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Volcano-sedimentary correlation and fault relationships in the Baker Lake Sub-basin, Thirty Mile Lake area, Nunavut[1]

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[1] Contribution to the Western Churchill NATMAP Project

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Abstract:

The volcanic succession of the Baker Lake Group in the Thirty Mile Lake area in ascending order is 1) felsic minette flows, 2) mafic minette flows, and 3) felsite flows. The succession is time-equivalent to the third-order sequences BL-2, BL-3, and BL-4 of the ca. 1.83 Ga Baker Lake second-order sequence (Baker Lake Group). Two sets of faults are recognized throughout the Baker Lake Sub-basin: an east-trending set of normal faults that have accommodated north-south extension and a conjugate set of strike-slip faults trending about 340° and 040° that have accommodated east-west extension and north-south shortening. The strike-slip faults offset and therefore postdate the normal faults. Faulting was contemporaneous with deposition of the Wharton Group (1765–1750 Ma) but ceased before deposition of the Barrensland Group (1720 Ma).

Résumé :

La série volcanique du Groupe de Baker Lake rencontrée dans la région du lac Thirty Mile se présente comme suit dans un ordre ascendant : 1) coulées de minette felsique, 2) coulées de minette mafique et 3) coulées de felsite. Cette série est équivalente dans le temps aux séquences BL-2, BL-3 et BL-4 de troisième ordre de la séquence de Baker Lake de deuxième ordre (Groupe de Baker Lake) dont l'âge est environ 1,83 Ga. Deux ensembles de failles ont été mis en évidence dans le sous-bassin de Baker Lake, soit un ensemble de failles normales à orientation est qui comprend une extension de direction nord-sud et un ensemble conjugué de décrochements à orientation d'environ 340° et 040° qui comprend une extension de direction est-ouest et un raccourcissement nord-sud. Les décrochements ont décalé les failles normales et se sont donc formées après elles. La fracturation est contemporaine du dépôt du Groupe de Wharton (de 1765 à 1750 Ma), mais elle s'est terminée avant le dépôt du Groupe de Barrensland (1720 Ma).

INTRODUCTION

This report is part of an ongoing study to characterize the sequence stratigraphy, chronostratigraphy, and structural geometry of the Baker Lake Sub-basin. Previous geological mapping of the Baker Lake Basin provided a lithostratigraphic subdivision of the Dubawnt Supergroup (**Fig. 1**; Donaldson, 1965; Gall et al., 1992; Rainbird and Hadlari, 2000). In an attempt to understand the chronostratigraphy and tectonic evolution of the basin, volcanic deposits from the Thirty Mile Lake area are compared and correlated to the sequence stratigraphic framework previously established for the Thirty Mile Lake area (Hadlari and Rainbird, 2000). The basin has been affected by at least two stages of faulting, which appear to predate deposition of the Barrensland second-order sequence (Barrensland Group).

GEOLOGICAL SETTING

The Baker Lake Basin comprises a series of northeast-trending intracontinental sub-basins hosting terrestrial siliciclastic and volcanic rocks that extend from Dubawnt Lake to Baker Lake (**Fig. 1**). The Baker Lake Sub-basin, which extends southwest from Baker Lake to Tulemalu Lake, contains Dubawnt Supergroup strata that unconformably overly rocks of the Archean MacQuoid–Gibson supracrustal belt (Tella et al., 1997; Hanmer et al., 1999), and the 1.9 Ga Kramanituar metamorphic complex (Sanborn-Barrie, 1994).

The Dubawnt Supergroup is subdivided by regional unconformities into the Baker Lake, Wharton, and Barrensland groups (Donaldson, 1965; LeCheminant et al., 1979; Gall et al., 1992). The Baker Lake Group is further subdivided into four formations. The South Channel Formation comprises alluvial-fan lithofacies containing clasts of basement rocks. Fluvial-eolian-lacustrine deposits of the Kazan Formation are considered to be the distal equivalents of the South Channel Formation (Rainbird and Hadlari, 2000). The Christopher Island Formation comprises ultrapotassic volcanic and associated volcaniclastic rocks. Fluvial-alluvial conglomerate units with Christopher Island Formation clasts are representative of the Kunwak Formation in the study area. Previous mapping has shown that South Channel, Kazan, and Christopher Island formations are exposed in the western Thirty Mile Lake area (LeCheminant et al., 1979; Blake, 1980).

