Towards an updated tectonostratigraphic framework for the Oxford Lake–Knee Lake greenstone belt, Manitoba

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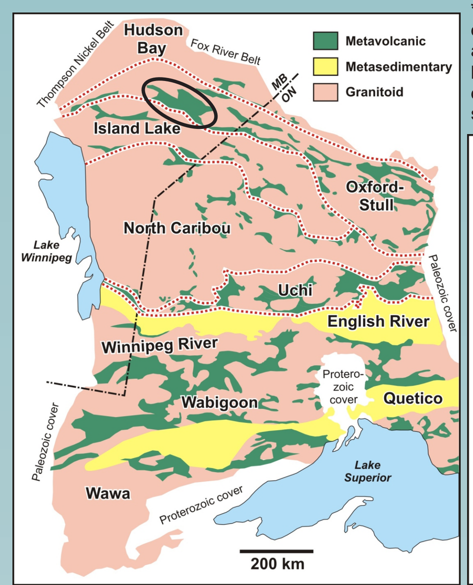
Introduction

In 2012 and 2013, the Manitoba Geological Survey remapped shoreline bedrock exposures at Oxford Lake, in the western portion of the Oxford Lake–Knee Lake greenstone belt, with the objectives of documenting the stratigraphy, tectonic evolution and economic potential. The Oxford Lake–Knee Lake belt is among the largest and most prospective belts in the western Superior province (below, left), yet remains under-explored.

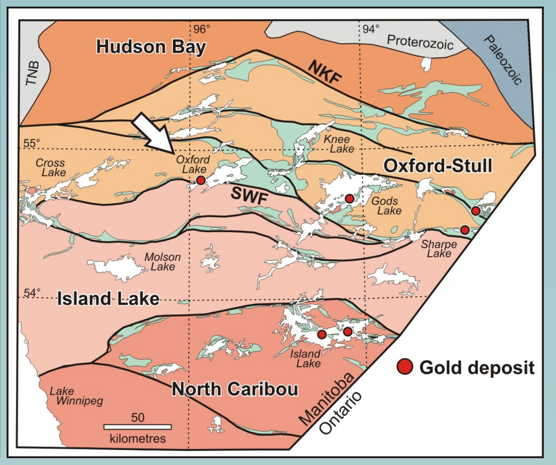
The Oxford Lake study incorporates new bedrock mapping with modern techniques of structural analysis, lithogeochemistry, Nd-Sm isotope geochemistry and U-Pb geochronology, and is designed to complement investigations done in the Knee Lake area during the Western Superior NATMAP project (Syme et al., 1997, 1998; Corkery et al., 2000).

On the basis of field relationships, a provisional tectonostratigraphic framework was devised during fieldwork in 2012 for supracrustal rocks at Oxford Lake, and key units were sampled for lithogeochemistry and U-Pb geochronology to test its veracity.

This poster presents preliminary U-Pb geochronological results* of laser ablation ICP-MS dating of zircon, which lend considerable support to the provisional framework and will facilitate a significant revision for the Oxford Lake–Knee Lake belt as a whole.



*Note: U-Pb geochronological results for detrital zircons are displayed on this poster as relative probability plots of $^{207}Pb/^{206}Pb$ ages (curves represent all data as indicated; cited ages are based on data ≤10% discordant). Results for igneous zircons are displayed on concordia diagrams, and include 42 analyses per sample (filtered as indicated for sample 96-12-375-A2).

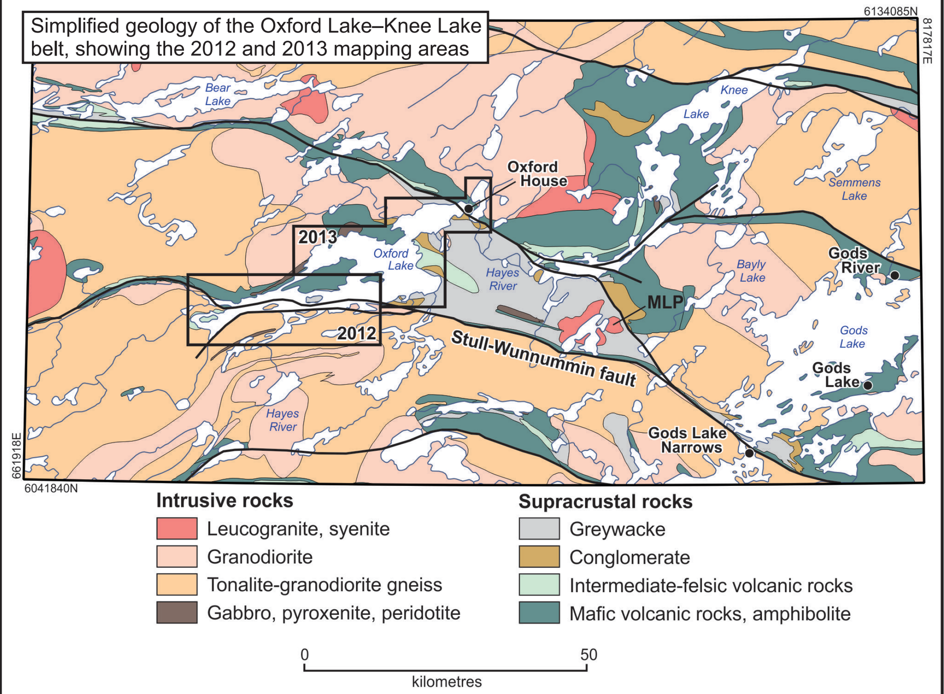


Regional setting

Oxford Lake is situated in the western 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 mostly of isotopically juvenile, ca. 2.83–2.70 Ga, subaqueous volcanic and sedimentary rocks, and is interpreted to represent an 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 (SWF; above, right) defines the south boundary of the OSD and is thought to represent a fundamental tectonic boundary in the western Superior province (Stott et al., 2010). The main strand of this fault trends from Sharpe Lake through Gods Narrows to Oxford Lake, where it roughly coincides with the southern boundary of the Oxford Lake–Knee Lake belt.

