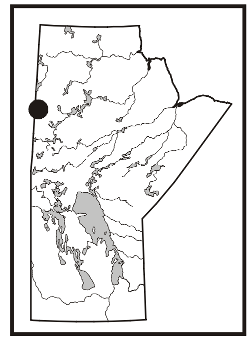
GEOCHEMISTRY AND TECTONIC FRAMEWORK OF THE KISSEYNEW DOMAIN-LYNN LAKE BELT BOUNDARY (PART OF NTS 63P/13)

by H.V. Zwanzig



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SUMMARY

- Highly recrystallized, mafic to ultramafic volcanic rocks, previously mapped as undifferentiated amphibolite, fall into various geochemically distinctive units that were defined in better preserved rocks by Zwanzig et al. (1999).
- Despite alteration involving alkali elements and structural attenuation of the units, the composition of the least mobile elements is remarkably uniform for tens of kilometres along strike and provides a valuable tool for mapping.
- Assemblages of volcanic units have geochemical and metallogenic affinities to 1) volcanic arcs, 2) marginal basin floor (N-MORB and contaminated MORB), and 3) an ocean island.
- A complexly folded crustal suture between the turbidite units of the Kisseynew Domain and the arc volcanic rocks of the Lynn Lake belt contains the marginal-basin basalts.
- Major structural breaks separate the arc and marginal-basin assemblages, even where units were attenuated to a thickness of only a few metres; shear zones that reactivate or cut these breaks may host precious-metal deposits.

INTRODUCTION

Updated trace-element data have recently demonstrated that the Lynn Lake belt and the adjacent margin of the Kisseynew Domain contain numerous tectonostratigraphic assemblages (Zwanzig et al., 1999). Each assemblage represents a package of rocks with a distinctive stratigraphy, geochemistry and inferred plate-tectonic setting. Various assemblages were interpreted to have been structurally juxtaposed along major tectonic breaks. Whereas, in the Lynn Lake belt, the resulting structural stack comprises subvertical northeast- to southeast-trending panels, on the Kisseynew Domain margin, it consists of complexly refolded structural sheets. One unit (Laurie Lake assemblage) in a tightly folded sheet on the northeast shore of Laurie Lake was identified as the southwest arm of a prominent belt of calc-alkaline rocks (Zwanzig et al., 1999). Sheets to the southeast were found to include MORB-like marginal-basin basalts (Hatchet Lake basalt and Tod Lake basalt) and an ocean-island assemblage (Pickerel Narrows amphibolite). These rocks are unconformably overlain by conglomerate and arenite (Missi Group), which occur at the top of each structural sheet. The ocean-floor assemblages extend from Laurie Lake more than 100 km southeast to an area southeast of Granville Lake. They are a key component of the Granville Lake structural zone, which forms the north boundary of the Kisseynew Domain (Zwanzig, 1990). This zone has recently been interpreted as a crustal suture that developed during northward subduction and accretion of the MORB-like assemblages beneath the Lynn Lake belt, and subsequent underthrusting by Kisseynew turbidite basin fill during continental collision in the Trans-Hudson Orogen (White et al., 2000).

Specific units were re-examined in 2000 along the Kisseynew Domain boundary at the southwest end of the Lynn Lake belt (Fig. GS-17-1). Samples of volcanic rocks were collected and geochemical analyses were obtained from Activation Laboratories Ltd. (codes 4LITHO-MAJ ELEM FUS ICP and 4LITHO-TRACE ELM FUS