The Baker Lake Group in the Thirty Mile Lake area comprises an up to 2000 m thick succession of conglomerate-sandstone and subordinate mudrock and can be subdivided into a hierarchy based on the concept of sequence stratigraphy (**Fig. 3**; Hadlari and Rainbird, 2000). Each of the three groups of the Dubawnt Supergroup represents the evolution of a successive depositional basin and is thereby classified as a second-order sequence (*see* Krapez, 1997). In the Thirty Mile Lake area, the Baker Lake Group second-order sequence comprises up to five basin-filling rhythms or third-order sequences

(BL-0 to BL-4 in Fig. 2). Each of these, in turn, may be further subdivided into progradational, aggradational, and retrogradational components or fourth-order sequence sets (Hadlari and Rainbird, 2000). Alluvial-fan facies associations characterize the lower part of the sedimentary succession (BL-1, BL-2). Fluvial and eolian facies characterize the upper part (BL-3, BL-4).

The Wharton Group is exposed north of Thirty Mile Lake and comprises the eolian-fluvial Amarook Formation and the Pitz Formation, that includes rhyolite and its intrusive equivalent Nueltin granite suite dated by U-Pb at 1765–1750 Ma (references *in* Peterson and van Breemen, 1999). The Barrensland Group unconformably overlies the Wharton and Baker Lake groups and includes the Thelon Formation, which contains diagenetic apatite cement dated by U-Pb at 1720 ± 6 Ma (Miller et al., 1989).

CHRISTOPHER ISLAND FORMATION VOLCANIC SUCCESSION

Most of the Christopher Island Formation ultrapotassic volcanic flows are of minette composition (Peterson and Rainbird, 1990). Minette is potassic, calc-alkaline lamprophyre that has phlogopite, clinopyroxene, ±olivine, ±magnetite phenocrysts, with sanidine only in the groundmass. Volcanic rocks of the Christopher Island Formation with sanidine and minor phlogopite phenocrysts are considered to be felsic minette, since they grade imperceptibly into true minette (*sensu* Peterson and Rainbird, 1990).

The full volcanic succession of the Christopher Island Formation occurs in the eastern part of study area A (Fig. 2). Northeast of Bunny bay (informal name), in the footwall of an east-trending, south-side-down normal fault approximately 100 m of felsic minette flows pass upwards gradationally into mafic minette flows. The lower felsic minette flows have a light orange groundmass and are rich with fine-grained (<1 cm) sanidine and minor phlogopite phenocrysts. Flows are approximately 5–10 m thick and commonly are bounded by zones of flow-top breccia. Upper felsic minette flows (**Fig. 4**) have a dark orange groundmass, 1–3 cm tabular to acicular sanidine phenocrysts, and phlogopite phenocrysts that are more abundant than in the lower flows. The upward transition from felsic minette to mafic minette flows occurs over about 5 m and is accompanied by a decrease in the abundance of sanidine phenocrysts and increase in size and abundance of phlogopite phenocrysts.

Mafic minette volcanic rocks are the most voluminous component of the Christopher Island Formation in the Thirty Mile Lake area and are thickest and most extensive near the margin of the basin (i.e. on the eastern shore of Bunny bay and the northern part of X-peninsula (informal name), **Fig. 2**). In the footwall of a east-southeast-trending, south-side-down normal fault, clast-supported cobble conglomerate is overlain by mafic minette flows, which pass upward into felsite flows. Clasts in the conglomerate are mainly sanidine+phlogopite porphyry, with very minor amounts (<5%) of mafic minette; clasts of basement are absent. Based on clast type, the conglomerate is interpreted to have been deposited close to the time of initial eruption of the mafic minette lavas. The overlying mafic volcanic rocks are approximately 500 m thick and comprise massive flows, volcanic sandstone, and conglomerate. At the top of the succession are sanidine-phyric felsite flows that form a dome-shaped topographic high, which is flanked by mafic-intermediate flows, volcanic breccia, and volcanic conglomerate. North of Bunny bay, two ovoid hills of felsite are flanked by mafic volcanic rocks; both lie on fault blocks that dip 30° or less and therefore it is possible that these are eroded, felsic volcanic domes. The volcanic succession at the eastern end of Thirty Mile Lake therefore is interpreted to be 1) felsic minette flows, 2) voluminous mafic minette flows, and 3) felsite flows.