Simplified geology of the Oxford Lake–Knee Lake belt, showing the 2012 and 2013 mapping areas

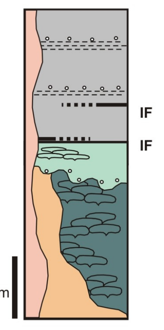


Regional stratigraphy

In the previous lithostratigraphic framework (right), supracrustal rocks in the OSD were divided into the older Hayes River group (HRG) and younger Oxford Lake group (OLG).

The HRG mostly consists of pillowed and massive basalt flows and gabbro, with minor intermediate to felsic volcanic rocks and fine-grained sedimentary rocks. Neither the stratigraphic base nor top of the HRG has been documented.

Voluminous tonalite-granodiorite plutons of the Bayly Lake complex were thought to intrude the HRG.



Both are unconformably overlain by the OLG, which was 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 turbidites, iron formation, quartz-lithic wacke and polymictic conglomerate.

Recent studies have indicated that this framework requires revision. U-Pb (zircon) ages for felsic volcanism in the 'HRG' span close to 200 m.y. (e.g., Corkery et al., 2000; Parks et al., 2006), whereas those for the volcanic subgroup of the OLG span roughly 30 m.y. (e.g., Corkery et al., 2000; Lin et al., 2006), and indicate that it was at least locally coeval with the sedimentary subgroup.

New results from the 2012 mapping area

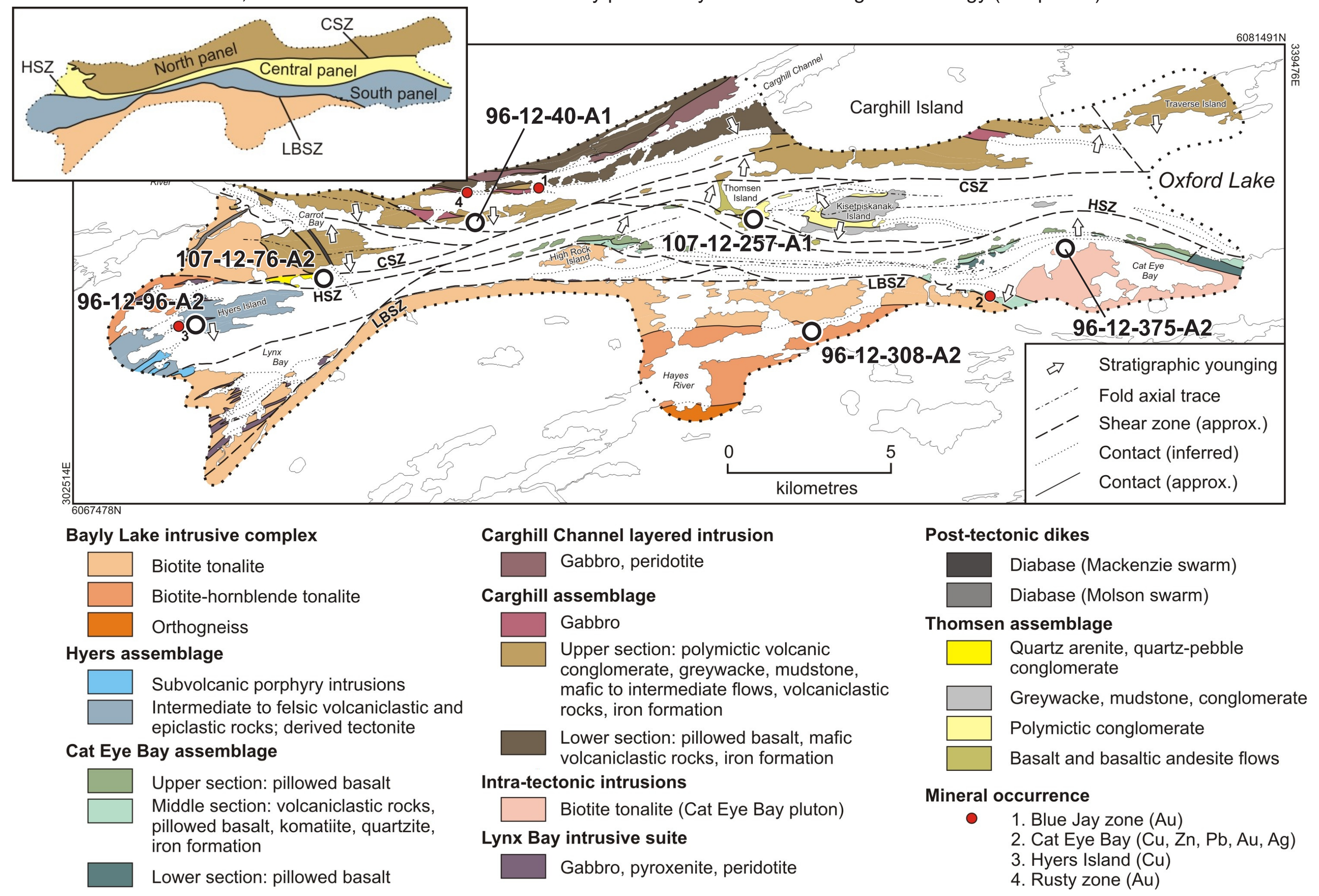
Provisional tectonostratigraphic framework (2012)

