Bedrock Geology and Economic Potential of Western Oxford Lake, Manitoba

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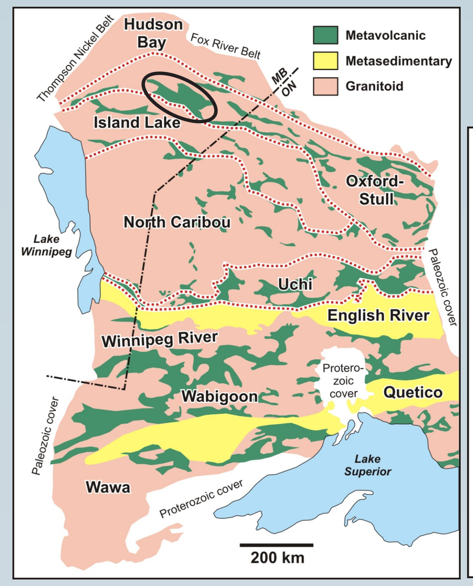
Introduction

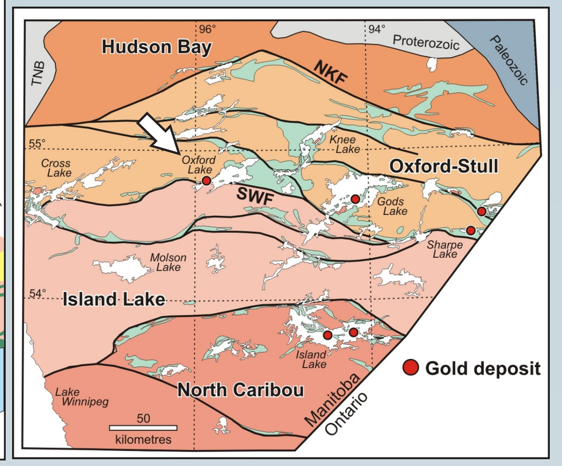
In 2012, the Manitoba Geological Survey initiated a program of bedrock geological mapping at Oxford Lake, at the western end of the Oxford Lake-Knee Lake belt. As the largest contiguous greenstone belt in the northwestern Superior Province, the Oxford Lake-Knee Lake belt is central to understanding the 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.

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.

Fieldwork in 2012 involved six weeks of 1:20 000 scale bedrock mapping of shoreline exposures in western Oxford Lake. This poster describes the preliminary results of this fieldwork; the results of follow-up analytical work will be reported in subsequent years of what is designed as a three-year mapping project.

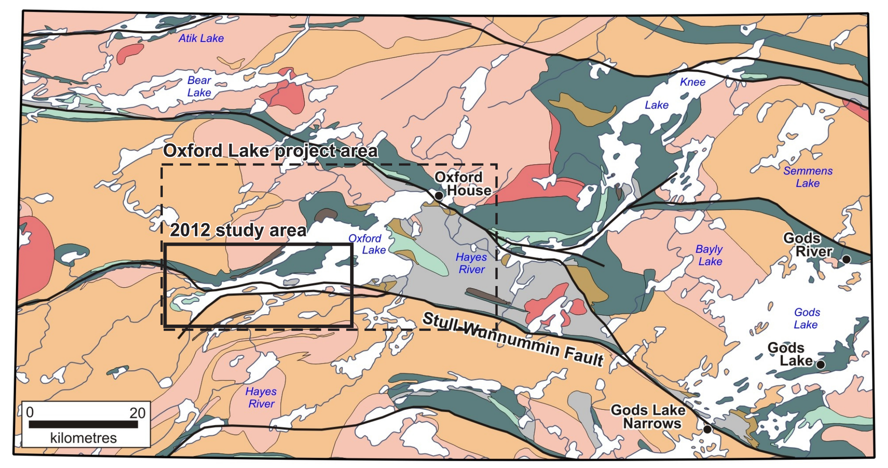




Regional setting

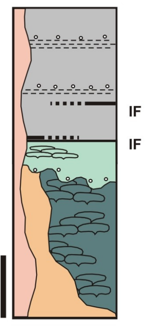
Oxford Lake is situated in the southwest portion of the regionally extensive Oxford Lake-Knee Lake greenstone belt in the Oxford-Stull Domain (OSD) of the western Superior Province (Stott et al., 2010). In Manitoba, the OSD consists of isotopically juvenile, ca. 2.85–2.70 Ga, subaqueous volcanic and sedimentary rocks and is interpreted to represent a fault-bounded oceanic terrane that was accreted to the north margin of the continental North Caribou terrane during amalgamation of the western Superior Province (Skulski et al., 2000).

The crustal-scale Stull-Wunnummin Fault defines the south margin of the OSD and is thought to represent a fundamental tectonic boundary in the northwestern Superior Province (Stott et al., 2010). The main strand of this fault trends from Sharpe Lake through Gods Lake Narrows to Oxford Lake, where it roughly coincides with the southern boundary of the Oxford Lake-Knee Lake belt.



