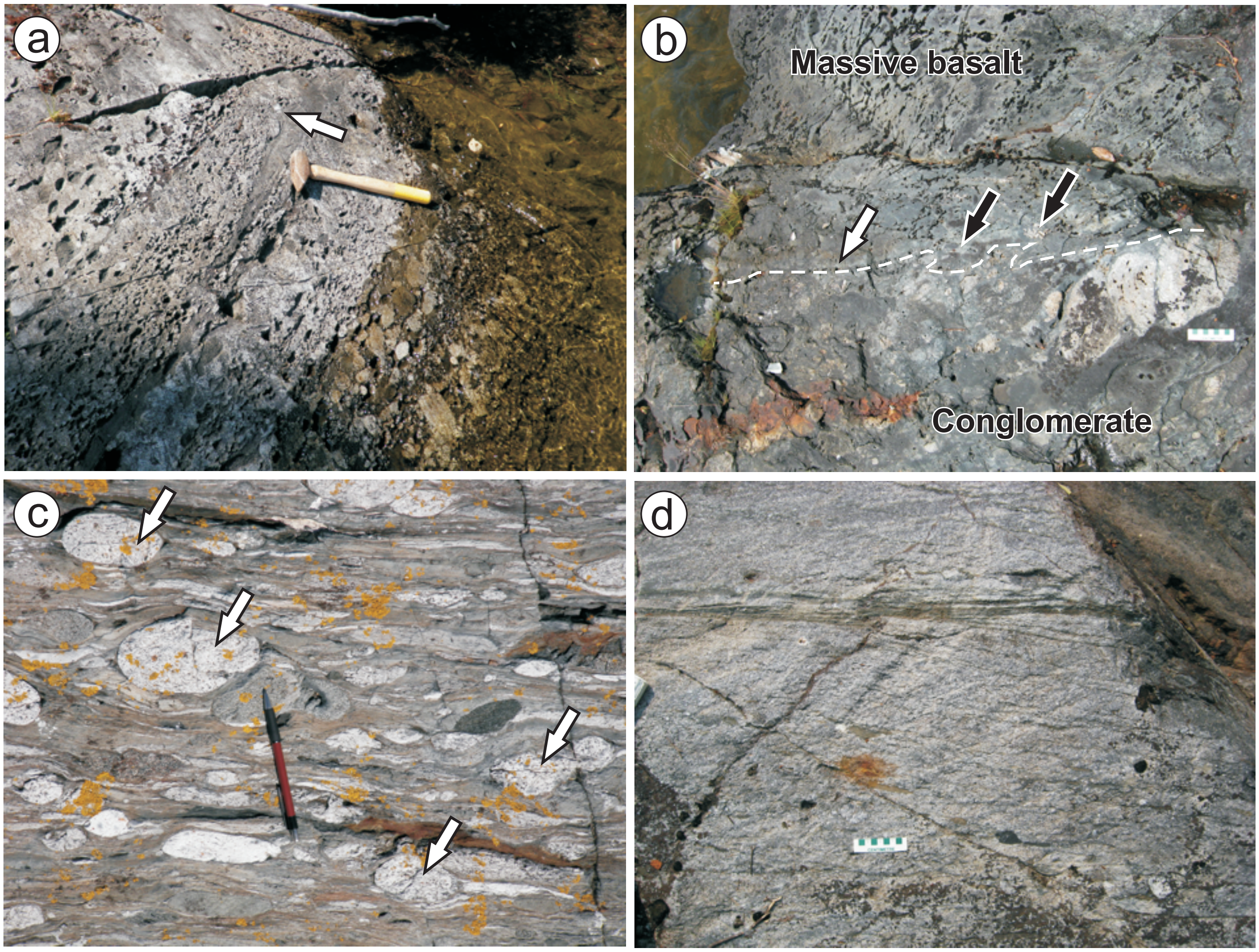


Figure GS-1-8: *Outcrop photographs of key rocks in the Thomsen assemblage:* ***a)*** *bedded polymictic conglomerate (subunit Ti2a), southeastern Thomsen Island; scour (arrow) and normally graded beds indicate tops to southwest; hammer handle points north;* ***b)*** *contact between 'HRG' basalt on west (top of photo) and 'OLG' conglomerate on east (bottom of photo), southeastern Thomsen Island; contact (dashed line) is locally chilled (white arrow) and extends several centimetres into the conglomerate to envelop rounded clasts of various rock types (black arrows);* ***c)*** *polymictic conglomerate (subunit Ti2b), small island 800 m north of the east end of Cat Eye Bay; note well-rounded granitoid clasts;* ***d)*** *crossbedded pebbly quartz arenite (unit Ti4) from the locality 600 m northeast of Hyers Island.*

of Thomsen Island and several small islands immediately to the west. The basalt is aphyric, sparsely amygdaloidal and locally variolitic, and tends to form particularly large bun-shaped pillows with prominent selvages. Massive flows and thin layers of amoeboid pillow breccia are minor components of this unit, and pillow orientations and cusps everywhere indicate tops to the north.