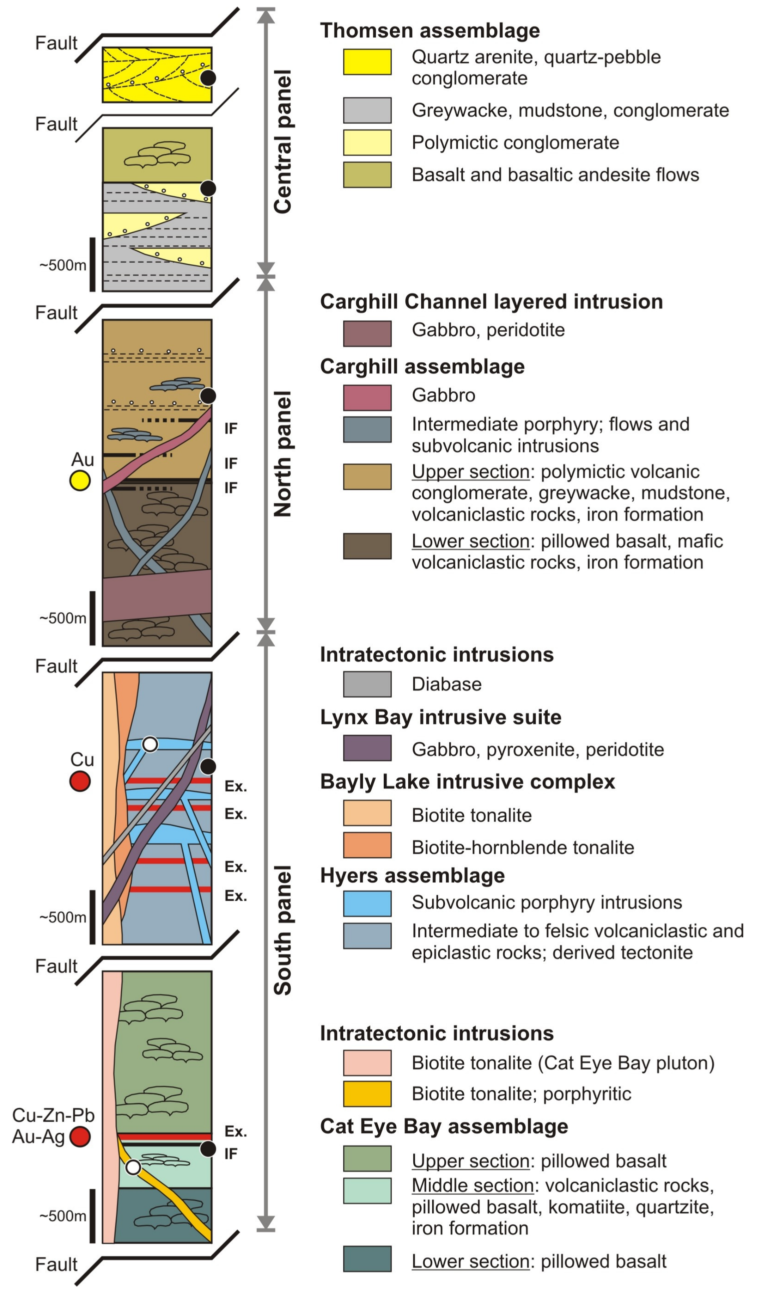
Based on field relationships documented during mapping in 2012, supracrustal rocks in western Oxford Lake were divided into four tectonostratigraphic assemblages (right), characterized by distinct associations of rock types and inferred to reflect different depositional settings and possibly ages. Pending results from U-Pb geochronology, and to avoid implied correlations with adjacent belts, these assemblages were assigned provisional names from geographic features at their type localities.

The map area was also divided into three main structural panels (below, inset): a 'south panel' containing the Cat Eye Bay and Hyers assemblages, bounded to the north by the Hyers shear zone (HSZ); a 'north panel' containing the Carghill assemblage, bounded to the south by the Carghill shear zone (CSZ); a 'central panel' confined by the HSZ and CSZ, and containing the Thomsen assemblage.

The Carghill assemblage is intruded to the north by granodiorite of the Semple River pluton. To the south, the Cat Eye Bay and Hyers assemblages lie in contact with tonalite of the Bayly Lake complex, which 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, these assemblages and shear zones are stitched by gabbro dikes of the Molson and Mackenzie swarms.

Systematic differences in cross-cutting relationships of intrusions suggested at least three broad ages of volcanism and sedimentation in western Oxford Lake, which has since been substantiated by preliminary results of U-Pb geochronology (this poster).