Regional stratigraphy

In the original scheme of Wright (1932), supracrustal rocks in the OSD were divided into the Hayes River Group (HRG) and Oxford Lake Group (OLG; Barry, 1960; Gilbert, 1985; Hubregtse, 1985). The HRG consists of pillowed and massive basalt flows and gabbro, with minor intermediate to felsic volcanic rocks and fine-grained sedimentary rocks. It is intruded by voluminous tonalite-granodiorite plutons of the Bayly Lake complex and unconformably overlain by the OLG. Neither the stratigraphic base nor top of the HRG has been documented.



The OLG unconformably overlies the HRG and has been subdivided into a lower volcanic subgroup, consisting of high-K calcalkalic to shoshonitic volcanic rocks and locally derived epiclastic rocks (Hubregtse, 1978, 1985; Brooks et al., 1982; Gilbert, 1985), and an upper sedimentary subgroup consisting of greywacke-mudstone turbidite, iron formation, quartz-lithic wacke and polymictic conglomerate. The latter rocks were deposited in shallow-marine to subaerial settings, likely in fault-bounded basins.

Recent studies indicate that this stratigraphic scheme is oversimplified and requires revision. U-Pb (zircon) geochronological results indicate that felsic volcanism in the 'HRG' spans close to 200 m.y. (e.g., Corkery et al., 2000; Parks et al., 2006), whereas that in the volcanic subgroup of the OLG spans roughly 30 m.y. (e.g., Corkery et al., 2000; Lin et al., 2006) and was at least locally coeval with deposition of the sedimentary subgroup.

For these reasons, the traditional stratigraphic scheme has not been adopted for this study.