Polymictic conglomerate of unit Ti2 is exposed along the southeastern shoreline of Thomsen Island and at various locations along the chain of islands and small reefs that extend to the east. It is particularly well exposed on a small wave-washed island approximately 800 m north of the east end of Cat Eye Bay, which lies immediately north of the Hyers shear zone. The conglomerate is matrix supported, poorly sorted and varies from crudely stratified to well bedded. Planar or lenticular beds in the latter display normal, reverse or compound size-grading and are interlayered with pebbly greywacke (Figure GS-1-8a). Two subunits are recognized on the basis of clast population: subunit Ti2a consists of locally derived clasts of volcanic and sedimentary rocks, whereas subunit Ti2b contains a distinct population of well-rounded, high-sphericity granitoid clasts that were apparently derived from more deeply eroded sources and underwent significant subaerial transport (Figure GS-1-8c). A sample of quartz greywacke from a thin interbed in subunit Ti2b at Thomsen Island has been submitted for U-Pb detrital zircon geochronology. Both subunits are thickly interlayered with intervals of planar-bedded feldspathic greywacke and mudstone (unit Ti3), indicating coeval deposition in a subaqueous fan setting.

Quartz arenite of unit Ti4 is exposed on a small peninsula and adjacent islands approximately 600 m northeast of Hyers Island. The quartz arenite is light grey or white, medium to coarse grained and pebbly, and is interstratified with polymictic conglomerate (subunit Ti4b) and sericitic mudstone (subunit Ti4a). Both quartz arenite and conglomerate contain tabular-planar and trough crossbeds (Figure GS-1-8d), indicating deposition in a subaerial fluvial setting. Beds of matrix- or clast-supported pebble to cobble conglomerate contain well-rounded clasts of vein quartz, chert and solid sulphide. These rocks are comparable to fluvial sandstone and conglomerate described by Syme et al. (1997) from Knee Lake, which have a maximum depositional age of ca. 2707 Ma (Corkery et al., 2000). A sample of the quartz arenite northeast of Hyers Island has been submitted for U-Pb detrital zircon geochronology.

Post-tectonic dikes (units Pt1 and Pt2)

A northeast-trending diabase dike is traced through Carrot Bay using high-resolution aeromagnetic survey data, and is inferred on the basis of field characteristics and orientation to be part of the Molson swarm (unit Pt1). This dike is exposed in two locations and varies from 30 to 40 m thick. The hangingwall contact in both locations dips at moderate to steep angles to the northwest and displays a very thick (~1 m) chilled margin. The diabase is medium grained, equigranular and massive, and appears to be magmatically zoned toward the hangingwall contact from melanocratic at the base to leucocratic at the top.

Two closely spaced, northwest-trending diabase dikes are also traced through Carrot Bay using high-resolution aeromagnetic survey data, and are inferred on the basis of field characteristics and orientation to be part of the Mackenzie swarm (unit Pt2). The eastern dike is exposed on both shorelines of the peninsula between Carrot Bay and Lynx Bay, and is approximately 25 m thick in outcrop. It is homogeneous and massive (i.e., nonfoliated), and consists of medium-grained equigranular diabase that is strongly magnetic.