INTRUSIVE ROCKS

Mafic minette dykes and sills are common in the basement rocks and within the sedimentary succession. Three different types of intrusion occur in the Thirty Mile Lake area. On the relatively well exposed X-peninsula (Fig. 2), sanidine+phlogopite porphyry occurs predominantly as sills within the sedimentary succession. Feeder dyke-sill networks can be traced laterally for hundreds of metres. Where sills are sufficiently thick to have cooled slowly they have a coarse-grained core zone, which has been described in the field as syenite (e.g. LeCheminant et al., 1979, 1987; Blake, 1980; Miller, 1980). The syenite porphyry is identical in colour, phenocryst composition, and crystal morphology to the orange, sanidine+phlogopite–phyric felsic minette flows that occur east of Bunny bay, and therefore is considered to be the intrusive equivalent to the flows.

A single dyke of hornblende monzonite occurs in the area of X-peninsula where it is crosscut by a sanidine+phlogopite porphyry dyke. The margins of the monzonite dyke are irregular, suggesting that the sediment it intruded was not lithified.

The third type of intrusion is a phlogopite syenomonzonite. Phlogopite phenocrysts occur in books up to 2 cm wide. The syenomonzonite dyke contains fine-grained, 5–8 cm mafic inclusions that have abundant phlogopite phenocrysts, up to 2 cm across. Crosscutting relationships with other intrusions are not apparent but the syenomonzonite may represent a composition that is transitional between monzonite and minette. If the mafic inclusions originated from minette magmas, then the genesis of the syenite intrusions and associated volcanic flows may be related to commingling of minette and monzonitic, or more siliceous granitic magmas. Further petrogenetic studies are currently underway to answer this question.

VOLCANIC-INTRUSIVE-SEDIMENTARY RELATIONSHIPS

The history of volcanism can be localized and diachronous throughout a sedimentary basin such that the depositional system must respond to rapid, localized filling of accommodation space by volcanic flows and associated sedimentary rocks. In the Thirty Mile Lake area we consider a volcanic succession that is time-stratigraphically equivalent to an adjacent sedimentary succession (cf. Hadlari and Rainbird, 2000). The volcanic stratigraphy consists of a succession of flows from sanidine+phlogopite–phyric felsic minette to felsite compositions (**Fig. 3**). The sedimentary counterpart utilizes a sequence stratigraphic framework wherein the Baker Lake Group is considered a second-order sequence comprising third-order depositional sequences (BL-0 through BL-4) that are up to 500 m thick (Fig. 3). Each depositional sequence is composed of, in ascending order, progradational, aggradational, and retrogradational fourth-order sequence sets characterized by the succession sandstone, conglomerate, and sandstone, respectively.

Sanidine porphyry clasts are rare in sequence BL-2, but occur in conglomerate at its base and are apparently absent from sequence BL-1. The hornblende monzonite dyke described above intrudes the base of the sequence BL-2 conglomerate. If it represents the contaminant to the minette magmas that produced the sanidine porphyry and associated flows, then its age would constrain the onset of felsic minette volcanism. Thus, felsic minette volcanism started near the base of sequence BL-2 in the Thirty Mile Lake area.

Coarse- and fine-grained sanidine porphyry clasts occur within conglomerate of sequence BL-3 at Thirty Mile Lake (**Fig. 5**) and have a modal abundance of 25–30%. Mafic minette clasts also occur but are rare (~1%). Thus felsic and mafic minette volcanism had both occurred prior to deposition of sequence

BL-3. Mafic minette, vent-proximal pyroclastic deposits overlie sandstone of sequence BL-4, hence mafic minette volcanism which began late in sequence BL-2, continued through until at least deposition of upper sequence BL-4.