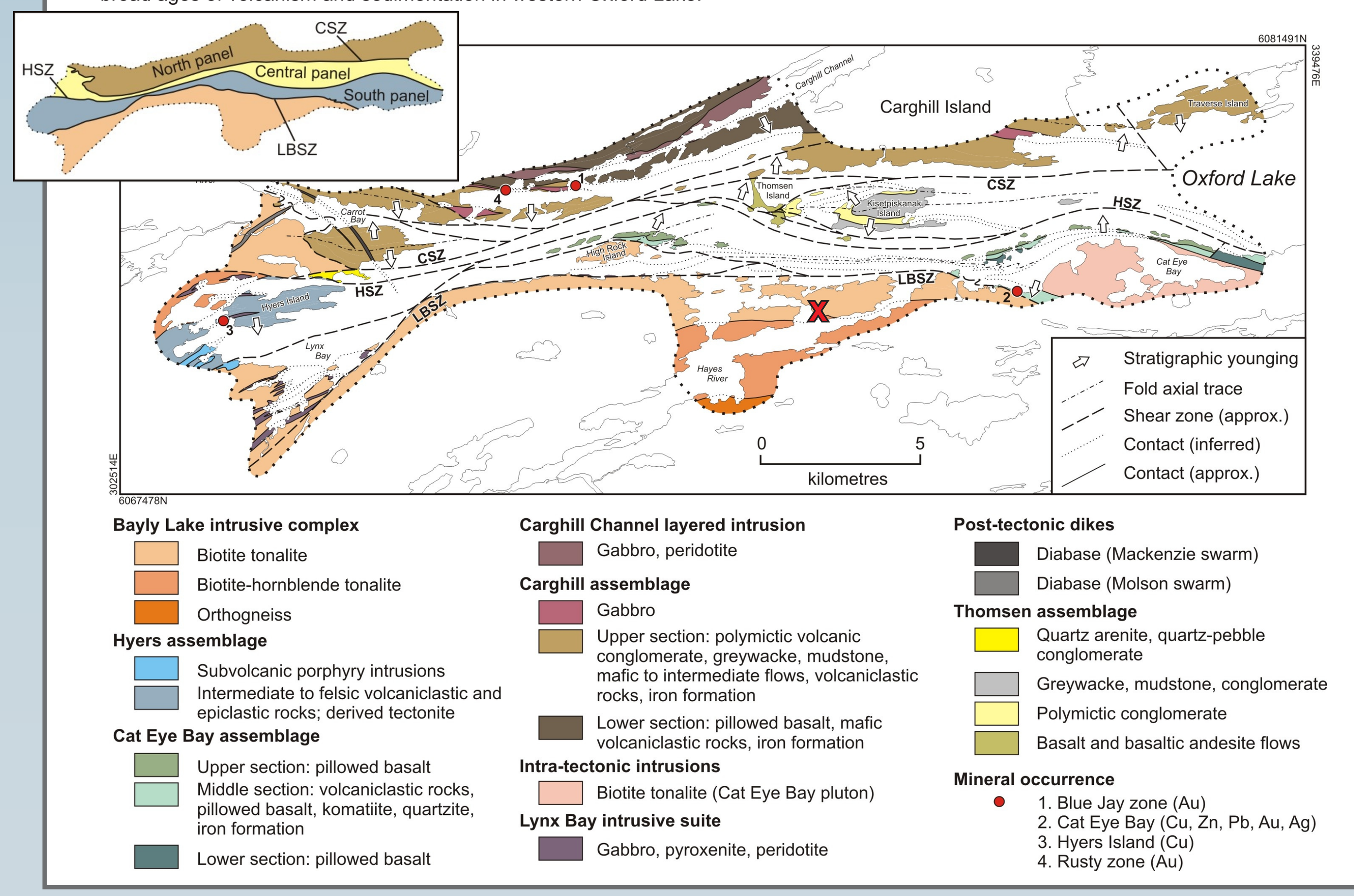
Local geology and tectonostratigraphy

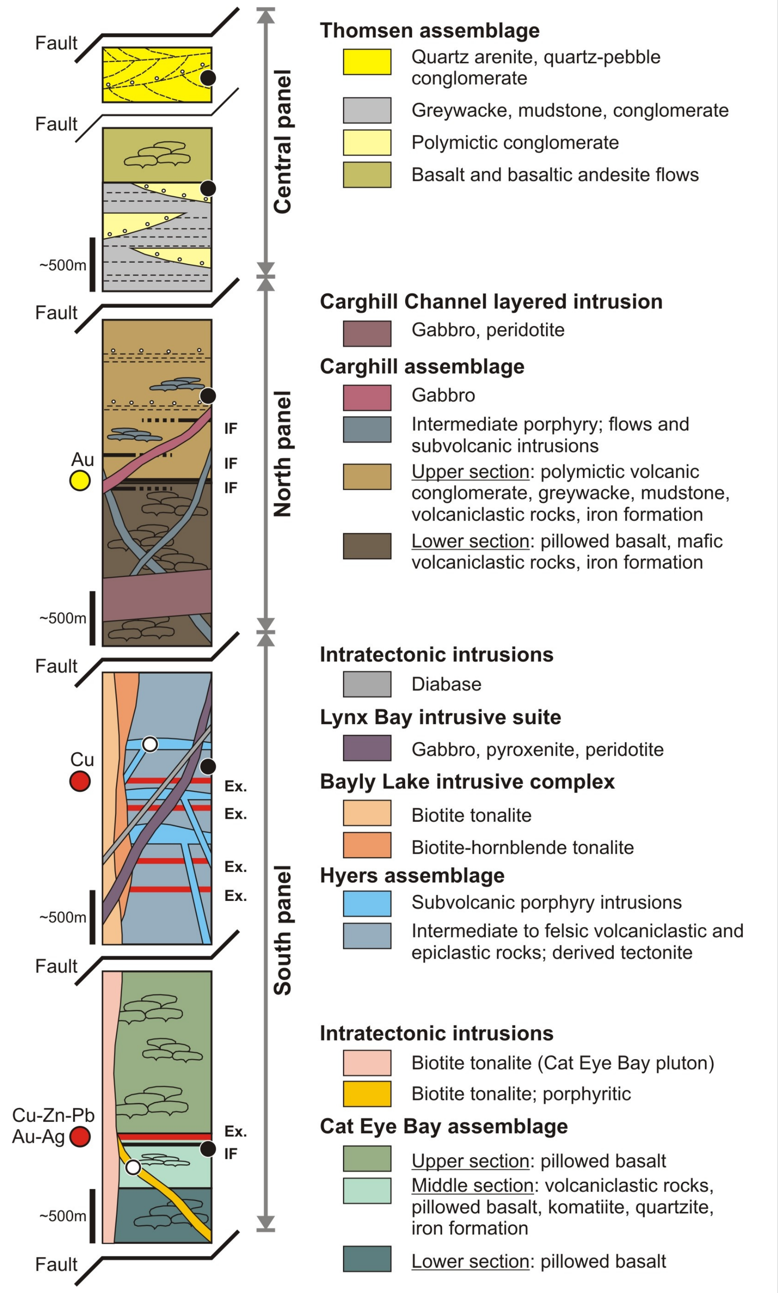
Supracrustal rocks in western Oxford Lake are provisionally divided into four tectonostratigraphic assemblages, characterized by distinctive associations of rock types and inferred to reflect different depositional environments and possibly ages. Pending the results of ongoing U-Pb geochronology, and to avoid implied correlations with adjacent belts, these assemblages have been assigned provisional names from geographic features at their type localities.