Structural geology

Supracrustal and intrusive rocks at Oxford Lake are variably metamorphosed and deformed. Metamorphic grade varies from amphibolite facies (hornblende±garnet, cordierite) along the margins of the belt to greenschist facies (chlorite±biotite, actinolite, sericite) in the interior. Map patterns, mesoscopic deformation structures and overprinting relationships indicate that the supracrustal rocks have been affected by at least three generations of ductile deformation structures. The earliest recognized structures are rare, tight to isoclinal, asymmetric fold closures and associated axial-planar foliations in intervals of thin-bedded greywacke and iron formation in the upper section of the Carghill assemblage (Figure GS-1-9a). These structures are overprinted by upright, tight to isoclinal, steeply plunging F_2 folds that appear to be parasitic to macroscopic F_2 closures that dominate map patterns in the interior portions of the major structural panels. These folds are associated with a penetrative and pervasive, subvertical, axial-planar S_2 foliation that trends east and is the main fabric observed in most outcrops outside of late shear zones. It is defined most prominently by flattened primary features and locally intensifies into a penetrative transposition fabric. Map patterns and reversals in structural facing direction indicate that the F_2 folds are doubly plunging on a macroscopic scale. Aligned metamorphic minerals and elongate primary features define down-dip mineral and stretching lineations, respectively, in the S_2 foliation plane. Along the margins of the belt, this L_2 lineation is defined by aligned hornblende porphyroblasts, indicating that it was likely coeval with peak metamorphism. Variations in the aspect ratios of deformed clasts, from markedly prolate (cigar shaped; Figure GS-1-9b) to oblate (pancake shaped), define distinct structural domains within and between the shear-bounded panels and may correlate with position in the macroscopic F_2 fold structures. However, the possibility of overprinting deformations cannot be ruled out. The S_2-L_2 fabric is generally symmetric, indicating that it is likely the product of flattening and stretching without significant translation.

Macroscopic F_2 folds at Oxford Lake are disrupted by an anastomosed network of subvertical ductile shear zones that bound the major structural panels and vary from northwest to southwest trending. These shear zones are characterized by penetrative mylonitic foliations defined by fine-grained chlorite and sericite with very well developed shear-sense indicators (e.g., S-C fabrics, shear bands, offset markers and asymmetric folds, porphyroclasts and boudins) on horizontal outcrop surfaces. Shear-sense indicators in northwest- or west-trending shear zones generally indicate dextral movement (Figure GS-1-9c), whereas those in southwest-trending segments indicate sinistral movement (Figure GS-1-9d). The most prominent example of the latter is the southwest extension of the Lynx Bay shear zone, which forms the western boundary of a large promontory in the northern margin of the Bayly Lake intrusive complex. Stretching lineations are everywhere steep, but the shear zones locally contain mineral or slickenline lineations that plunge shallowly in the plane of the mylonitic foliation; these features can be interpreted in terms of overprinting deformations or a single progressive deformation of transpressional style, as has been described for similar structures at Knee Lake and elsewhere (e.g., Lin and Jiang, 2001; Lin et al., 2006). Asymmetric Z-folds are developed throughout the western portion of the Oxford Lake belt and are associated with a weak to moderate axial-planar crenulation cleavage (S_3) that overprints the regional S_2 foliation and isoclinal F_2 folds at a shallow counterclockwise angle (Figure GS-1-9e). Mutual overprinting relationships with the mylonitic foliation in the dextral shear zones indicate contemporaneous folding and shearing during the latest increments of ductile deformation at Oxford Lake.