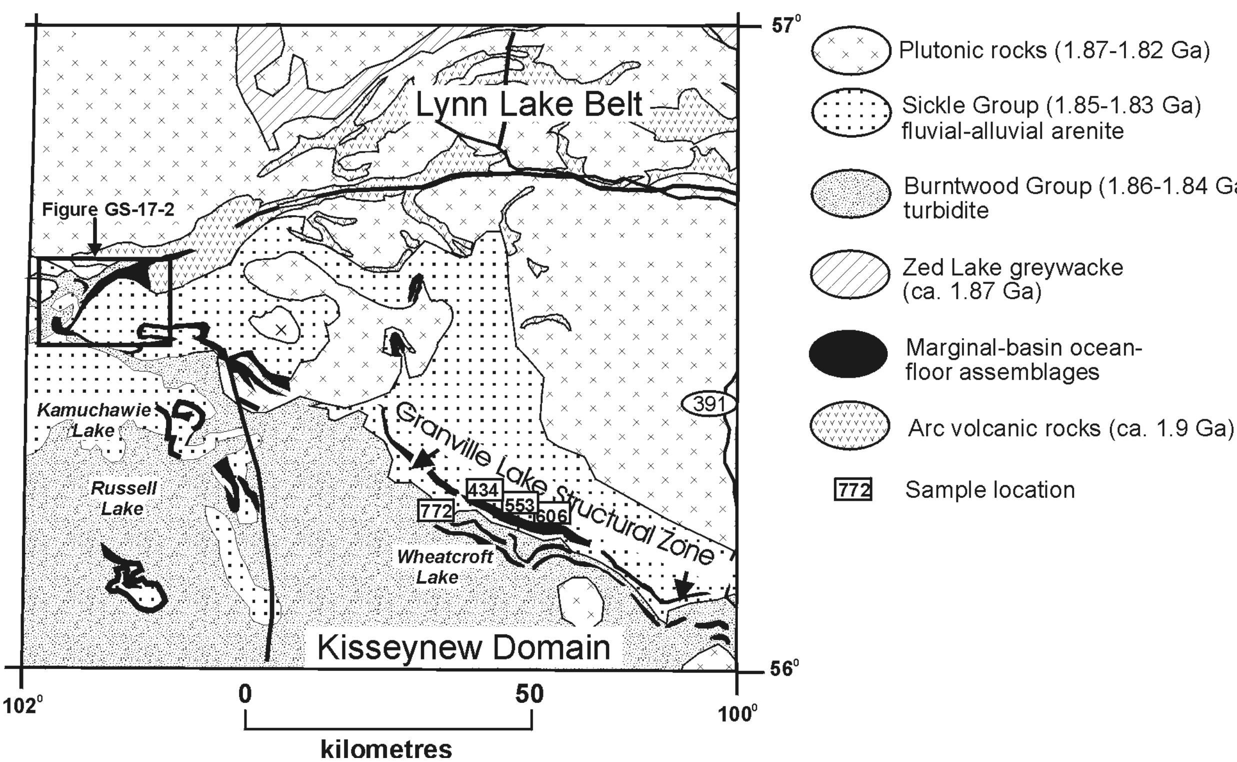

Figure GS-17-1: Geological map showing the Lynn Lake volcanic belt and Kisseynew Domain separated by the Granville Lake Structural Zone. Locations of selected geochemical samples are shown.

ICP/MS). Results will be used to help trace the units southwest across Laurie Lake and east along Eager Lake. Major- and trace-element geochemistry was also updated for existing samples from Granville Lake, Kamuchawie Lake and Russell Lake (Fig. GS-17-1). Preliminary results from 29 new analyses are summarized here and compared in simple variation diagrams to the data of Zwanzig et al. (1999). An important goal of this work is to delineate the Granville Lake suture zone at localities where it has only been inferred. Based on existing showings and a prominent As anomaly in glacial till to the south, this work may have application to precious-metal exploration.

A second objective is to trace probable splays of the Johnson Shear Zone along Tod Lake (Tod Lake Fault of Gilbert et al., 1980) and possibly across Laurie Lake (Fig. GS-17-2). To that end, a reconnaissance of shear zones was undertaken with C.J. Beaumont-Smith. Syn- to post-metamorphic (late collisional) shear fabrics, similar to those reported in Au-bearing zones in the central part of the Lynn Lake belt (Beaumont-Smith, GS-12, this volume), indicate that further work may provide promising results.

GEOCHEMICAL RESULTS

Mafic to ultramafic volcanic map units, each with a distinctive geochemical composition reported by Zwanzig et al. (1999), can be extended using the new data. These units have lost most of their primary structural features and were generally mapped as undifferentiated amphibolite in the new sampling area on Laurie and Eager lakes (Gilbert et al., 1980), as well as in parts of the Granville Lake area (Zwanzig, 1981), north of Kamuchawie Lake (Zwanzig and Wielezynski, 1975) and at Russell Lake (Lenton, 1981). The new data suggest that, like the better preserved rocks discussed in the study by Zwanzig et al. (1999), the amphibolite comprises units with tectonic affinities to 1) arcs, 2) marginal-basin floors, and 3) ocean islands. They are considered to be, respectively, part of the 1) Laurie Lake assemblage, 2) Hatchet Lake and Tod Lake basalts, and 3) Pickerel Narrows amphibolite (as summarized in Table GS-17-1).