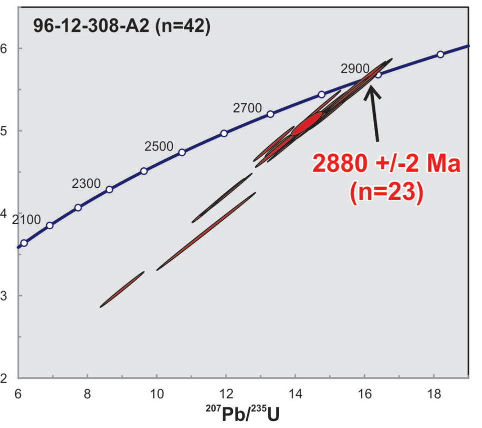


Bayly Lake intrusive complex

The Bayly Lake complex (BLC) includes gabbroic-tonalitic orthogneiss, biotite-hornblende tonalite and biotite tonalite. Tonalite of the BLC intrudes the Hyers assemblage and is strongly recrystallized, with a penetrative L>S shape fabric.

Lineated bt-hb tonalite of the BLC yielded an intrusive age of 2880 ±2 Ma, which represents the minimum age for the Hyers assemblage, and the BLC as the major source of detritus in the fluvial section of the Thomsen assemblage.

Strongly lineated bt-hb tonalite.



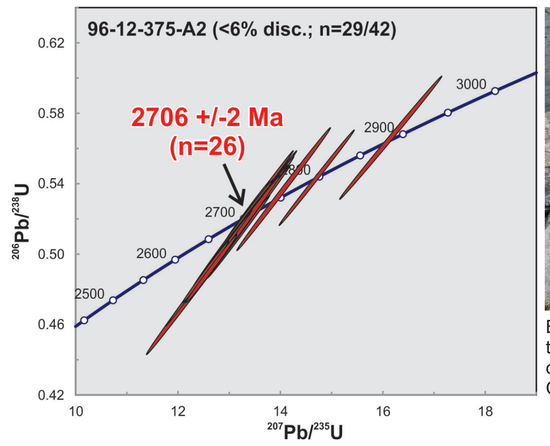
Intratectonic intrusions

Gabbro, syenogranite and tonalite-granodiorite intrusions are widespread in the south panel, where they post-date at least one generation of penetrative deformation in the country rocks. This relationship is not observed in other panels and was initially interpreted to indicate a more complex history and perhaps older relative age for the south panel. The latter interpretation is now supported by preliminary U-Pb data (above) indicating a minimum age of 2880 Ma for the Hyers assemblage.

The Cat Eye Bay pluton is the largest of the 'intratectonic' intrusions and consists of homogeneous biotite granodiorite that intrudes the Cat Eye Bay assemblage. U-Pb zircon ages from this pluton indicate an emplacement age of 2706 ±2 Ma, which also represents the minimum age for early penetrative deformation of the Cat Eye Bay assemblage.

The absence of such intrusions in the north panel may indicate that it was juxtaposed with the south panel after the 'intratectonic' magmatism; its age with respect to the early deformation is unknown.

In the case of the central panel, the Thomsen assemblage contains granitoid-clast conglomerate and abundant ~2710–2700 Ma detritus, indicating that it was deposited after the magmatic episode represented by the Cat Eye Bay pluton, and must post-date at least one phase of early deformation.

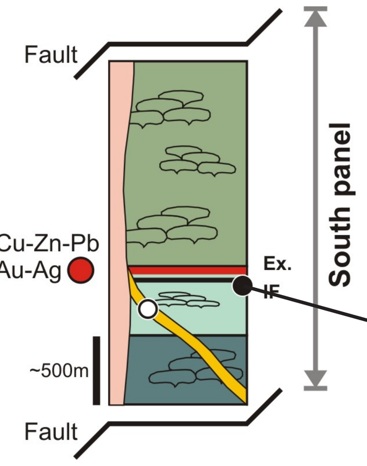


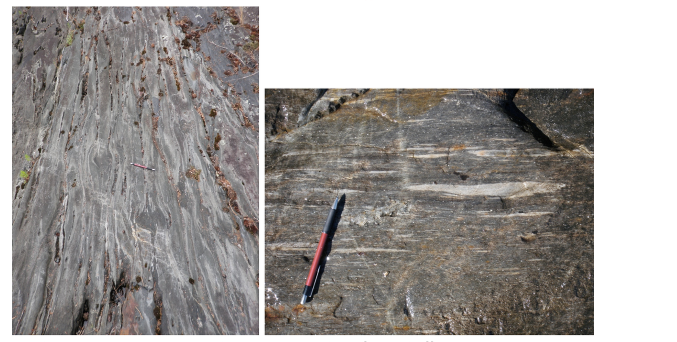
Biotite granodiorite at the north margin of the Cat Eye Bay pluton containing large rafts of mafic tectonite incorporated from the adjacent Cat Eye Bay assemblage.

Cat Eye Bay assemblage

The Cat Eye Bay assemblage consists mostly of basalt flows, with minor komatiite flows, felsic volcaniclastic rocks, iron formation and quartzite. 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 semi-conformable and is nowhere observed in superficially similar basalt in the upper section, suggesting that the alteration may be syngenetic. The middle section is capped by a sulphide-facies iron formation that may represent an important exhalite marker horizon for base-metal exploration.

