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Lithogeochemical studies in the Uchi–Confederation greenstone belt, northwestern Ontario: implications for Archean tectonics[1]

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Abstract: The Uchi–Confederation greenstone belt consists of three volcanic units that span over 250 million years (2989–2735 Ma) that have previously been termed the Balmer, Woman, and Confederation assemblages. Recent geochemical data indicate that the ca. 2840 Ma rocks of the Woman assemblage may be absent from this greenstone belt. The western portion of the group previously interpreted as the Woman assemblage are actually ca. 2880 Ma basaltic volcanic rocks, referred to herein as the Narrow Lake assemblage, whereas the eastern portion is probably part of the Confederation assemblage. Structural and geochronological studies indicate that the volcanic strata formed in situ rather than having been juxtaposed tectonically.

The distribution, structure, and geochemistry of units within the Confederation assemblage (ca. 2740 Ma) indicate that it formed as a rifted arc. However the tectonic settings of the older volcanic units are ambiguous.

Résumé : La ceinture de roches vertes d'Uchi–Confederation comprend trois unités volcaniques qui couvrent une période de plus de 250 millions d'années (de 2 989 à 2 735 Ma). Ces unités avaient précédemment été désignées sous les noms d'assemblages de Balmer, de Woman et de Confederation. Des données géochimiques récentes indiquent que les roches d'environ 2 840 Ma de l'assemblage de Woman pourraient ne pas se rencontrer dans cette ceinture de roches vertes. La partie ouest du groupe interprété antérieurement comme étant l'assemblage de Woman est en fait constituée de roches volcaniques basaltiques d'environ 2 880 Ma, ici appelées «assemblage de Narrow Lake», tandis que la partie est fait probablement partie de l'assemblage de Confederation. Des études structurales et géochronologiques indiquent que les strates volcaniques se sont acumulées en place et n'ont pas été juxtaposées tectoniquement.

La répartition, la structure et la géochimie des unités au sein de l'assemblage de Confederation (environ 2 740 Ma) indiquent que l'assemblage s'est constitué sous la forme d'un arc de divergence. Toutefois, le cadre tectonique des unités volcaniques plus anciennes est ambigu.

[1] Contribution to the Western Superior NATMAP Project

INTRODUCTION

This paper reports results from the 1999 field season in the Uchi–Confederation greenstone belt of the Uchi Subprovince of the Superior Province, northwestern Ontario. One of the purposes of this project, which is part of the Western Superior NATMAP, is to constrain relationships among the different aged volcanic and sedimentary units that represent a greater than 250 million year record of supracrustal rocks within this greenstone belt (Nunes and Thurston, 1980; Rogers et al., 1999).

The Berens River and English River subprovinces bound the Uchi–Confederation greenstone belt to the north and south, respectively, with the Janette Lake and Trout Lake batholiths to the east and west (Fig. 1; Stott and Corfu, 1991). This greenstone belt was previously interpreted as three distinct mafic to felsic volcanic cycles (Goodwin, 1967; Pryslak, 1971a, b; Thurston, 1985) that formed between ca. 2960 and 2740 Ma (Nunes and Thurston, 1980; Wallace et al., 1986). These cycles were later reinterpreted by Stott and Corfu (1991) as the Balmer (ca. 2960 Ma), Woman (ca. 2840 Ma), and Confederation (ca. 2740 Ma) lithotectonic assemblages; the distribution of which are summarized in Figure 1.

Rogers et al. (1999) and Tomlinson and Rogers (1999) presented initial results that suggested that the Woman assemblage is not as extensive as previously believed, with the western portion representing a distinct and potentially significantly older period of volcanism. This interpretation is developed further here, such that the western Woman assemblage (Tomlinson and Rogers, 1999) is tentatively reclassified as the Narrow Lake assemblage, although it may actually correlate with the Bruce Channel assemblage of the Red Lake greenstone belt (Stott and Corfu, 1991). The eastern portion of the former Woman assemblage is provisionally reinterpreted as belonging to the Confederation assemblage (Fig. 2).