Wide variations of alkali elements and Ca within these units of amphibolite indicate that most of the rocks are altered to some extent. Consequently, plots of the least mobile elements are used to evaluate the data.

The assemblage types are distinguished on a simple plot of TiO_2 versus MgO that shows the fields of modern arc, MORB/BABB (back-arc basin basalt) and Hawaiian tholeiite (Fig. GS-17-3). The newly analyzed samples of Pickerel Narrows amphibolite from Granville Lake represent picrite of ocean-island affinity with a high content of TiO_2. High-Mg basalt that is depleted in TiO_2 is interpreted to be komatiitic (*see* 'Komatiitic Basalt and Felsite' section, below).

Laurie Lake Assemblage

Two new samples of low-Ti basalt were collected on the east shore of Laurie Lake (4010 on Fig. GS-17-2). They comprise highly flattened pillow basalt and porphyritic volcanic breccia, which is locally scoriaceous. The basalt lies stratigraphically beneath the Sickle Group basal conglomerate and above a coarse hornblende-bearing greywacke-turbidite. It occurs in a south-trending belt on the east side of the Laurie Lake dome, where lithologically similar rocks were recorded as units 4, 4b and 4f during the original mapping (Gilbert et al., 1980). The new samples suggest that the Laurie Lake arc assemblage extends for nearly 25 km along the east shore of this lake and further east. In an N-MORB–normalized extended-element plot, the low-Ti basalt has a similar profile to the main calc-alkaline part of the Laurie Lake assemblage (Fig. GS-17-4a); however, it contains less MgO and more Fe_2O_{3tot}, and has a higher Th/Nb ratio (Table GS-17-1). The basalt may represent an arc tholeiite belonging to the Fox mine succession, which overlies the calc-alkaline rocks at the extracted volcanogenic massive sulphide (VMS) deposit (Zwanzig, 1999).

Farther west on Laurie Lake, dark green amphibolite with prominent lenses and layers rich in coarse-grained diopside closely resembles highly recrystallized parts of the Laurie Lake assemblage. This rock is inverted on the north side of the Laurie Lake dome and may extend around the dome farther west toward Saskatchewan.

Hatchet Lake Basalt

Hatchet Lake basalt has a restricted compositional range and TiO_2/MgO ratios typical of N-MORB (Fig. GS-17-3), but is somewhat depleted in Zr (Table GS-17-1). It occurs in the southeast-facing structural sheet that overlies Burntwood Group turbidite southeast of the Laurie Lake assemblage (Zwanzig et al., 1999). Basalt from a highly flattened, dark grey weathering pillowed flow at a new sampling locality on Laurie Lake has a similar TiO_2/MgO ratio, as well as the characteristic, horizontal, MORB-normalized, extended-element profile (Fig. GS-17-4b). This rock lies in the upper part of the inverted structural package on the north side of the Laurie Lake dome and is cut off along the overturned unconformity at the base of the Sickle Group (4003 on Fig. GS-17-2).

Tod Lake Basalt

The most widespread map unit of basalt contains 1.0–2.5% TiO_2 and is classified as Tod Lake basalt (Fig. GS-17-3). It is Fe-rich and contains relatively high concentrations of Zr (Table GS-17-1). Zwanzig et al. (1999) suggested that it formed in a marginal basin by fractionation and contamination from a parent magma similar to that of the Hatchet Lake basalt. The contaminating crust or sedimentary rocks were probably heterogeneous and thus produced variable enrichment in light rare-earth elements (LREE) and depression of high field-strength element (HFSE)/rare-earth element (REE) ratios. Accordingly, the basalt shows trace-element variations between, and locally within, sampling areas. This is illustrated by La/Yb ratios (Table GS-17-1) and MORB-normalized extended-element plots (Fig. GS-17-4c to -4e). The new data from Granville Lake show a negative trace-element slope (Fig. GS-17-4d); data from widely scattered samples in South Bay, across the Laurie Lake dome, show a less prominent slope; and the old data (mainly from Tod Lake) show the most gentle slope (Fig. GS-17-4c). Rocks from a mafic sheet within the structural stack of Burntwood Group turbidite on Wheatcroft Lake lack a negative Nb anomaly (Fig. GS-17-4e).

Despite the variations in detail, the trace- and major-element compositions of Tod Lake basalt are similar over an area equivalent to that of the arc-related volcanic rocks in the Lynn Lake belt and probably extending east and west beyond the area of sampling.