Two samples of kyanite(±fuchsite) quartzite from the middle section (below left, indicated by black dot) were processed for U-Pb geochronology but did not yield any zircon; its age remains unknown.





Tectonized pillowed basalt, lower section.

Heterolithic felsic tuff breccia in the middle section.

Kyanite-fuchsite quartzite in the middle section.

Oxide-facies iron formation in the middle section.

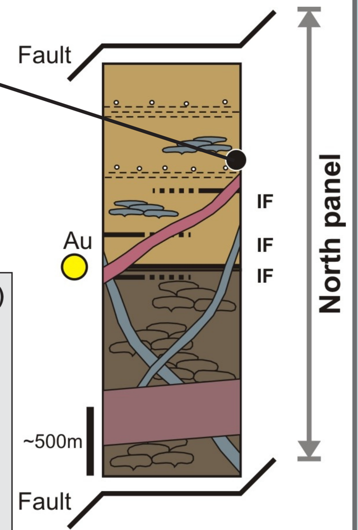
Carghill assemblage

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. 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 of shoshonitic affinity, and proximally-derived volcaniclastic rocks. Thin-bedded greywacke, mudstone and oxide-facies iron formation at the base of the upper section host the 'Rusty zone', for which a resource of 800,000 tonnes grading 6 g/t Au has been calculated (A.F. 72085).

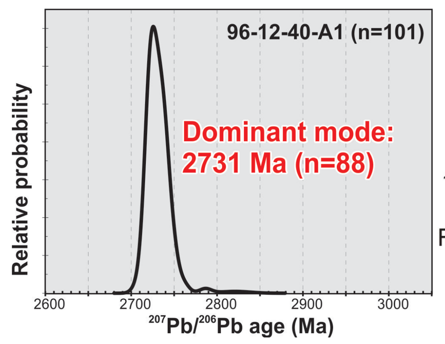
As described below, new U-Pb geochronological data indicate significantly different ages for the lower and upper sections of this assemblage.

Polymictic volcanic conglomerate in the upper section.

Normally-graded beds of volcanic sandstone in the upper section.

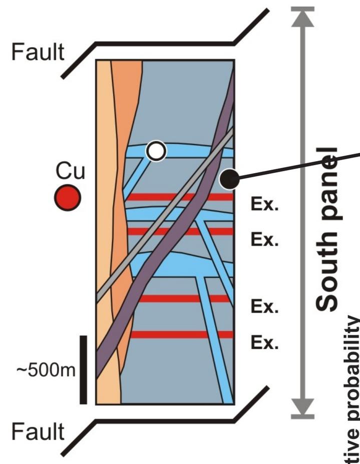


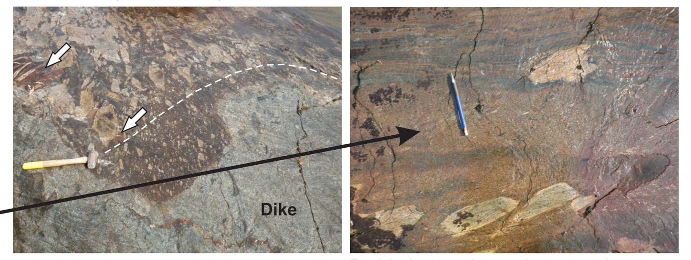
Volcanic sandstone from the upper section of the assemblage (far right, black dot) yielded abundant zircon grains, which define a single age population at ~2731 Ma. Seven grains with identical ages of 2719 Ma indicate the maximum depositional age and are interpreted to closely approximate the age of associated volcanism.



Hyers assemblage

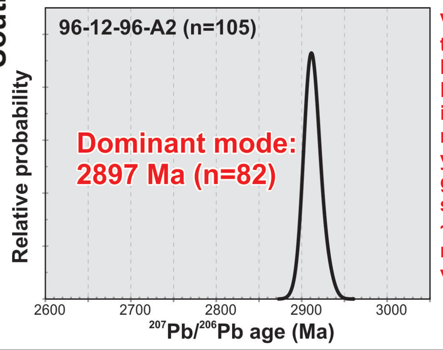
The Hyers assemblage consists mostly of intermediate to felsic volcaniclastic rocks and subvolcanic intrusions, and minor epiclastic rocks. Stratiform zones of alteration and sulphide mineralization on Hyers Island include southward progressions from stringer- to replacement-style ankerite alteration, capped by 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 VMS deposit, for which a small resource of 317 500 tonnes grading 2.5% copper has been calculated (A.F. 72236).





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

Bedded volcanic sandstone and conglomerate.



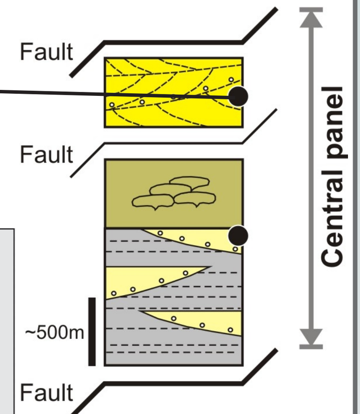
Volcanic sandstone from the stratigraphic hangingwall of the Hyers Island Cu deposit (far left, indicated by black and red dots, respectively) yielded abundant zircon grains, which define a single age population at ~2897 Ma, interpreted to represent the age of felsic volcanism.