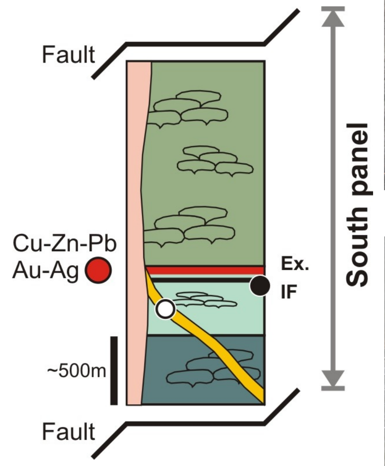
The map area is also divided into three main structural panels. The south panel contains the Cat Eye Bay and Hyers assemblages and is bounded to the north by the Hyers Shear Zone (HSZ), whereas the north panel contains the Carghill assemblage and is bounded to the south by the Carghill Shear Zone (CSZ). The central panel is confined by the HSZ and CSZ, and contains the Thomsen assemblage.

The Carghill assemblage is intruded to the north by granodiorite of the Semple River pluton (Hubregtse, 1985). To the south, the Cat Eye Bay and Hyers assemblages lie in contact with tonalite of the Bayly Lake complex, and lies in tectonic contact with the Cat Eye Bay assemblage across the Lynx Bay Shear Zone. At the west end of Oxford Lake, the assemblages and shear zones are stitched by gabbro dikes of the Molson and Mackenzie swarms.

As described below (see 'Intratectonic dikes'), systematic differences in cross-cutting relationships of intrusions suggest at least three broad ages of volcanism and sedimentation in western Oxford Lake.








Tectonized pillowed basalt, lower section

Heterolithic felsic tuff breccia in the middle section

Layered fuchsitic quartzite in the middle section

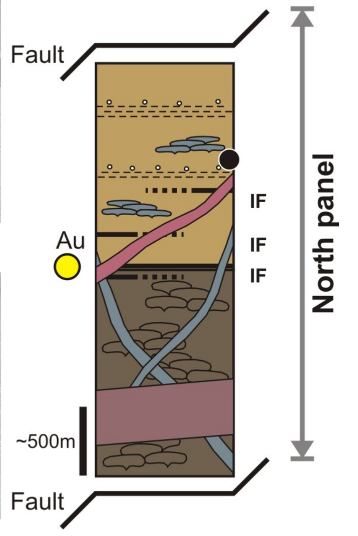
Oxide-facies iron formation in the middle section


Pillowed basalt in the lower section of the Carghill assemblage

Oxide-facies iron formation in pillowed basalt of the lower section

Polymictic volcanic conglomerate in the upper section

Proximal basaltic tuff breccia (note intact pillows) in the upper section

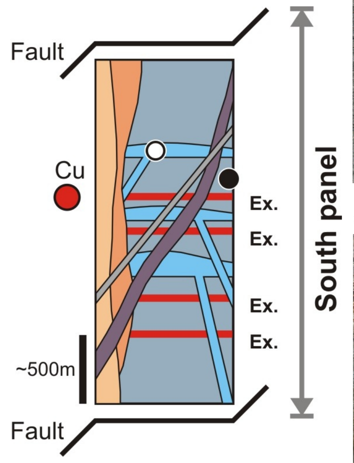


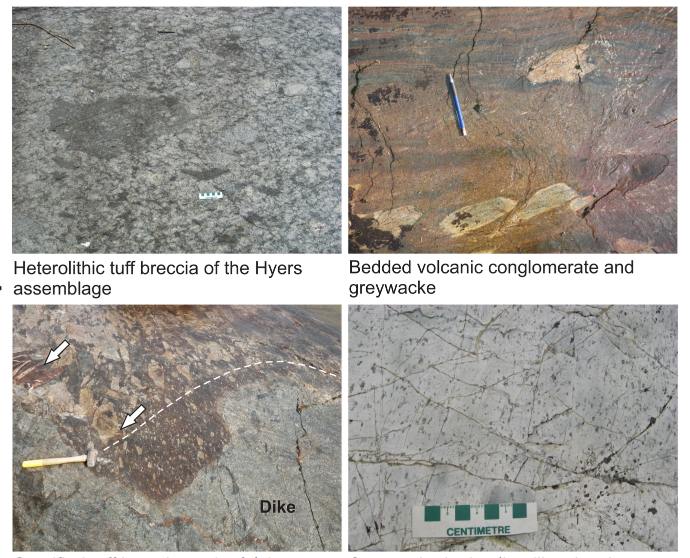
Cat Eye Bay assemblage

The Cat Eye Bay assemblage consists mostly of basalt flows, with minor ultramafic flows, felsic volcaniclastic rocks, iron formation and quartzite. Map patterns, younging criteria and industry high-resolution aeromagnetic data indicate that the assemblage defines a macroscopic anticline. Distinctive lower, middle and upper sections appear to define a mappable stratigraphy and suggest an analogy to Archean basalt-komatiite-quartzite-iron formation rift sequences documented elsewhere in the Superior Province. Pillowed basalt flows in the lower section contain epidote-silica and garnet alteration that appears to be semiconformable and is nowhere observed in superficially similar basalt in the upper section, suggesting that it may be syngenetic. The middle section is typically capped by a sulphide-facies iron formation that may represent an important exhalite marker horizon for base-metal exploration.