Pickerel Narrows Amphibolite

Mafic to ultramafic rocks (Pickerel Narrows amphibolite of Zwanzig et al. [1999]) with exceptionally high contents of TiO_2 (Fig. GS-17-3), Zr and La/Yb ratios (Table GS-17-1) were obtained from sample collections that extend over 1500 m along the south shore of Granville Lake (Fig. GS-17-1). These rocks include alkali olivine basalt and picrite (?)flows with very consistent MORB-normalized extended-element profiles that have a steep negative slope (Fig. GS-17-4f). They are part of an ocean-island assemblage interlayered with the upper part of the Tod Lake basalt. The succession is overlain by a unit of ultramafic rock containing flattened fragments with variable textures and weathering colours. Rounded (?)boulders and angular clasts suggest that the unit may be a locally derived conglomerate. The relatively steep slope of the extended-element plots of some samples shows an affinity to the ocean-island assemblage.

Komatiitic Basalt and Felsite

High-Mg basalt with highly depleted contents of TiO_2, Zr and LREE (Fig. GS-17-3 and -4g) occurs in the structural stack on Granville Lake, and north of the Hatchet Lake basalt on Laurie Lake (4001 on Fig.

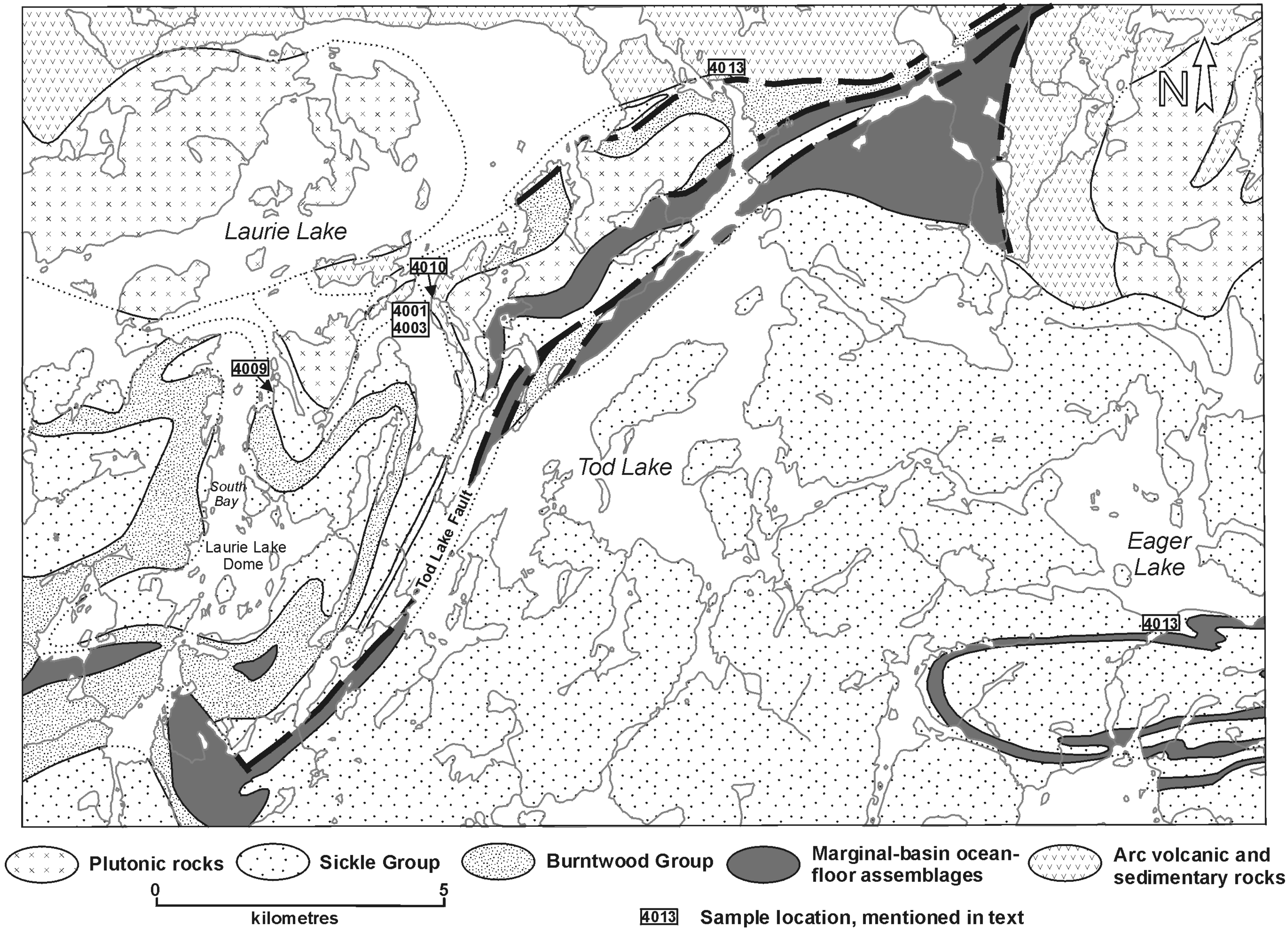

Figure GS-17-2: Geological map of the Laurie Lake–Eager Lake area (after *Gilbert et al., 1980*)*, showing the locations of selected geochemical samples.*

Table GS-17-1: Typical and average analyses of selected elements and element ratios.

Sample	Unit	Source	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	TiO_2/MgO	La/Yb_N	Th/Nb_N	Zr