There is no sequence stratigraphic equivalent to the felsite lavas in the Thirty Mile Lake area; however, on the Kunwak River between Princess Mary Lake and Thirty Mile Lake (**Fig. 1**), felsic volcanic clasts occur within conglomerate that closely underlies the unexposed unconformity between the Baker Lake second-order sequence and the Wharton second-order sequence. This conglomerate was mapped as Kunwak Formation by LeCheminant et al. (1979) and is interpreted to represent the top of the Baker Lake second-order sequence on the south side of the Baker Lake Basin. Therefore, the felsite lavas can probably be considered the youngest volcanic rocks of the Baker Lake second-order sequence.

FAULTING OF THE BAKER LAKE BASIN

In the Baker Lake Sub-basin, strata of the Baker Lake second-order sequence have characteristics that suggest they were deposited in an east-trending half-graben. On the northern margin of the basin, the entire Baker Lake second-order sequence is about 500 m thick (Rainbird and Hadlari, 2000). On the southern margin, at Thirty Mile Lake, the sequence is over 2000 m thick (**Fig. 3**). This difference is interpreted to reflect differential subsidence and accommodation. Paleocurrents at the northern and southern margins of the basin are directed inward (transverse), whereas in outcrops from the centre of the basin they are east-directed (axial). Since the highest accommodation occurred along the southern margin of Baker Lake Sub-basin, the basin-bounding fault is inferred to have been located immediately south of the preserved basal unconformity. Subsequent faulting has made it difficult to identify faults that may have been active at the time of deposition of the Baker Lake second-order sequence. Using outcrop studies and geophysical maps, Ryan et al. (2000) interpreted a prominent lineament that is parallel to the southeastern margin of Baker Lake Sub-basin to be a fault with significant north-dipping normal displacement. This is perhaps the best candidate for a syndepositional normal fault in the Baker Lake Sub-basin.

Quartz vein-breccia zones trending about 340°occur primarily within Christopher Island Formation volcanic rocks (**Fig. 6**). These breccia zones are interpreted to be zones of dilation. The timing of the quartz-vein brecciation is constrained by the occurrence of quartz-vein breccia clasts in conglomerate of the Kunwak Formation (**Fig. 7**), considered to be the youngest deposits of the Baker Lake second-order sequence. The quartz-vein breccia clasts contain angular fragments of mafic minette and therefore postdate mafic minette volcanism. Therefore we interpret the approximatley 340° quartz-vein breccia zones to be late syndepositional dilational faults oriented transverse to the Baker Lake Sub-basin half-graben.

In the western Thirty Mile Lake area there are two principal sets of faults (**Fig. 2**). The first set trend about 100° with south-side-down normal displacement and separate blocks of variable bedding attitude (~30–70°NW dip). The degree of tilting of the fault blocks increases from north (~30°) to south (~70°) and the faults are postulated to converge along a south-dipping detachment. The normal faults offset all units in the area, including basal conglomerate of the Wharton Group northeast of Bunny bay (Fig. 2).

The second is a conjugate set of faults with apparent strike-slip separation. They typically are not exposed but can be inferred from map patterns. Faults trending about 340° separate map units in a dextral manner and faults trending about 040° separate map units sinistrally. These faults offset all map units in the area, including the Wharton Group, and the approximately 100° normal faults.

The same set of conjugate faults is present at the northern end of Christopher Island, near the preserved eastern end of the Baker Lake Sub-basin (study area "B", **Fig. 1**). This area is dominated by dextral approximately 340° strike-slip faults (e.g. South Channel Fault, which separates the basal unconformity by 10 km; Schau and Hulbert (1977)), sinistral approximately 040° faults with lesser separation (generally less than 50 m) and fracture sets with orientations of approximately 100°, 340°, and 040° (**Fig. 8**). Kink bands (**Fig. 9, 10**) and tension gashes (**Fig. 11**) that are oriented parallel to the strike-slip faults overprint fractures that are parallel to the normal faults (~100°). Locally, fractures trending about 100° overprint the fractures trending approximately 340° and 040° (**Fig. 8**).