Carghill assemblage

The Carghill assemblage includes distinctive lower and upper sections. The lower section is dominated by basalt or basaltic andesite flows with minor mafic volcaniclastic rocks and iron formation, and is intruded by the Carghill Channel layered mafic-ultramafic intrusion. Younging criteria everywhere indicate tops to the south. Ubiquitous subvolcanic intrusions are generally representative of effusive rocks in the upper section. Volcanic conglomerate and greywacke-mudstone turbidite dominate the upper section, and are interstratified with minor brecciated or massive flows of porphyritic basaltic andesite and andesite, and proximally-derived volcaniclastic rocks. At the base of the upper section, thin-bedded greywacke, sulphidic mudstone and oxide-facies iron formation host the Rusty zone gold deposit, for which a resource of 800,000 tonnes grading 6 g/t Au has been calculated (A.F. 72085).





Heterolithic tuff breccia of the Hyers assemblage

Bedded volcanic conglomerate and greywacke

Stratified tuff breccia cut by felsic porphyry dike (note ankerite clasts)

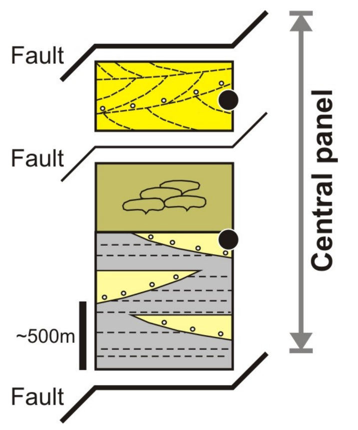
Quartz-phyric rhyolite dike showing hypabyssal porphyry texture


Polymictic conglomerate with abundant granitoid cobbles

Greywacke-mudstone turbidites showing scour, load structures and rip-up clasts

Pillowed basalt or basaltic-andesite flows (above conglomerate at Thomsen Island)

Cross-bedded quartz-lithic greywacke showing quartz and sulphide pebbles



Hyers assemblage

The Hyers assemblage consists mostly of intermediate to felsic volcaniclastic rocks, subvolcanic intrusions and derived epiclastic rocks. Rare bedforms indicate that the stratigraphy is subvertical and tops to the south. Stratiform zones of alteration and sulphide mineralization exposed along the western shoreline of Hyers Island represent either four distinct horizons or a single horizon that has been repeated by folding or faulting. Local southward progressions from stringer- to replacement-style ankerite alteration are capped by stringer or massive, near-solid to solid sulphide (pyrite ±chalcopyrite). Massive ankerite is found as clasts in overlying volcaniclastic rocks, indicating its syngenetic nature. The southern zone hosts the Hyers Island deposit, for which a small resource of 317 500 tonnes grading 2.5% copper has been calculated (A.F. 72236).

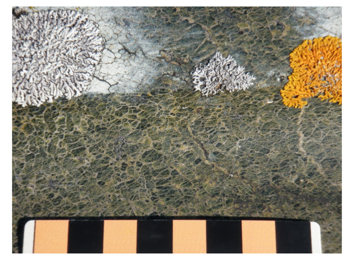
Thomsen assemblage

The Thomsen assemblage is defined to include four distinct units: polymictic conglomerate, greywacke-mudstone turbidites, basalt and basaltic andesite flows, and quartz arenite and quartz-pebble conglomerate. The conglomerate 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. Thick interlayers of greywacke-mudstone turbidite indicate deposition in a submarine fan, which is overlain by pillowed basalt and basaltic andesite flows. Quartz arenite and quartz-pebble conglomerate likely represent the youngest supracrustal rocks in western Oxford Lake; they were deposited in a fluvial-alluvial setting and contain well-rounded clasts of vein quartz and sulphide.


Tonalitic orthogneiss of the Bayly Lake complex intruded by intratectonic syeno-granite dikes

Bayly Lake intrusive complex

The Bayly Lake complex includes gabbroic-tonalitic orthogneiss, biotite-hornblende tonalite and biotite tonalite-granodiorite. The orthogneiss is strongly layered and recrystallized, and preserves evidence of early ductile deformation. Biotite-hornblende tonalite is also strongly recrystallized, with a penetrative L>S shape fabric. Biotite tonalite intrudes the Hyers assemblage and lies in tectonic contact to the north with the Cat Eye Bay assemblage.


Serpentinized peridotite of the Lynx Bay suite; glacially-polished surface shows cumulate texture


Strongly lineated bt-hb tonalite of the Bayly Lake complex

Lynx Bay intrusive suite

The Lynx Bay suite includes serpentinized peridotite and gabbro, with minor pyroxenite. The peridotite is only observed in the type locality, whereas the gabbro is much more widespread and forms abundant thick dikes in the Bayly Lake complex. The peridotite locally contains a well-preserved cumulate texture defined by euhedral crystals of serpentinized olivine. Spectacular examples of glacially sculpted and polished outcrops suggest that this material might be suitable for carving.