Average	Laurie Lake assemblage	OF-99-13	52.3	15.79	7.99	9.65	10.0	2.96	0.30	0.64	0.07	3.54	5.07	49
4010-1	Laurie Lake assemblage	Laurie L.	50.9	15.92	10.18	6.75	11.2	3.20	0.62	0.72	0.11	6.16	6.63	79
Average	Hatchet Lake basalt	OF-99-13	49.4	14.98	13.37	8.22	10.1	2.23	0.18	1.12	0.14	0.79	1.61	54
4003	Hatchet Lake basalt	Laurie L.	50.3	15.16	10.87	9.11	9.61	3.47	0.41	0.84	0.09	0.63		52
Average	Tod Lake basalt	OF-99-13	51.0	14.95	13.60	5.39	9.71	2.95	0.32	1.72	0.32	1.54	3.54	99
4009-1	Tod Lake basalt	South Bay	47.5	14.53	14.66	8.33	9.62	3.25	0.22	1.66	0.20	1.79	1.44	77
4015	Tod Lake basalt	Eager L.	48.3	14.03	14.03	6.50	11.5	2.67	0.63	1.91	0.29	2.80	4.37	118
606	Tod Lake basalt	Granville L.	51.4	15.69	11.56	5.65	10.2	2.83	0.60	1.72	0.30	3.18	5.68	113
772-8	Tod Lake basalt	Wheatcr L.	47.0	14.02	15.67	8.16	10.8	1.86	0.08	1.86	0.23	1.61	1.64	117
Average	Tod Lake type sills	Wheatcr L.	45.0	14.84	15.84	9.07	12.3	1.09	0.15	1.16	0.13	2.73	1.93	53
Average	Pickerel Narrows assembl	Granville L.	43.0	8.45	16.04	17.90	10.8	0.47	0.28	2.49	0.14	14.19	2.37	157
434-2	Pickerel Narr pillow basalt	Granville L.	42.3	14.69	16.29	8.82	10.9	2.42	0.60	3.37	0.38	6.91	1.62	192
Average	Granville Lake fragmental	Granville L.	48.8	8.52	11.15	18.58	10.5	0.94	0.09	1.07	0.06	3.96	3.83	63
4001	Komatiitic basalt	Laurie L.	47.3	15.47	12.93	9.82	11.7	1.74	0.30	0.46	0.05	0.29		18
553-2	Komatiitic basalt	Granville L.	48.6	12.88	9.17	15.17	11.8	1.65	0.44	0.10	0.01	0.39		6
4013-2	Pyroxenite	Laurie R.	48.5	6.68	13.18	16.19	13.6	0.86	0.23	0.33	0.02	3.55	7.83	25

Values in weight percent (volatile free), except for Zr, which is in ppm
$_N$–chondrite normalized