BALMER ASSEMBLAGE

The Balmer assemblage (Fig. 2) occurs to the east of and is intruded by the ca. 2860–2840 Ma Trout Lake batholith (Noble, 1989; V. McNicoll, unpub. data, 1999). Previous studies (e.g. Pryslak, 1971a; van Staal, 1998; Rogers et al., 1999) described this assemblage as primarily massive tholeiitic basalt with minor felsic volcaniclastic rocks and wacke. No pillowed flows are known within the Balmer assemblage, despite an apparent submarine environment as indicated by interbedded tuffaceous and sedimentary rocks. This is in contrast to the structurally higher units where pillow basalt units are very common. Consequently the upper assemblage boundary is in part constrained by the presence of pillowed flows. In the Narrow Lake area the structural top of the Balmer assemblage is marked by a quartz and feldspar

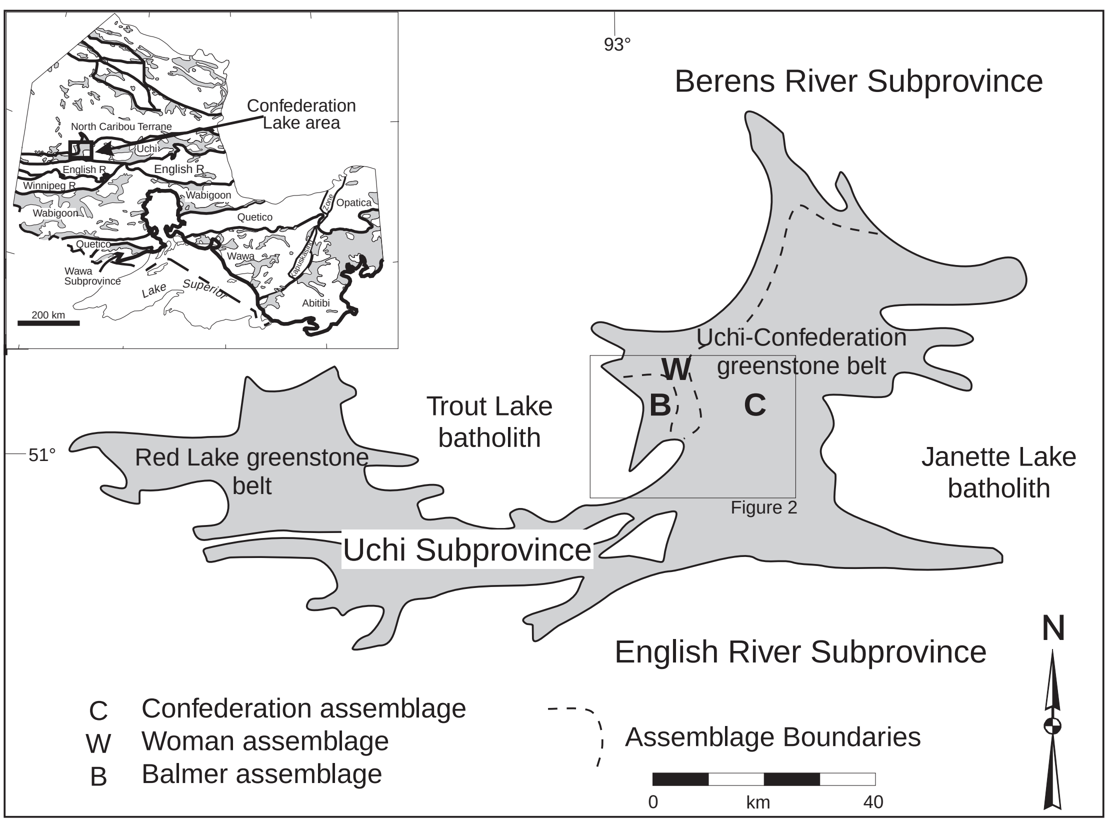

Figure 1. *Simplified distribution of the Uchi–Confederation greenstone belt, with its previously defined assemblage boundaries and relative position to regional features (modified after Stott and Corfu, 1991; van Staal, 1998).*