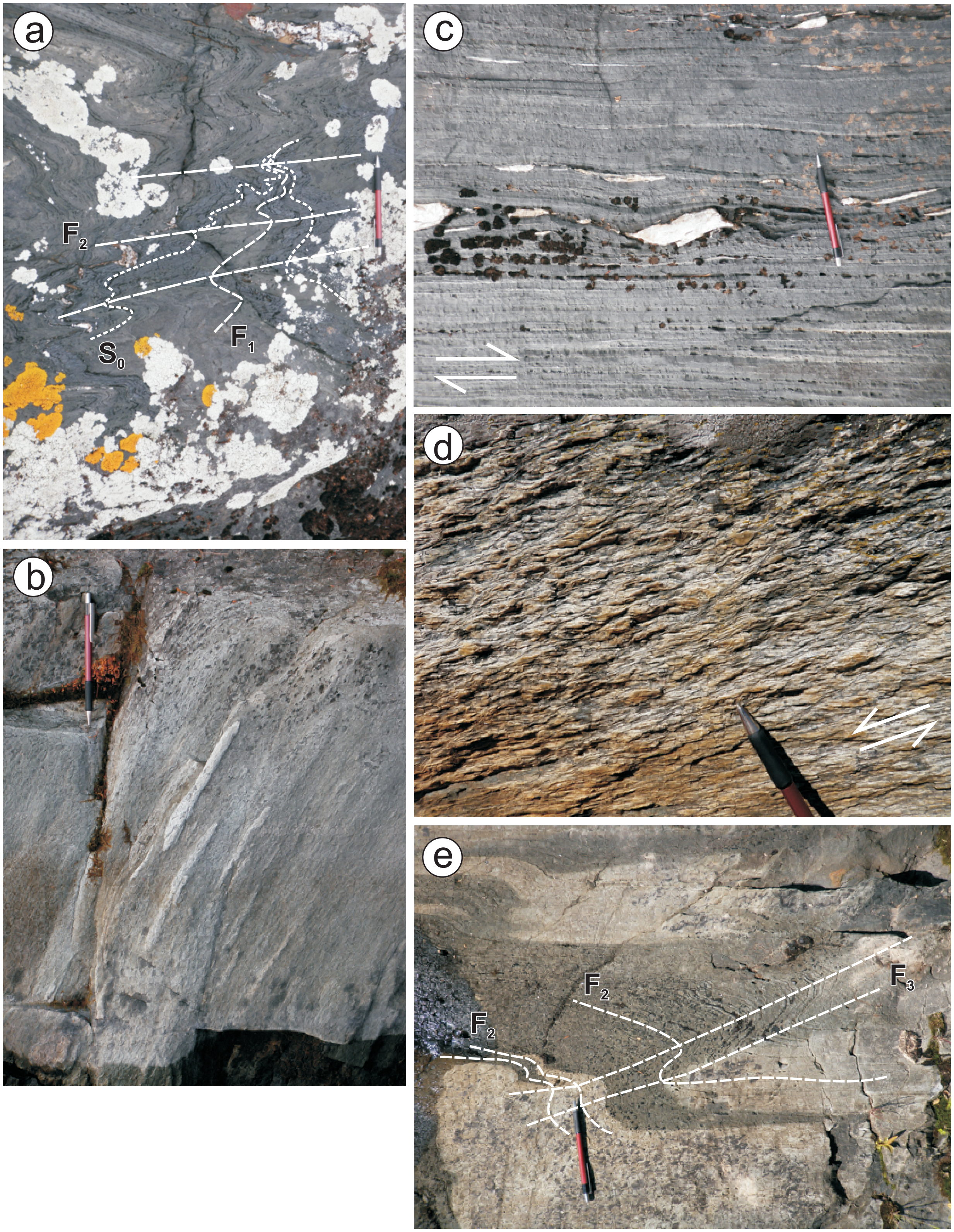


***Figure GS-1-9:** Outcrop photographs of mesoscopic deformation structures in the study area: **a)** isoclinal F_1 fold (defined by iron formation; S_0) overprinted by tight to isoclinal F_2 folds, Carghill assemblage, northeast of Carrot Bay; **b)** steep prolate L_2 stretching lineation defined by elongate clasts in volcanic conglomerate, Carghill assemblage, west of Thomsen Island; **c)** shear bands and asymmetric quartz boudins in chloritic mylonite of the Hyers shear zone (indicating dextral movement), northeast of Cat Eye Bay; pencil points north; **d)** S-C fabric and shear bands in tonalitic mylonite in the southwest-trending segment of the Lynx Bay shear zone (indicating sinistral movement), south of Lynx Bay; **e)** overprinting relationships between isoclinal F_2 S-folds and open F_3 Z-folds, Carghill assemblage, northeast of Carrot Bay.*

Economic considerations

Previous mineral exploration at Oxford Lake has resulted in the discovery of several base- and precious-metal occurrences in the western portion of the lake, thus demonstrating its significant exploration potential. Results from the 2012 mapping program improve understanding of the stratigraphic and structural context of these occurrences and can therefore be used to formulate new exploration strategies. The Cat Eye Bay occurrence (A.F. 93258) is interpreted to represent strongly deformed and metamorphosed, exhalative base-metal sulphide mineralization situated on the south limb of a major anticline. A thick sulphide-facies iron formation appears to define the equivalent stratigraphic interval on the north limb of this fold and may thus represent an important marker horizon for base-metal exploration. At Hyers Island, massive ankerite defines one or more stratiform horizons with all the hallmarks of exhalative base-metal sulphide systems, and is associated with one known copper deposit (A.F. 72236); ongoing lithogeochemistry and geochronology will help elucidate the stratigraphic setting of these horizons. The preliminary results from our detailed structural analysis of folds and shear zones at Oxford Lake provide important new constraints on the possible structural settings and controls of gold mineralization, and provide an improved geological context for the Rusty zone (A.F. 72085), which is the most significant deposit discovered to date.