Thick dike of equigranular gabbro of the Lynx Bay suite cutting bt tonalite of the Bayly Lake complex

Intratectonic dikes

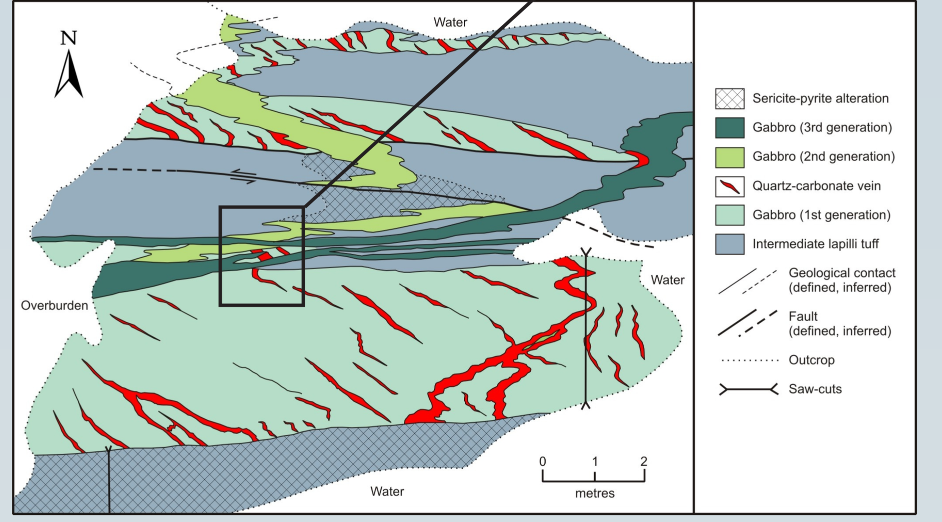
The term 'intratectonic' refers to dikes that discordantly cut at least one generation of ductile deformation fabric in the country rocks but are overprinted by later ductile or brittle-ductile deformation structures. In the map area, these dikes include gabbro/diabase, syenogranite and biotite tonalite. At the east end of Hyers Island, intratectonic gabbro dikes postdate two earlier generations of brittle-ductile deformation and are tightly folded (see below).

The widespread occurrence of 'intratectonic' dikes in the south panel suggests relatively protracted magmatism and deformation, and older relative ages for the Cat Eye Bay and Hyers assemblages. Intratectonic dikes are absent from the north panel, which instead contains abundant subvolcanic intrusions (i.e., hypabyssal intrusions that texturally resemble overlying effusive rocks), indicating that the Carghill assemblage may post-date an orogenic cycle recorded by the south panel. Hypabyssal intrusions are rare in the central panel and conglomerate in the Thomsen assemblage includes abundant granitoid clasts, suggesting a relatively young depositional age.

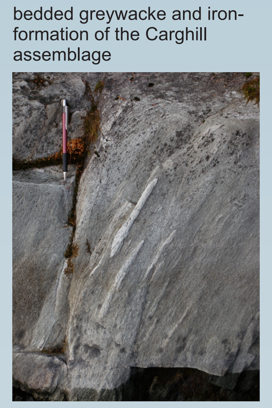
These inferences will be tested using U-Pb zircon geochronology on samples collected in 2012.


Syenogranite dike cutting L-S tectonite fabric in tonalite of the Bayly Lake complex

Gabbro dikes showing variable overprinting relationships with deformation structures



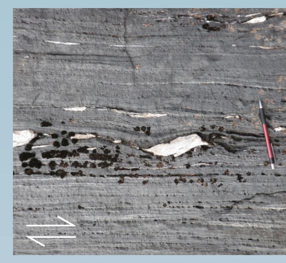

F1-F2 fold interference in bedded greywacke and iron-formation of the Carghill assemblage

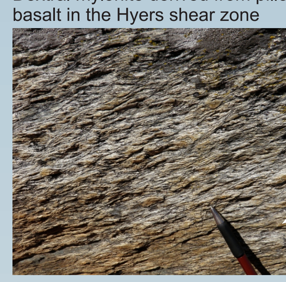

L2 stretching lineation in volcanic conglomerate of the Carghill assemblage

Structural geology

Supracrustal rocks at Oxford Lake have been affected by at least three generations of ductile deformation structures. The earliest recognized structures are rare isoclinal fold closures. These folds are overprinted by upright, tight to isoclinal, F2 folds that appear to be parasitic to doubly plunging macroscopic F2 folds that dominate map patterns within the major structural panels. These folds are associated with a penetrative and pervasive, subvertical, axial-planar S2 foliation that trends east and is the main fabric observed in most outcrops outside of late shear zones. This fabric typically contains a prominent down-dip stretching lineation defined by elongate clasts and pillows.