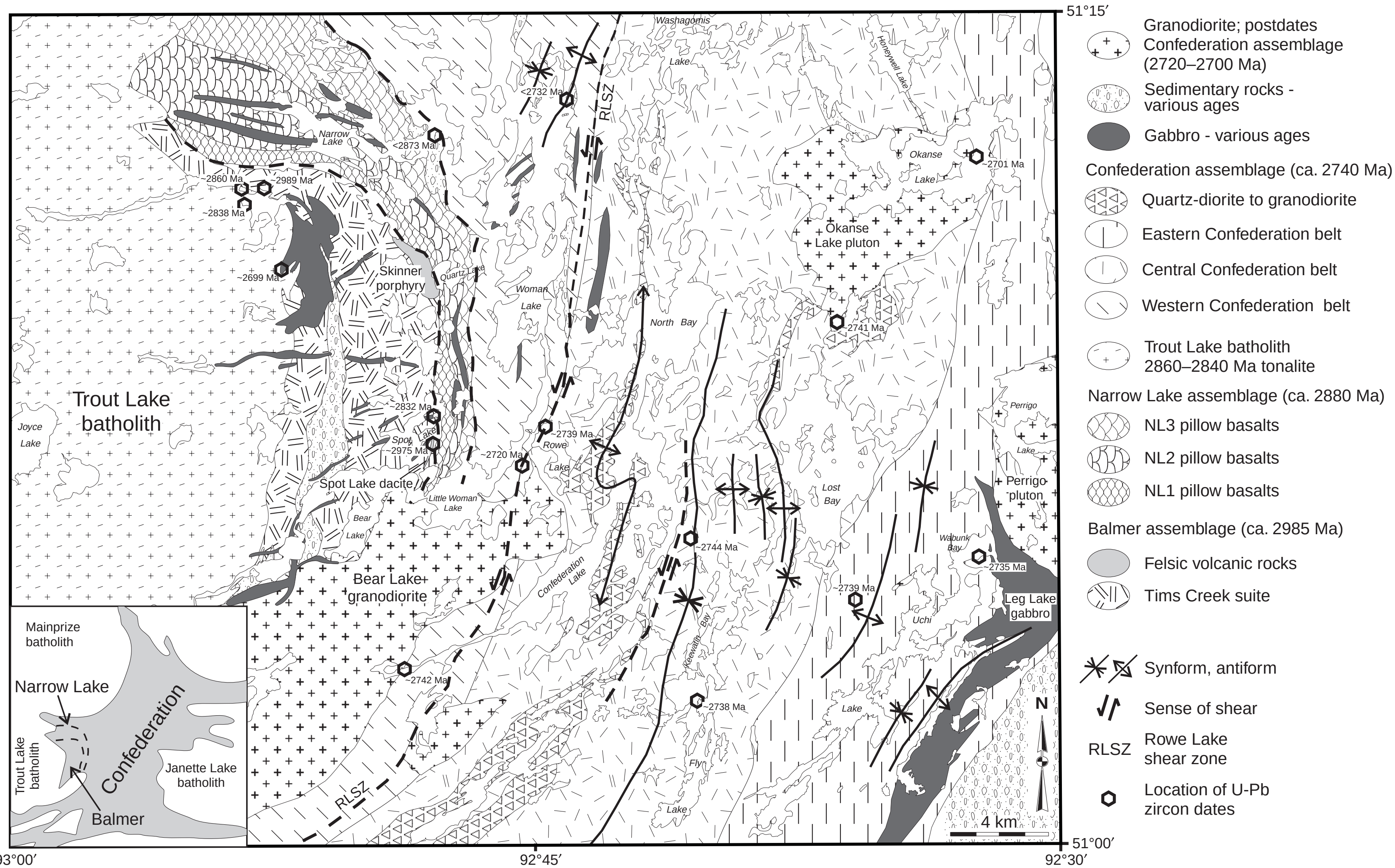

Figure 2. Geology of the Confederation Lake area (NTS 52 N/02). Inset map illustrates the distribution of the revised assemblages.