From an economic perspective, one of the interesting results of the 2012 program is the identification of a possible carbonatite dike on the southern shoreline of the large island in the Hayes River (Figure GS-1-2). This dike is recessively weathered and hosted by biotite tonalite of the Bayly Lake intrusive complex. It is approximately 1.5 m thick and consists of alternating bands of carbonate and apatite, with thin septa of altered tonalite. In one location, a narrow subsidiary dike appears to fill a right-stepping dilational jog along a dextral shear fracture. The dike contacts are sharp, planar and flanked by narrow haloes of potassic alteration in the tonalite. Petrographic examination of thin sections indicates that the mineralogy is dominated by calcite (possibly also dolomite) and apatite, with subordinate magnetite, chlorite, clinopyroxene, amphibole, monazite, biotite, allanite and zircon. Whole-rock geochemistry reveals enriched rare earth elements (REE) + Y (1000 ppm) and Sr (1643 ppm). Trace and REE patterns are similar to those for known carbonatite intrusions; however, further analyses are required to determine the exact nature of the Oxford Lake dike.

Acknowledgments

The authors thank M. Gregorchuk and R. Hiebert (University of Manitoba) and M. Hamilton (Brandon University) for cheerful assistance in the field; N. Brandson and E. Anderson (MGS) for efficient expediting services; P. Lenton, M. McFarlane, L. Chackowsky, M. Pacey and B. Lenton (MGS) for digital cartographic, GIS and drafting expertise; M. Koziol (Alto Ventures Ltd.) for logistical advice and free access to proprietary data; H. Crane for facilitating a meeting with the Chief and Council of the Bunibonibee Cree Nation; Wings Over Kississing for efficient air support; and L. Murphy (MGS) for leading a field visit by members of the Bunibonibee Cree Nation.

References

Anderson, S.D., Kremer, P.D. and Martins, T. 2012a: Geology and structure of southwest Oxford Lake (east part), Manitoba (parts of NTS 53L12, 13); Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, Preliminary Map PMAP2012-2, 1:20 000 scale.

Anderson, S.D., Kremer, P.D. and Martins, T. 2012b: Geology and structure of southwest Oxford Lake (west part), Manitoba (parts of NTS 53L12, 13, 63I9, 16); Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, Preliminary Map PMAP2012-1, 1:20 000 scale.

Barry, G.S. 1959: Geology of the Oxford House–Knee Lake area, Oxford Lake and Gods Lake Mining Divisions, 53L/14 and 53L/15; Manitoba Department of Mines and Natural Resources, Mines Branch, Publication 58-3, 39 p.

Barry, G.S. 1960: Geology of the western Oxford Lake–Carghill Island area, Oxford Lake Mining Division, 53L/13; Manitoba Department of Mines and Natural Resources, Mines Branch, Publication 59-2, 37 p.

Beaumont-Smith, C.J., Anderson, S.D., Bailes, A.H. and Corkery, M.T. 2003: Preliminary results and economic significance of geological mapping and structural analysis at Sharpe Lake, northern Superior Province, Manitoba (parts of NTS 53K5 and 6); *in* Report of Activities 2003, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 140–158.

Bell, R. 1879: Report on the country between Lake Winnipeg and Hudson Bay; Geological and Natural History Survey of Canada, Report of Progress for 1877–78, Part CC.

Bell, R. 1881: Report on Hudson's Bay and some of the lakes and rivers lying to the west of it; Geological and Natural History Survey of Canada, Report of Progress for 1879–80, Part C, p. 1C–113C.

Brock, R.W. 1911: The Hudson Bay route; *in* Summary Report of the Geological Survey Branch of the Department of Mines for the calendar year 1910; Sessional Paper 26, p. 14–26.

Brooks, C., Ludden, J., Pigeon, Y. and Hubregtse, J.J.M.W. 1982: Volcanism of shoshonite to high-K andesite affinity in an Archean arc environment, Oxford Lake, Manitoba; Canadian Journal of Earth Sciences, v. 19, p. 55–67.

Bruce, E.L. 1920: Knee Lake district, northeastern Manitoba; Canada Department of Mines, Geological Survey, Summary Report, 1919, Part D, p. 1D–11D.

Corkery, M.T., Cameron, H.D.M., Lin, S., Skulski, T., Whalen, J.B. and Stern, R.A. 2000: Geological investigations in the Knee Lake belt (parts of NTS 53L); *in* Report of Activities 2000, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 129–136.

Gilbert, H.P. 1985: Geology of the Knee Lake–Gods Lake area; Manitoba Energy and Mines, Geological Services, Geological Report GR83-1B, 76 p.