DISCUSSION

Volcano-sedimentary correlations indicate that alkaline volcanism occurred throughout the depositional history of the Baker Lake second-order sequence. The volcanic succession of felsic minette flows, mafic minette flows, and felsite flows filled accommodation space around volcanic centres; elsewhere it was filled with clastic detritus derived from uplifted basement rocks. In the Thirty Mile Lake area volcanic centres were aligned parallel to, and basinward from, the presently exposed basin margin.

The compositional changes within the volcanic succession in the Thirty Mile Lake area are similar to a felsic-mafic-felsic succession at Dubawnt Lake (Peterson and Rainbird, 1990). The genesis of the lower felsic volcanic rocks was attributed to crustal contamination of minette magmas, followed by near primary (lamproite and minette) and fractionated (intermediate to felsic minette and lamproite) magma extrusion.

A similar interpretation can be applied to the Thirty Mile Lake volcanic succession. The transition from lower felsic minette flows to the middle mafic minette flows is gradational, implying that the end-member magmas had interacted in some way. The genesis of the minette magmas was due to partial melting of an enriched upper mantle source (Peterson et al., 1994), but the origin of the felsic minette flows is presently unknown. An answer may come from intrusions within the sedimentary succession that indicate possible magma mixing. A hornblende monzonite dyke that intrudes sequence BL-2 on X-peninsula is crosscut by a porphyry dyke that may represent the intrusive equivalent to the felsic minette flows. Commingling features such as mafic phlogopite-phyric inclusions within the monzonite indicate that it likely represents a hybrid of mafic minette and monzonitic magmas; however, a more siliceous magma, such as granite, could have mixed with the mafic minette magma. In the MacQuoid Lake area, Sandeman et al. (2000) have documented field evidence for commingling between lampeophyic (spessartite not minette), monzonitic, and ca. 1830 Ma monzogranitic magmas. The transition from lower felsic minette flows to the mafic minette flows would then mark the cessation of contamination, perhaps due to depletion of the monzonitic-granitic magma reservoir. Upper felsite flows may represent fractionated minette magmas.

The key to deciphering the volcanic succession in the Thirty Mile Lake area is recognition of the various faults. The outcrop of basal Wharton Group conglomerate northeast of Bunny bay provides clear evidence that east-trending normal faults have significant displacement. Presence of the conglomerate shows that the complete Baker Lake second-order sequence is preserved in the Thirty Mile Lake area and that contrasting but time-correlative strata are repeated northward in the basin as block faults. It also implies that significant normal and strike-slip faulting occurred after deposition of the basal Wharton Group conglomerate.

Similar fault relationships occur north of Pitz Lake, along the northern margin of the Baker Lake Sub-basin (Fig. 1; Rainbird and Hadlari, 2000). There, normal and strike-slip faults crosscut the Wharton Group. Facies variations across dextral, 340° strike-slip faults suggest they also were active during deposition of the Wharton Group.

These fault patterns also occur near the western margin of the Baker Lake Basin in the Dubawnt Sub-basin (Fig. 1). On the south shore of Dubawnt Lake, rapakivi granite of the Nueltin suite, considered to be the intrusive equivalent of the Pitz Formation rhyolite, intrudes 040° sinistral strike-slip faults. Peterson and Rainbird (1990) concluded that these faults were coeval with eruption of the Pitz Formation rhyolite.

Fracture set and tension gash relationships from Christopher Island in the eastern Baker Lake Sub-basin can be related to regional faulting. They indicate that east-west normal faults and related fractures trending approximately 100° formed after deposition of the basal Wharton Group. A conjugate set of dextral approximately 340° and sinistral approximately 040° strike-slip faults and fractures offset and deformed the normal faults and fractures trending approximately 100°. All of these were overprinted by later fractures trending approximately 100° possibly due to reactivation of the normal faults.