Thomsen assemblage

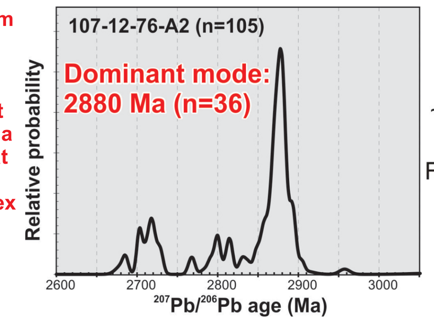
The Thomsen assemblage includes four distinct units: polymictic conglomerate; greywacke-mudstone turbidites; basalt–basaltic andesite flows; quartz arenite and quartz-pebble conglomerate. The conglomerate contains abundant, well-rounded, granitoid clasts that were apparently derived from more deeply eroded sources and underwent significant subaerial transport. Thick interlayers of greywacke-mudstone turbidite indicate deposition in a submarine fan, locally overlain by pillowed basaltic 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 clasts of vein quartz and sulphide.

Crossbedded quartz-lithic greywacke showing quartz and sulphide pebbles.

Polymictic conglomerate with abundant granitoid cobbles.



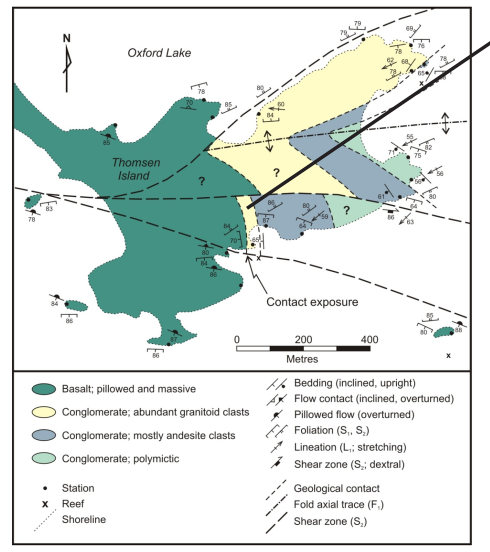
Quartz-lithic greywacke from the fluvial facies of the Thomsen assemblage (far right, indicated by upper black dot) yielded abundant zircon grains, which define a prominent age population at ~2880 Ma, likely sourced from the Bayly Lake complex (see above). Three grains with identical ages of 2702 Ma indicate the maximum depositional age.



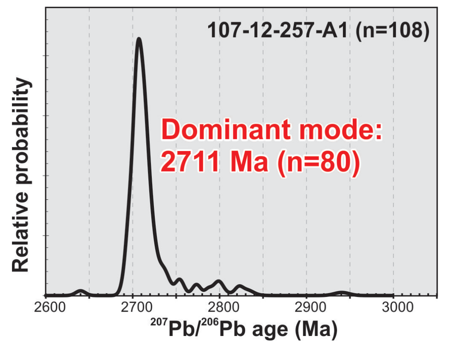
Hayes River group – Oxford Lake group 'unconformity'

Barry (1960) and Hubregtse (1985) described an unconformable contact between the HRG and OLG, based in part on a classical locality at Thomsen Island (below, left) that was interpreted as a folded angular unconformity across which HRG basalt was overlain by east-younging OLG conglomerate. However, this interpretation is at odds with key field relationships at this locality. In particular, younging criteria reveal that the conglomerate becomes younger toward the basalt, in a direction opposite to that predicted by the unconformity model. Moreover, the basalt appears to be 'chilled' along the exposed contact, indicating a younger relative age. Hence, both of these units are now included in the Thomsen assemblage.

Quartz arenite below the contact yielded abundant zircon grains, which define a prominent age population at ~2711 Ma. Four grains with ages of 2695 Ma indicate the maximum depositional age; these rocks are among the youngest identified in the Oxford–Stull domain.



Conglomerate and sandstone immediately beneath the basalt.



Economic considerations

Results from MGS mapping provide important new stratigraphic and structural context for several historical base- and precious-metal occurrences at Oxford Lake:

Base-metal VMS: the Cat Eye Bay occurrence (Cu-Zn-Pb-Au-Ag) is hosted by the middle section of the Cat Eye Bay assemblage (sulphide-facies iron formation at the top of this section may represent an important exhalite marker horizon for base-metal exploration), whereas the Hyers Island deposit (Cu) is associated with stratiform ankerite alteration in the Hyers assemblage.

Orogenic gold: the Rusty zone (Au) is hosted by iron formation at the contact between the upper and lower sections of the Carghill assemblage.

Carbonatite-hosted rare-metals?: the Bayly Lake complex is cut by a carbonatite dike consisting of dolomite, calcite, fluorapatite, tremolite and phlogopite, with accessory magnetite, allanite, monazite, bastnäsite, parisite and uraninite (Reimer, 2014); it is strongly enriched in rare-earth elements.