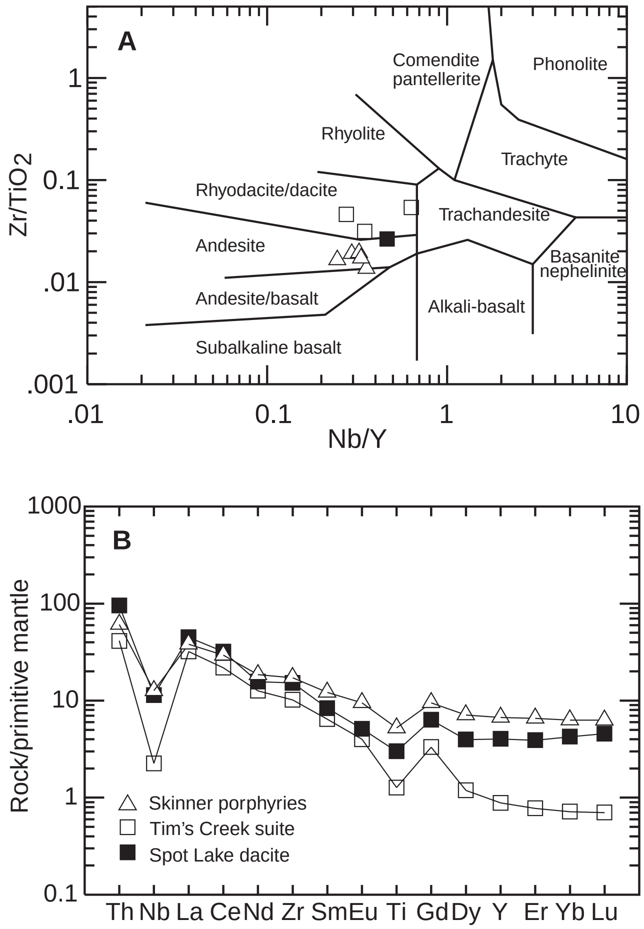

Figure 3. A) *Zr/TiO_2-Nb/Y lithology discriminant plot after Winchester and Floyd (1977);* ***B)*** *Primitive mantle normalized multi-element spidergram of mean compositions of the Balmer assemblage volcanic rocks. Normalization factors* after *Taylor and McLennan (1985).*

xenocrystic, dacitic to rhyodacitic crystal tuff (herein the Skinner porphyry) whereas further south a sparsely phyric, dacitic tuff (herein the Spot Lake dacite) occurs.

Geochemical data indicates that there are no *senso stricto* basaltic volcanic rocks within the Balmer assemblage. The most mafic volcanic rocks analyzed to date (referred to herein as the Tims Creek suite) have basaltic andesite to andesitic compositions (Fig. 3, Table 1). Two petrographically and chemically distinct felsic volcanic suites have been identified within the Balmer assemblage (Fig. 2, 3, Table 1). The Tims Creek suite at the base of the Balmer assemblage has a U-Pb zircon age of 2989 ± 2 Ma (V. McNicoll, unpub. data, 1999), is significantly older than the 2975 ± 1 Ma (V. McNicoll, unpub. data, 1998) age of the Spot Lake dacite. This data suggests that the Balmer assemblage represents either a relatively long-lived (ca. 15 million years) period of volcanism, or several discrete batches of volcanism.