CONCLUSIONS

The volcanic succession in the Thirty Mile Lake area is 1) felsic minette flows, 2) mafic minette flows, and 3) felsite flows. The succession is time-equivalent to the third-order stratigraphic sequences BL-2, BL-3, and BL-4 of the ca. 1.83 Ga Baker Lake second-order sequence (Baker Lake Group). The lower felsic minette flows may have derived from mixing monzonitic or granitic magmas with minette magmas. The upper felsite flows may represent late-stage magmatic differentiates from magmas of minette composition.

Two sets of faults occur throughout the Baker Lake Sub-basin. East-trending normal faults accommodated north-south extension and have tilted strata basinward such that correlative sequences are repeated. A conjugate set of strike-slip faults trending approximately 340° and 040° have accommodated east-west extension and north-south shortening and offset the east-trending normal faults. Faulting occurred throughout deposition of the Wharton Group. The greatest offset and tilting postdated the Wharton Group (< 1750 Ma) but preceded deposition of the overlying Barrensland Group (> 1720 Ma).

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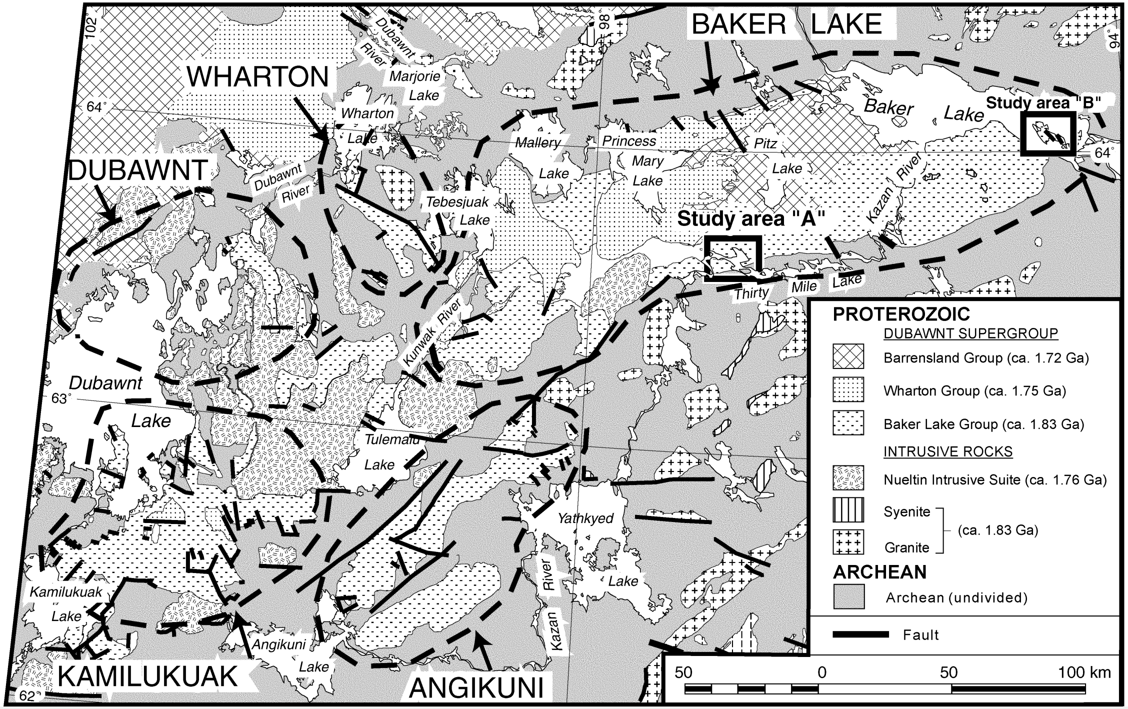

Figure 1. Geology of the Baker Lake Basin comprising the Baker Lake, Wharton, Dubawnt, Kamilukuak and Angikuni Sub-basins (*after* Donaldson, 1965; LeCheminant et al. 1979; Blake 1980), showing locations of study areas discussed in this report.