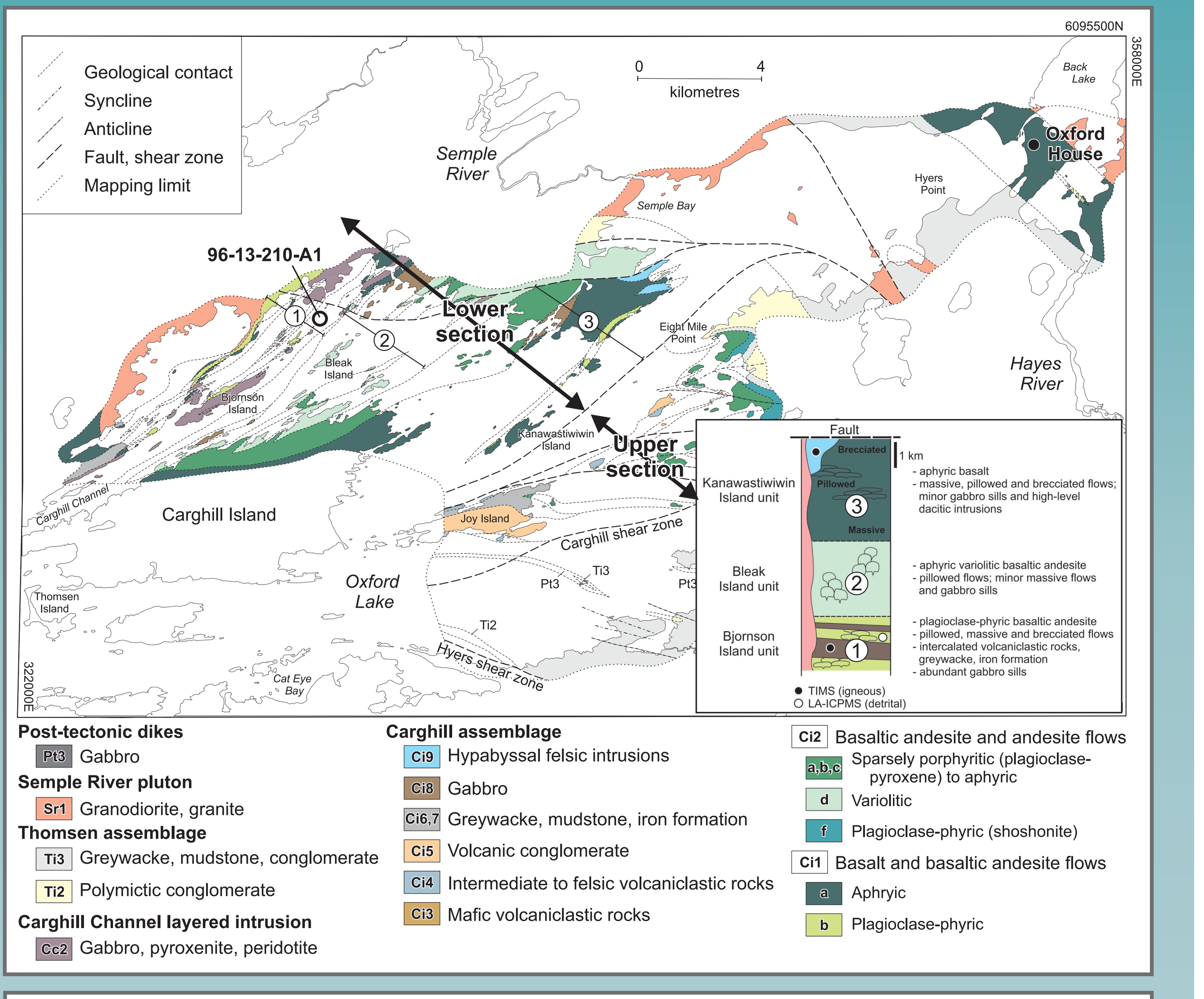
Komatiite-hosted magmatic nickel?: komatiite flows are closely associated with oxide and sulphide-facies iron formations in the middle section of the Cat Eye Bay assemblage.

Massive ankerite alteration with stringer pyrite; Hyers Island VMS system.

Auriferous oxide-facies iron formation; Rusty zone discovery outcrop.

Recessively weathered carbonatite dike cutting the Bayly Lake complex.

New results from the 2013 mapping area

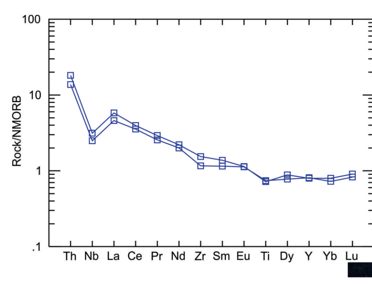


Carghill assemblage - Lower section

Field work in 2013 was focussed on the eastern extension of the Carghill assemblage, which is considerably thicker and exceptionally well exposed in eastern Oxford Lake (above). On the basis of field characteristics of subaqueous basaltic lava flows, the lower section was provisionally subdivided into 3 major stratigraphic units (above, inset).

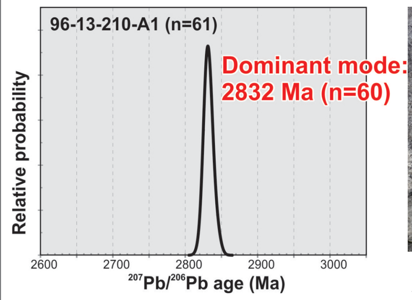
1) Bjornson Island unit (type flow: plagioclase-phyric): consists of pillowed and massive, aphyric to plagioclase-phyric, basaltic andesite flows, associated volcaniclastic rocks, and subordinate greywacke, volcanic conglomerate, felsic volcaniclastic rocks and iron formation; defines the base of the assemblage and is at least 2 km thick, cut out by the Semple River pluton; intruded by basaltic dikes and sills, which are lacking in the overlying Bleak Island unit.