Chemically, all of the Balmer assemblage volcanic rocks are LREE enriched with a moderate to steeply dipping REE profile (Fig. 3B). They are enriched in Th, exhibit pronounced negative Nb anomalies and have Nd isotopic signatures consistent with crustal contamination (εNd values from +0.3 to +1.6), possibly by significantly older crust (Tomlinson and Rogers, 1999).

NARROW LAKE ASSEMBLAGE

The rocks provisionally designated herein as the Narrow Lake assemblage (Fig. 2) were previously considered to be the structurally lowest part of the Woman assemblage (Stott and Corfu, 1991; Rogers et al., 1999). These rocks occur within a generally eastward-younging, approximately 1.5–4 km thick belt that extends from Narrow Lake in the north to Little Woman Lake in the south (Fig. 2). The Narrow Lake assemblage has provisionally been divided into three suites of mafic volcanic rocks (referred to herein as NL1, NL2, and NL3) on the basis of minor differences in trace element and REE compositions (Fig. 4, Table 1). Each suite consists predominantly of pillowed flows that are intruded by numerous diabase to gabbroic sills. Although the gabbro sills are chemically similar to the surrounding basaltic rocks, it is unclear whether the gabbros are syn- or postvolcanic. The basaltic suites form an eastward-younging, layer-cake stratigraphy with the NL1 suite of rocks occurring at the base of the assemblage, immediately overlying the Balmer assemblage. The NL3 suite is overlain by a sedimentary unit consisting of a narrow band of iron-formation (less than 10 m thick) at Little Woman Lake to a greater than 100 m thick section at Narrow Lake of texturally immature bedded wacke units that contain large amounts of volcanic detritus (Fig. 2).

It is apparent from field relations that the Narrow Lake assemblage disconformably to unconformably overlies the Balmer assemblage at Spot Lake (van Staal, 1998; Rogers et al., 1999) and is therefore younger than ca. 2975 Ma. Furthermore a gabbro dyke that provides a minimum age for the Narrow Lake assemblage rocks of 2832 ± 2 Ma (V. McNicoll, unpub. data *in* Rogers et al., 1999) cuts this assemblage

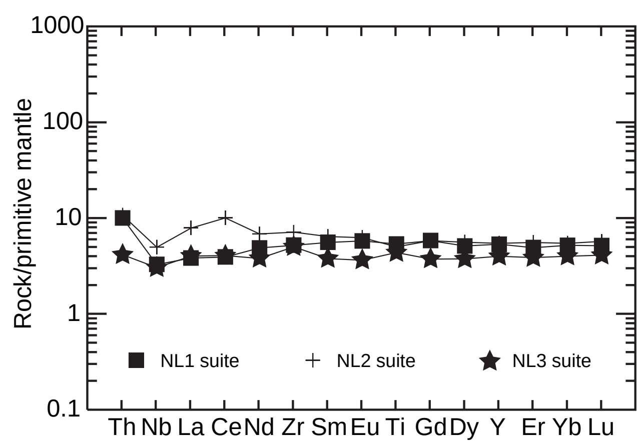

Figure 4. *Primitive mantle normalized multi-element spidergram of mean compositions of the Narrow Lake assemblage volcanic rocks. Normalization factors* after *Taylor and McLennan (1985).*

Table 1. Mean and standard deviations for whole-rock chemical analyses of the Balmer and Narrow Lake assemblages.