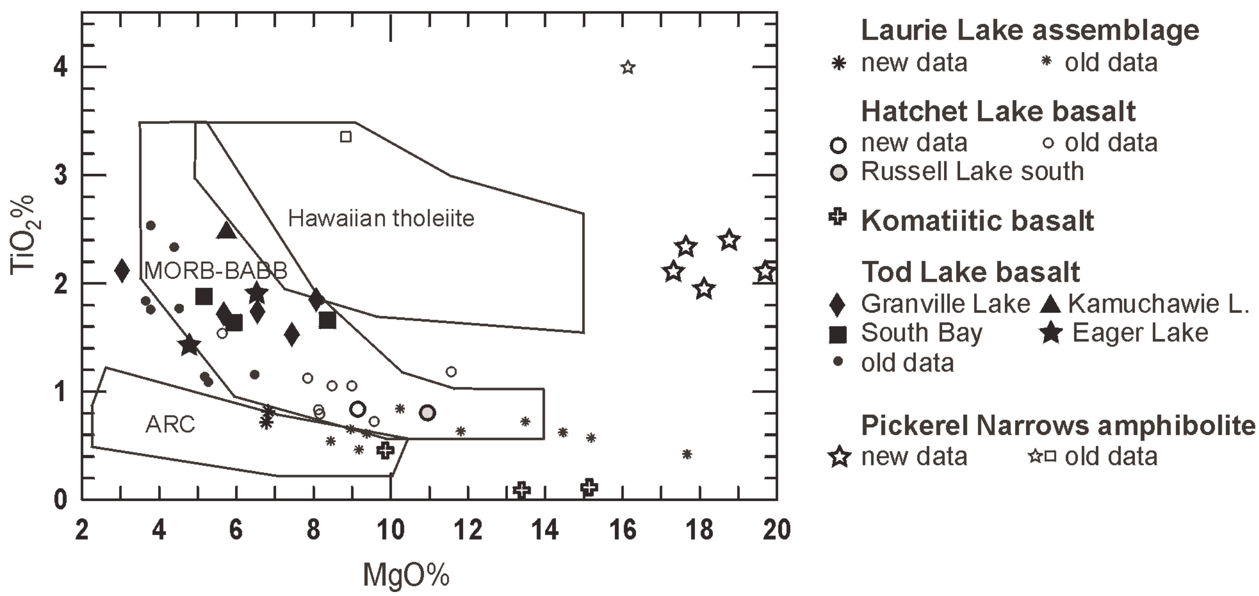

Figure GS-17-3: Plot of TiO_2 vs. MgO from mafic-ultramafic volcanic rocks in various tectonic assemblages along the Kisseynew Domain–Lynn Lake belt boundary (fields of modern tectonic environments after *Stern et al. [1995]; old data* from *Zwanzig et al. [1999]).*

GS-17-2). Its positively sloped MORB-normalized profile with negative Ti anomaly is typical of komatiitic basalt.

The komatiitic basalt occurrence on Laurie Lake is adjacent to the Laurie Lake felsite, which is a dyke or bed of Na-rhyolite tuff characterized by an intermediate to heavy REE profile with positive slope (Fig. GS-17-4g). The overall trace-element signature of the felsite has been related to arc rifting (Zwanzig et al., 1999). The Laurie Lake felsite may be part of a related bimodal suite, together with the komatiitic basalt.

Laurie River Ultramafic Intrusion

A small, highly recrystallized intrusion that probably represents pyroxenite and olivine pyroxenite occurs on the north shore of the Laurie River between Laurie Lake and Tod Lake. The poorly exposed body stratigraphically underlies the unconformity at the base of the Sickle Group, analogous to the Laurie Lake assemblage. Its negatively sloped, MORB-normalized, extended-element plot with negative Nb, Zr, Hf and Ti anomalies is very similar to the calc-alkaline Laurie Lake assemblage, which may be an extrusive equivalent of the Laurie River intrusion (Fig. GS-17-4h and -4a).

TECTONIC STACKING

Three of the lithotectonic assemblages of volcanic rocks occur in separate structural sheets, as indicated by younger sequences of the Sickle Group or Burntwood Group stacked between them. Contacts between assemblages are tectonic; only the Tod Lake basalt and the Pickerel Narrows amphibolite appear to be in stratigraphic contact, because thin (?)flow units are interlayered without evidence of faulting. Different tectonic environments are inferred for these assemblages based on the geochemical data (Zwanzig et al., 1999 and this report). They include volcanic-arc, marginal-basin, possible arc-rift and ocean-island settings. The assemblages, which are generally less than 300 m thick (in most areas <10 m thick), represent fault slivers of the original terranes. The structural pile that contains these slivers is the result of extensive telescoping and tectonic stacking; the faults between them must be major tectonic discontinuities.