Macroscopic F2 folds are disrupted by subvertical ductile shear zones, which include those that bound the major structural panels. Shear-sense indicators in west-trending shear zones generally indicate dextral movement, whereas those in southwest-trending segments indicate sinistral movement. Stretching lineations are everywhere steep; however, the shear zones locally contain shallowly plunging mineral lineations or striae, which can be interpreted in terms of overprinting deformation 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). Z-folds are developed throughout the study area and overprint the S2-F2 fabric at a shallow counterclockwise angle.


Dextral mylonite derived from pillowed basalt in the Hyers shear zone


Sinistral mylonite derived from tonalite in the Lynx Bay shear zone


F2-F3 fold interference in bedded greywacke of the Carghill assemblage

Economic considerations: base & precious metals

Previous mineral exploration has resulted in the discovery of several base- and precious-metal occurrences in western Oxford Lake, thus demonstrating its significant exploration potential. Results from the 2012 mapping provide stratigraphic and structural context for these occurrences and can be used to formulate new exploration strategies.

The Cat Eye Bay occurrence (A.F. 93258) is hosted by the middle section of the Cat Eye Bay assemblage and is interpreted to represent exhalative base-metal sulphide mineralization; sulphide-facies iron formation at the top of this section may represent an important marker horizon for base-metal exploration.

Stratiform horizons of exhalative base-metal sulphide mineralization in the Hyers assemblage are associated with syngenetic, stringer- to massive-style, ankerite alteration and include the Hyers Island copper deposit (A.F. 72236); ongoing lithogeochemistry and geochronology will help elucidate the stratigraphic setting of these horizons.

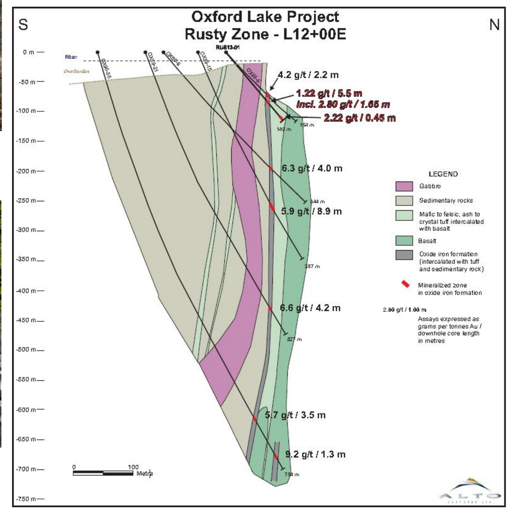
Preliminary results of our detailed stratigraphic and structural analysis provide new constraints on the settings and controls of gold mineralization, and an improved geological context for the Rusty zone (A.F. 72085), which is the most significant deposit discovered to date. In conjunction with the results of industry high-resolution aeromagnetic surveys, our mapping indicates that the distinctive stratigraphic interval that hosts this deposit can be traced along strike over 8 km to Carghill Island, but has not been systematically drill-tested.


Quartz-sericite phyllonite with disseminated to near-solid pyrite, chalcopyrite, sphalerite; Cat Eye Bay occurrence

Sulphide-facies iron formation at the top of the middle section of the Cat Eye Bay assemblage (marker horizon)

Strongly transposed auriferous oxide-facies iron formation; Rusty zone discovery outcrop

Vertical cross section through the Rusty zone, showing the stratigraphic setting of iron formation-hosted gold mineralization near the base of the upper section of the Carghill assemblage. Recent results of confirmation drilling by Alto Ventures Ltd. shown in red text.




Ankerite (± sericite, chlorite) alteration and stringer chalcopyrite; discovery outcrop of the Hyers Island Cu deposit

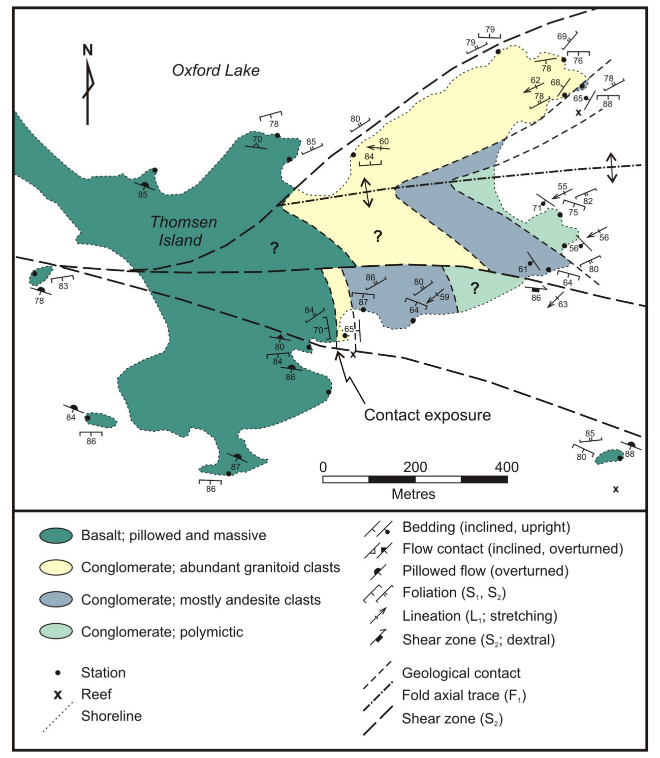
Massive ankerite alteration with stringer pyrite; Hyers Island