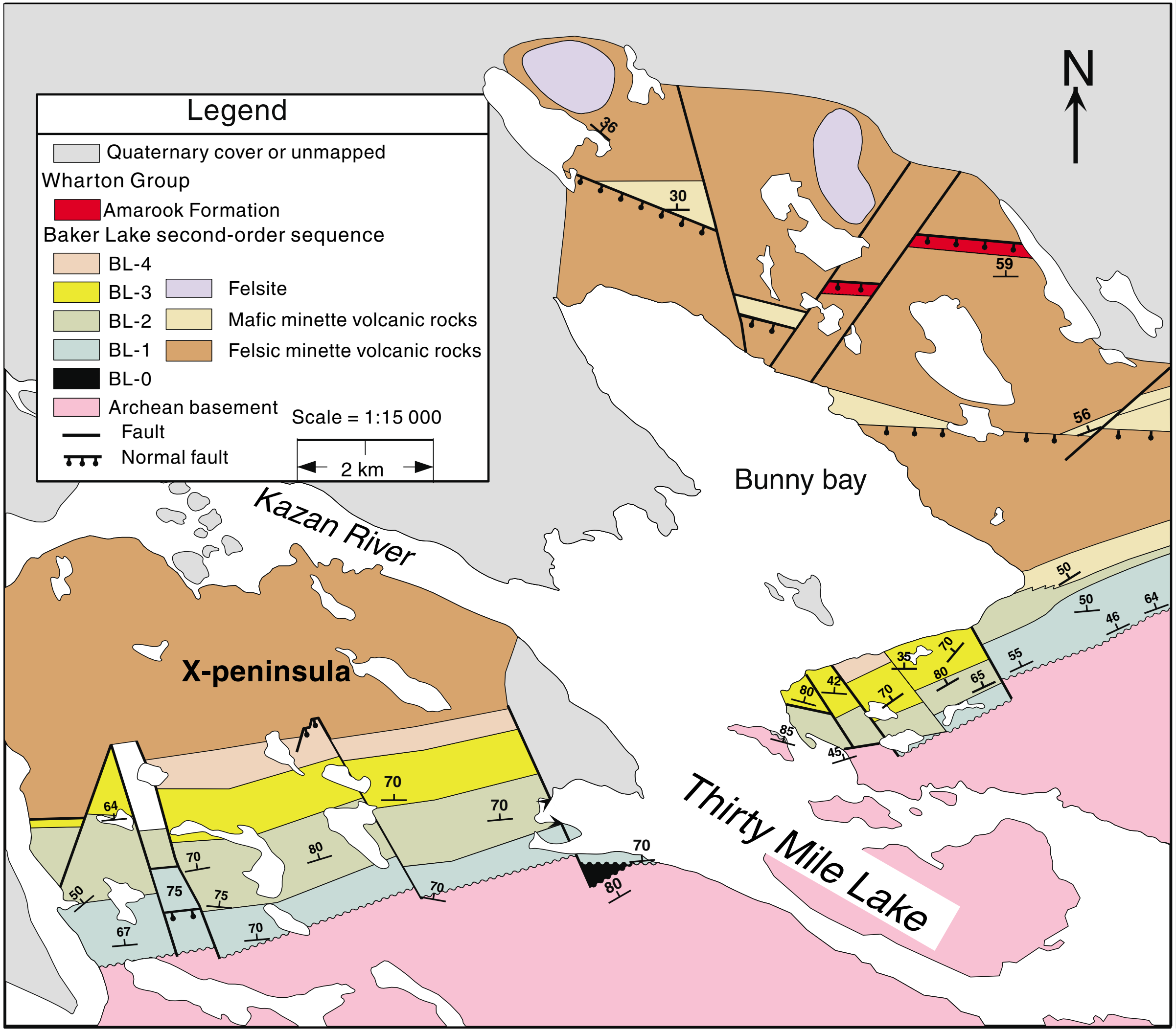

Figure 2. Geology of western Thirty Mile Lake area (study area "A" *in* Fig. 1).