Haskins, R.A. and Stephenson, J.F. 1974: Geology and mineralization of western Oxford Lake and Carrot River (53L-13; 63I-16S, 9N); *in* Summary of Geological Field Work 1974, Manitoba Department of Mines, Resources and Environmental Management, Mineral Resources Division, Exploration and Geological Survey Branch, Geological Paper GP2/74, p. 35–46.

Haskins, R. and Evans, D.S. 1977: "Cat Eye Bay" (53L/13); *in* Report of Field Activities 1976, Manitoba Department of Mines, Resources and Environmental Management, Mineral Resources Division, Mineral Evaluation and Administration Branch, Exploration Operations Branch, p. 66–68.

Heaman, L.M., Machado, N., Krogh, T.E. and Weber, W. 1986: Precise U-Pb zircon ages for the Molson dyke swarm and the Fox River sill: constraints for Early Proterozoic crustal evolution in northeastern Manitoba; Contributions to Mineralogy and Petrology, v. 94, p. 82–89.

Hubregtse, J.J.M.W. 1978: Chemistry of cyclic subalkaline and younger shoshonitic volcanism in the Knee Lake–Oxford Lake greenstone belt, northeastern Manitoba; Manitoba Department of Mines, Resources and Environmental Management, Mineral Resources Division, Geological Paper GP78/2, 18 p.

Hubregtse, J.J.M.W. 1985: Geology of the Oxford Lake–Carrot River area; Manitoba Energy and Mines, Geological Services, Geological Report GR83-1A, 73 p.

LeCheminant, A.N. and Heaman, L.M. 1989: Mackenzie igneous events, Canada: Middle Proterozoic hotspot magmatism associated with ocean opening; Earth and Planetary Science Letters, v. 96, p. 38–48.

Lin, S. and Jiang, D. 2001: Using along-strike variation in strain and kinematics to define the movement direction of curved transpressional shear zones: an example from northwestern Superior Province, Manitoba; Geology, v. 29, p. 767–770.

Lin, S., Davis, D.W., Rotenberg, E., Corkery, M.T. and Bailes, A.H. 2006: Geological evolution of the northwestern Superior Province: clues from geology, kinematics, and geochronology in the Gods Lake Narrows area, Oxford–Stull terrane, Manitoba; Canadian Journal of Earth Sciences, v. 43, p. 749–765.

McInnes, W. 1913: The basins of Nelson and Churchill Rivers; Canada Department of Mines, Geological Survey, Memoir 30, 146 p.

Richardson, D.J. and Ostry, G. 1996: Gold deposits of Manitoba; Manitoba Energy and Mines, Economic Geology Report ER86-1 (2nd Edition), 114 p.

Skulski, T., Corkery, M.T., Stone, D., Whalen, J.B. and Stern, R.A. 2000: Geological and geochronological investigations in the Stull Lake–Edmund Lake greenstone belt and granitoid rocks of the northwestern Superior Province; *in* Report of Activities 2000, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 117–128.

Southard, G.G. 1977: Exploration history, compilation and review, including exploration data from cancelled assessment files, for the Gods, Knee and Oxford lakes areas, Manitoba; Manitoba Department of Mines, Resources and Environmental Management, Mineral Resources Division, Open File Report OF77/5, 93 p.

Stott, G.M., Corkery, M.T., Percival, J.A., Simard, M. and Goutier, J. 2010: A revised terrane subdivision of the Superior Province; *in* Summary of Field Work and Other Activities 2010, Ontario Geological Survey, Open File Report 6260, p. 20-1–20-10.

Syme, E.C., Corkery, M.T., Bailes, A.H., Lin, S., Cameron, H.D.M. and Prouse, D. 1997: Geological investigations in the Knee Lake area, northwestern Superior Province (parts of NTS 53L/15 and 53L/14); *in* Report of Activities, 1997, Manitoba Energy and Mines, Geological Services, p. 37–46.

Syme, E.C., Corkery, M.T., Lin, S., Skulski, T. and Jiang, D. 1998: Geological investigations in the Knee Lake area, northern Superior Province (parts of NTS 53L/15 and 53M/2); *in* Report of Activities, 1998, Manitoba Energy and Mines, Geological Services, p. 88–95.

Wright, J.F. 1926: Oxford and Knee Lakes area, northern Manitoba; *in* Canada Department of Mines, Geological Survey, Summary Report, 1925, Part B, p. 16B–26B.

Wright, J.F. 1932: Oxford House area, Manitoba; *in* Canada Department of Mines, Geological Survey, Summary Report, 1931, Part C, p. 1C–25C.