Strongly transposed and sulphidized iron formation; Rusty zone hangingwall

HRG - OLG 'unconformity'

Barry (1960) and Hubregtse (1985) described an unconformable contact relationship between the HRG and OLG, based in large part on a classical locality on Thomsen Island, where field relationships were interpreted to indicate a folded angular unconformity across which north-younging basalt (HRG) is overlain by east-younging polymictic conglomerate (OLG).

Although appealing some respects, this interpretation could not be reconciled with field relationships we observed at this locality. In particular, unambiguous younging criteria indicate that the conglomerate becomes younger toward the basalt, in a direction opposite to that predicted by the unconformity model. Moreover, the basalt is chilled and amygdaloidal along the contact, and appears to be intrusive. Hence, the basalt is considered to be younger than the conglomerate and both of these units are included in the Thomsen assemblage. As shown at right, the angular discordance can be explained by a combination of folds and late shear zones.



Pillowed and massive basalt flows, 40 m west of contact

Contact between massive basalt and polymitic conglomerate


Bedded polymictic conglomerate and sandstone, 10 m east of contact

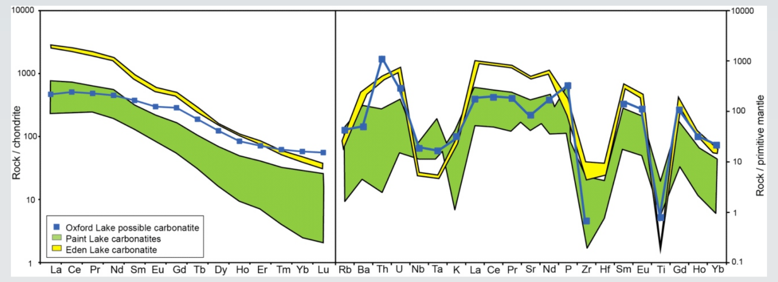
Economic considerations: nickel & rare-metals

The preliminary results of our mapping indicate previously unrecognized potential for komatiite nickel and carbonatite rare-metal deposits at Oxford Lake.

A possible carbonatite dike (indicated by red 'X' on map) was identified along the Hayes River south of Oxford Lake, in biotite tonalite of the Bayly Lake complex. It consists of alternating bands of carbonate and apatite, with subordinate magnetite, chlorite, clinopyroxene, amphibole, monazite, biotite, allanite and zircon. Narrow haloes of potassic alteration flank the contacts and a thin subsidiary dike appears to fill a dilational jog along a dextral shear fracture. Whole-rock geochemistry reveals strongly enriched trace and rare-earth elements, and multi-element profiles (below) which similar to those for known carbonatite intrusions. However, further analyses are required to determine the exact nature of the Oxford Lake dike and to assess the potential for carbonatite rare-metal deposits.


Recessively weathered dike of possible carbonatite in biotite tonalite of the Bayly Lake complex

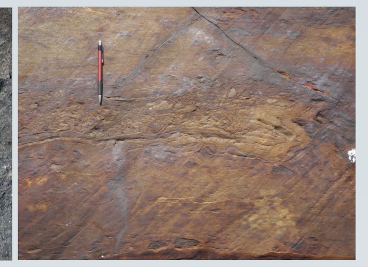
Detail of thin dike of possible carbonatite, showing narrow halo of wall-rock alteration

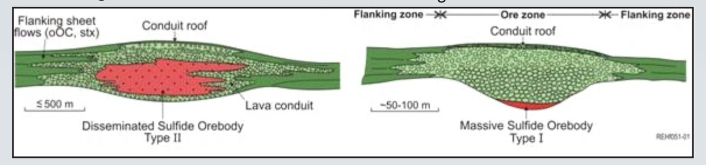


Chondrite- and primitive mantle-normalized multi-element diagrams showing the profile for the possible carbonatite dike at Oxford Lake in comparison to known carbonatite intrusions

Spinifex- and cumulate-textured ultramafic rocks in the middle section of the Cat Eye Bay assemblage are interpreted to represent komaiite flows and are closely associated with thick intervals of oxide and sulphide-facies iron formations, suggesting that potential may exist for komatiite nickel deposits.

Spinifex texture in ultramafic rocks of possible effusive origin (i.e., komatiite) in the middle section of the Cat Eye Bay assemblage


Contorted and brecciated laminae in sulphide-facies iron formation at the top of the middle section of the Cat Eye Bay assemblage



Idealized cross-sections of komatiite-hosted nickel sulphide deposits, showing disseminated and massive sulphide bodies associated with flow channels or conduits (source: CSIRO, 2001)

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