	Balmer assemblage					Narrow Lake assemblage					
	Tims Creek		Skinner		Spot Lake	NL1		NL2		NL3	
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	Mean	SD
	n=5		n=3		n=1	n=8		n=9		n=8	
wt%											
SiO_2	56.59	0.72	70.03	1.11	69.54	48.47	2.92	51.61	4.48	50.24	3.52
TiO_2	0.84	0.05	0.20	0.06	0.48	0.86	0.21	0.70	0.20	0.81	0.10
Al_2O_3	15.48	1.00	15.25	0.18	14.55	14.66	1.65	15.12	1.93	14.12	1.78
Fe_2O_3	8.03	1.03	1.63	0.15	2.77	12.45	1.44	9.80	2.29	11.29	2.38t
MnO	0.13	0.02	0.03	0.02	0.09	0.22	0.05	0.20	0.05	0.20	0.04
MgO	4.54	0.72	0.48	0.09	1.64	8.24	1.76	6.71	2.72	7.30	0.63
CaO	5.51	1.50	1.92	0.68	1.91	9.04	1.14	9.78	3.54	9.25	1.31
Na_2O	3.12	0.91	4.61	0.47	0.34	2.00	0.42	2.17	1.45	2.18	0.76
K_2O	1.51	0.71	2.38	0.40	4.01	0.43	0.43	0.35	0.54	0.16	0.10
P_2O_5	0.22	0.06	0.05	0.03	0.15	0.07	0.03	0.05	0.01	0.09	0.05
LOI	3.70	2.00	2.67	0.42	4.60	4.32	3.65	4.11	2.47	5.14	3.84
Total	99.78	0.29	99.41	0.32	100.15	100.81	0.84	100.63	0.90	100.79	0.44
ppm											
Ba	222.6	123.6	727.7	169.0	224.0	39.2	38.0	71.0		51.0	
Cd	0.1	0.0	0.2	0.3	0.1	0.6					
Co	26.5	4.7	3.0	0.8	7.4	47.5	2.3	31.7		59.2	
Cr	201.2	55.1	161.9	25.9	171.2	353.9	110.6	681.5	322.9	279.6	99.5
Cs	1.6	1.2	1.3	0.1	1.2	0.5	0.7	1.1	2.0	0.1	0.1
Ga	14.3	2.1	19.5	4.7	13.7	13.2	2.0	10.2		13.2	
Hf	3.4	0.4	2.3	0.1	3.9	1.5	0.1	1.4		1.9	
Nb	7.1	1.3	1.3	0.6	6.4	1.8	0.7	1.7	0.5	2.8	0.6
Ni	62.6	25.2	4.7	1.2	10.0	141.3	38.2	180.6	58.2	106.3	32.7
Pb	4.8	2.0	4.5	2.3		6.0					
Rb	51.2	41.8	53.8	10.1	72.0	12.6	16.2	1	17.4	2.6	3.5
Sc	14.2	4.8	2.0	0.0	5.0	39.5	9.2	39.0	10.8	36.9	10.5
Sn	1.5	0.7	1.4	0.3	0.9	1.1	0.1	0.3		0.5	
Sr	163.5	65.6	388.7	96.3	23.2	106.9	0.2	59.2		219.0	
Ta	0.5	0.1	0.1	0.0	0.4	0.1	0.0	0.1		0.2	
Th	3.9	1.1	2.6	0.4	6.1	0.6	1.0	0.3	0.1	0.7	0.4
U	1.1	0.5	1.2	0.2	1.9	0.1	0.0	0.1	0.0	0.2	0.2
V	148.0	30.4	22.7	6.5	42.0	270.1	38.1	254.9	56.7	247.0	40.2
Y	22.8	3.3	3.0	0.1	13.7	18.3	3.5	13.7	3.0	18.7	1.7
Zn	94.0	16.5	24.0	4.6		96.0	0.0				
Zr	143.0	20.5	84.4	1.7	126.4	43.5	7.9	41.9	12.9	59.5	13.9
La	21.00	2.94	17.67	7.99	24.70	2.12	0.83	2.23	0.78	4.38	1.24
Ce	42.24	5.22	31.33	10.28	45.90	5.66	1.67	5.87	2.54	14.51	7.83
Pr	5.18	0.76	4.11	1.78	4.63	0.99	0.34	0.82	0.26	1.59	0.32
Nd	19.70	1.85	13.47	6.87	16.70	5.24	1.43	4.08	1.04	7.34	1.61
Sm	4.22	0.66	2.23	1.02	2.90	1.95	0.55	1.32	0.31	2.25	0.45
Eu	1.24	0.10	0.52	0.17	0.67	0.76	0.22	0.48	0.14	0.83	0.16
Gd	4.37	0.75	1.52	0.57	2.91	2.68	0.69	1.73	0.34	2.68	0.35
Tb	0.73	0.09	0.19	0.08	0.42	0.50	0.14	0.32	0.07	0.50	0.07
Dy	4.07	0.43	0.68	0.10	2.27	2.94	0.59	2.16	0.46	3.22	0.33
Ho	0.82	0.09	0.10	0.02	0.48	0.70	0.16	0.50	0.10	0.73	0.08
Er	2.46	0.28	0.29	0.03	1.46	1.85	0.34	1.46	0.32	2.10	0.24
Tm	0.39	0.03	0.03	0.01	0.29	0.32	0.10	0.23	0.04	0.33	0.04
Yb	2.34	0.25	0.27	0.02	1.58	1.95	0.46	1.50	0.32	2.04	0.32
Lu	0.36	0.04	0.04	0.00	0.26	0.30	0.07	0.24	0.05	0.33	0.05