A seismic profile across the east end of Granville Lake has been interpreted to show that the tectonic stack dips moderately northeast and extends through both the upper and lower crust (White et al., 2000). The hanging-wall block contains mainly the arc-related rocks of the Lynn

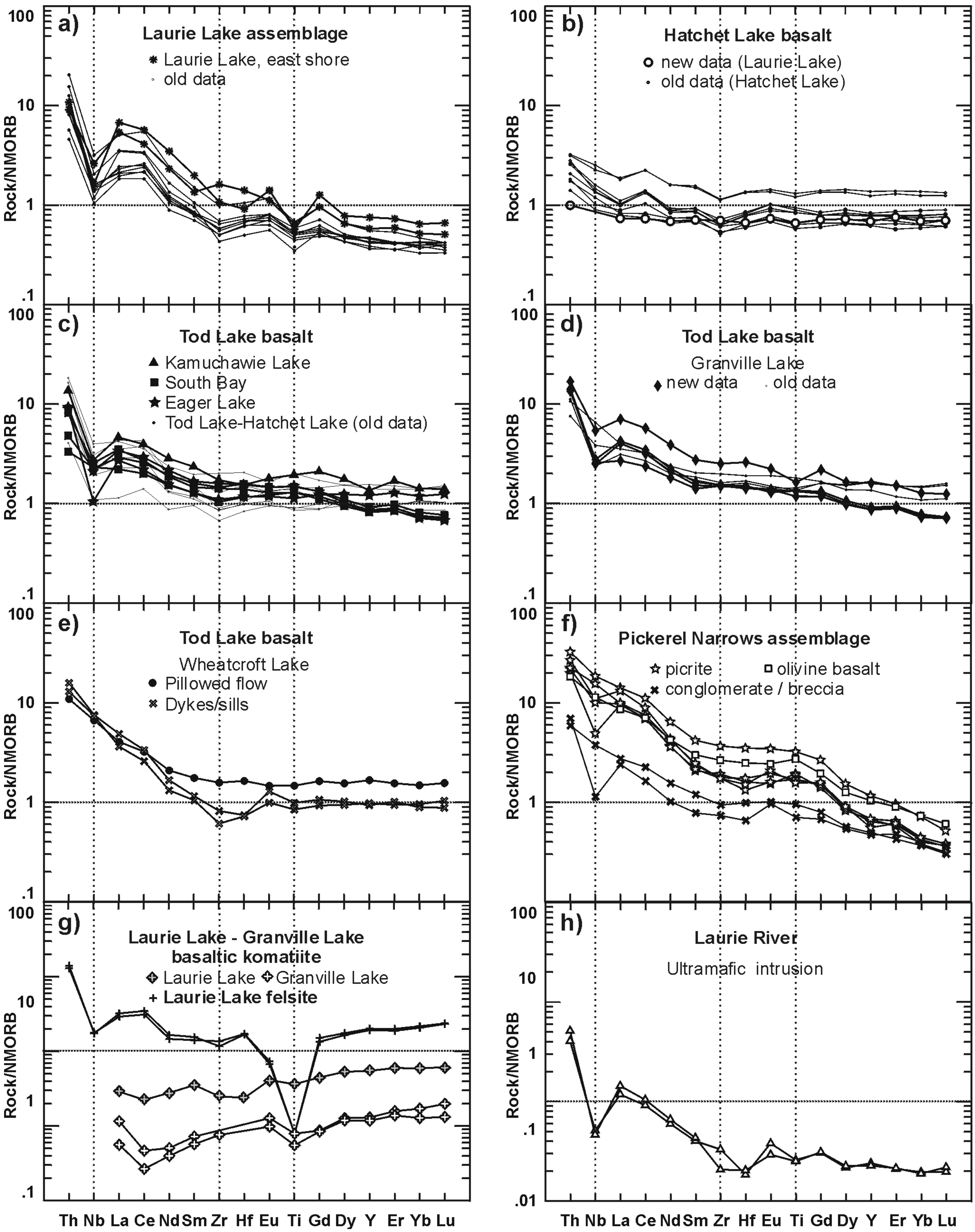

Figure GS-17-4: N-MORB–normalized extended-element plots from igneous rocks in various tectonic assemblages along the Kisseynew Domain–Lynn Lake belt boundary (normalizing values after *Sun and McDonough [1989]; old data* from *Zwanzig et al. [1999]).*

Lake belt, whereas the footwall is dominated by the younger Burntwood Group turbidite of the Kisseynew Domain. The crustal suture between these blocks is the Granville Lake Structural Zone (Zwanzig, 1990), which is dominated by the ocean-floor–marginal-basin assemblages that locally contain volcanic remnants of ocean-island affinity.