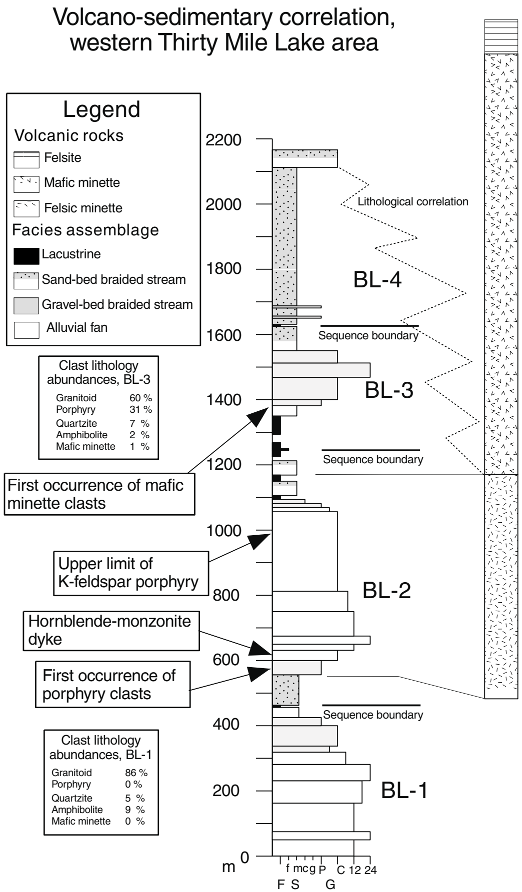

Figure 3. Sequence stratigraphic correlation of volcanic and sedimentary sequences in the western Thirty Mile Lake area.

Figure 4.

Sanidine and minor phlogopite porphyritic felsic minette flow.

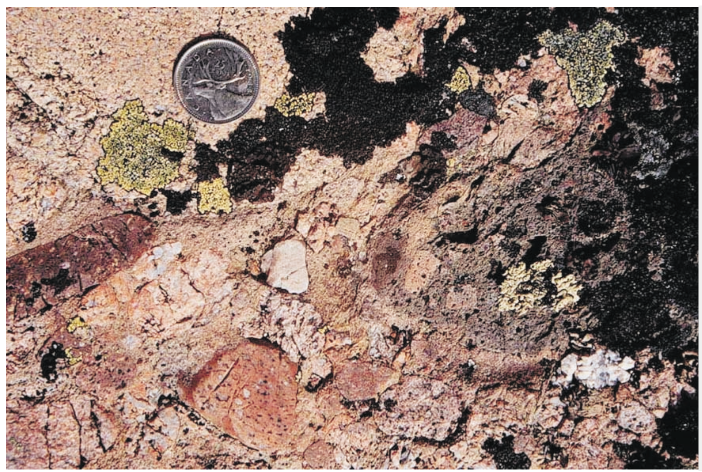

Figure 5.

Sanidine porphyry and mafic minette clasts within conglomerate of the third-order sequence BL-3.

Figure 6. Quartz-vein breccia in mafic minette flows of the Christopher Island Formation. Lens cap for scale is 5 cm.

Figure 7.

Quartz-vein breccia clast (approximately 20 cm wide) within conglomerate of the Kunwak Formation.

Figure 8. The dominant approximately 100° fracture set shows dextral rotation to about 340° by two kink bands that trend about 040°. These kinks are linked by a set of fractures trending about 340°. The compass is oriented at 098° and the pen 040°. The approximately 100° set of fractures are parallel to a regional set of normal faultstrending about 100°. The approximately 340° set of fractures are parallel to a regional set of approximately 340° strike-slip faults of dextral displacement.

Figure 9. Fracture set trending about 100° and kink band trending about 040° defined by dextral rotation of approximately 100° fractures towards about 340°.

Figure 10. Three fracture sets, trending about 100°, 040°, and 40°, are developed. The pen is oriented at 340°. The approximately 100° fracture set crosscuts the other fracture sets in the left-central part of the photograph.

Figure 11. Tension gashes show progressive sinistral rotation, over a strain gradient leftward of the pen, from fractures trending approximately 040°. The pen is oriented at 048. These are interpreted to be related to a regional set of sinistral strike-slip faults that trend about 040°.