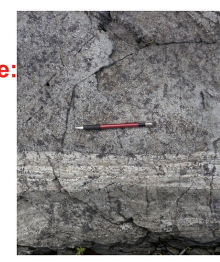
Geochemical affinity: Nb-enriched arc



Plagioclase-phyric basaltic flow breccia.

Volcanic sandstone (below, right) from the Bjornson Island unit yielded abundant zircon grains, which define a single age population at 2832 Ma, interpreted as the age of associated felsic volcanism. Similar U-Pb ages have been obtained from felsic volcanic rocks in 'classic' Hayes River group at Knee Lake.

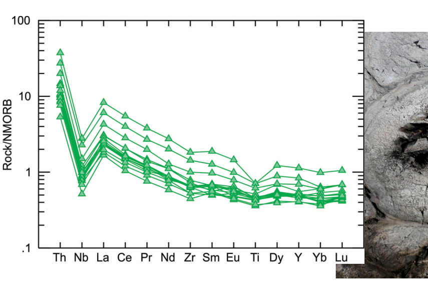




Normally-graded volcanic sandstone and mudstone.

2) Bleak Island unit (type flow: variolitic): consists almost exclusively of pillowed basaltic andesite flows, with only minor massive flows and very rare flow-breccia; epiclastic rocks are absent; type basaltic andesite is pale grey, aphyric, non-amygdaloidal and strongly variolitic; varioles typically increase in size and abundance toward pillow cores, where they commonly coalesce into dense masses; ~3 km in thickness and remarkably homogeneous.

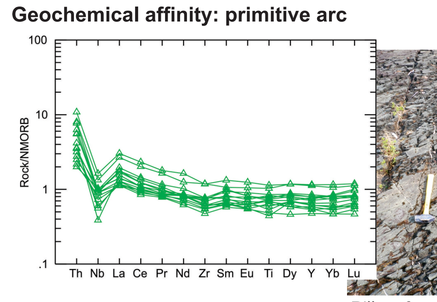
Geochemical affinity: primitive to evolved arc



Large bulbous pillow of variolitic basaltic andesite (note drain-out structures to upper left of hammer).

3) Kanawastiwiwin Island unit (type flow: aphyric): defines the top of the lower section and is ~4 km in thickness; consists of massive, pillowed and brecciated flows composed of amygdaloidal, non-variolitic and typically aphyric basalt; base of the unit is dominated by pillowed and massive flows, whereas the top includes a much higher proportion (up to 50% in places) of pillow-fragment breccia.

Geochemical affinity: primitive arc



Pillow-fragment breccia near the top of the Kanawastiwiwin Island unit.

Carghill assemblage - Upper section

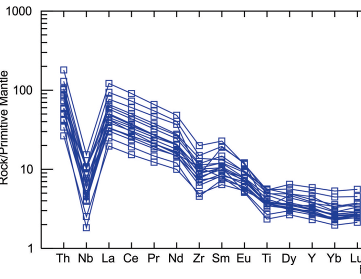
The upper section of the Carghill assemblage is at least 2 km thick and shows a systematic progression from the dominantly epiclastic lithofacies in the west to dominantly volcanic lithofacies in the east.

1) Epiclastic lithofacies: feldspathic greywacke and heterolithic volcanic conglomerate, with minor coherent flows of pyroxene (±plagioclase)–phyric andesite and associated volcaniclastic rocks; coherent flows are high-K calcalkalic–shoshonitic andesite and dacite; **maximum depositional age ~2719 Ma (sample 96-12-40-A1)**

2) Volcanic lithofacies: coherent, brecciated and pillowed flows, intercalated with spectacular examples of primary autoclastic (±hyaloclastic) and pyroclastic deposits; shallow-subaqueous eruptive setting; rounded boulders indicate local subaerial exposure; some basaltic andesite flows are densely packed with tabular phenocrysts of plagioclase (clasts of this rock are common in the Thomsen assemblage, indicating its younger relative age)

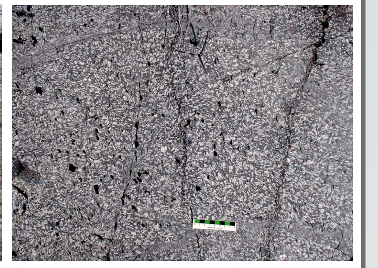
Chemical affinity: varies from shoshonitic or high-K calcalkalic-arc (mafic flows) to low-K calcalkalic (felsic flows)

The lower and upper sections of the 'Carghill assemblage', as defined in 2012, are significantly different in terms of lithology, depositional setting, chemical affinity and apparent age, suggesting they represent at least two distinct assemblages. Hence, pending results of additional geochronology, the 2012 tectonostratigraphic framework will require further revision.



Autoclastic breccia composed of angular blocks of plagioclase-phyric andesite.

Rounded boulder of plagioclase-phyric andesite in volcanic conglomerate (note hammer for scale).



Coherent basaltic andesite flow (shoshonite), showing densely-packed plagioclase phenocrysts.