On Laurie Lake, the tectonic stack has been domed, highly flattened and refolded (Fig. GS-17-2). The structural relief due to the doming has provided a complete transect across the stack from South Bay, in the core of the Laurie Lake dome, northeast to the Laurie River, in the Lynn Lake belt. The deepest structural level, which is the main part of the dome, consists of large recumbent folds of the youngest rocks (the Burntwood and Sickle groups). Layered amphibolite, herein identified by geochemical criteria as Tod Lake basalt, separates the Burntwood and Sickle groups. Locally, hornblende-bearing quartzofeldspathic gneiss, derived from coarse-grained greywacke, lies between two fault-bounded sheets of Tod Lake basalt. Laminated quartzite, interpreted as chert, stratigraphically overlies the upper sheet of basalt and is, in turn, stratigraphically overlain by the Sickle Group. The whole structural package of amphibolite and gneiss is very similar to a section on Granville Lake, and represents the crustal suture exposed in the Granville Lake Structural Zone. At the deepest structural level, in South Bay, the zone is generally reduced by extreme attenuation to a few metres thickness. The deep part of the zone is easily recognized only on the west shore of South Bay, where a thickness of 200 m is preserved.

The sampled section of amphibolite on the north side of the dome contains a repetition of the suture zone at a higher structural level. This is the section in which the overturned unconformity at the base of the Sickle Group is underlain by Hatchet Lake basalt (MORB) and komatiitic basalt with Laurie Lake felsite (arc rift). Nearby, along strike, the unconformity is underlain by Laurie Lake assemblage (arc), along with hornblende-bearing greywacke. This section is up to 300 m thick. It is interpreted to contain three or four major tectonic breaks. An anticlinal core of Burntwood Group metasedimentary rocks to the northeast is bounded by another structural break. These attenuated terrane slivers and their tectonic discontinuities represent a structural style that is more complex than previously assumed. The style was produced by tectonic stacking, followed by ductile, polyphase deformation.

The timing of tectonic stacking and subsequent deformation are problems that require U-Pb zircon dating. The unconformity at the base of the Sickle Group overlies various arc and MORB-like units on the east shore of Laurie Lake and on adjacent islands at site 4001 (Fig. GS-17-2). The same relationship was reported at Tod Lake, and was interpreted to indicate that the accretion of the marginal-basin floor to the arc assemblages occurred early in the tectonic history, whereas subsequent thrusting involved the Sickle Group (White et al., 2000). Doming, refolding and final thrusting, such as along the Tod Lake Fault, occurred during peak and waning metamorphism. The late reactivation of shear zones produced zones of phyllonite and carbonate alteration that are well exposed on the west shore of Tod Lake. Displacement was probably connected with faulting along the Johnson Shear Zone in the central Lynn Lake belt.

APPLICATION TO MINERAL EXPLORATION

It has been shown in the Flin Flon Belt that the various tectonic assemblage types differ in mineral potential (Syme et al., 1999). An alteration zone with garnet, anthophyllite, gedrite and small amounts of Cu, Zn and Au (location 24 in Ferreira, 1993) occurs between Hatchet Lake basalt (MORB) and komatiitic basalt, along strike from the Laurie Lake felsite. More work is required to determine whether the Fox mine succession of arc tholeiite extends along the southeast shore of Laurie Lake, and possibly also occurs along the north shore at the Lar VMS deposit (Ferreira, 1993). The extreme attenuation of these units in the central and southern parts of Laurie Lake requires detailed mapping, in order to identify mineralized zones that are expected to be very thin. The surprisingly good preservation of trace- and rare-earth–element patterns makes lithogeochemistry an important tool for such mapping and for identifying favourable units.

The Caimito Au showing, on central Laurie Lake (location 25 in Ferreira, 1993), is hosted by deformed vein quartz in one of the high-strain zones that cut or reactivate the early tectonic breaks. Displacement along such zones may have been linked to that on the Johnson Shear Zone to the northeast. The zones lie in the wedge-shaped hanging-wall block above the Granville Lake Structural Zone, which probably served as a crustal-scale detachment zone (White et al., 2000) and as a possible channel for fluids feeding the shear zones.

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