boundary. Although the basaltic volcanic rocks within this assemblage may have formed at any time during this ca. 140 million year period, the age of the conformably (to disconformably) overlying wacke unit is constrained by detrital zircons to have a maximum age of ca. 2880 Ma (V. McNicoll, unpub. data *in* Rogers et al., 1999). It is unclear whether these detrital zircons are locally derived or exotic; however, the immature nature of the wacke makes a local source probable and therefore this maximum age of sedimentary deposition may represent the crystallization age of the underlying volcanic rocks.

All of the Narrow Lake mafic volcanic suites are fairly primitive with relatively flat REE profiles, although some Th enrichment and minor negative Nb anomalies do occur indicating a small amount of crustal involvement (Fig. 4). This is consistent with Nd-isotopic data that indicates a component of old crust in their petrogenesis (εNd values of 0.0 to +1.4; Tomlinson and Rogers, 1999). Furthermore, given the small amount of crustal assimilation evident from the trace element compositions, the Nd-isotopic data indicates that the assimilated crust must be significantly older than the volcanic rocks, and probably greater than 3.0 Ga.

CONFEDERATION ASSEMBLAGE

The Confederation assemblage consists of ca. 2740 Ma supracrustal rocks and comprises the majority of the Uchi–Confederation greenstone belt (Stott and Corfu, 1991; Rogers et al., 1999). Field relationships, chemical analyses, and new U-Pb zircon ages suggest that the Confederation assemblage may be more extensive than previously thought. The rocks previously classified as the structurally highest part of the Woman assemblage (Rogers et al., 1999) have provisionally been reinterpreted as the westernmost portion of the Confederation assemblage.

The primary evidence that the rocks previously identified as the eastern part of the Woman assemblage belong to the Confederation assemblage comes from two new U-Pb zircon dates. The first of these is a 2742 ± 2 Ma age (V. McNicoll, unpub. data, 1999) for a dacitic, welded tuff from the south of Confederation Lake that Rogers et al. (1999) had postulated represented an extension of the Woman assemblage south of the Bear Lake granodiorite (Fig. 2). This interpretation was based on the petrographic similarity and on-strike continuity with a suite of welded tuffs on Woman Lake. Furthermore, the welded tuffs from southern Confederation Lake are chemically identical to the welded tuffs from Woman Lake. If the correlation of units to the north and south of the Bear Lake granodiorite is correct, then the age of ca. 2840 Ma (F. Corfu, unpub. data, 1986) obtained for the tuffs from Woman Lake cannot be reliable. Other significant new data derive from detrital zircons from a conglomerate-wacke unit previously inferred to belong to the uppermost Woman assemblage (Rogers et al., 1999). All of the analyzed zircons from this sample are Confederation age (ca. 2742–2732 Ma; V. McNicoll, unpub. data, 1999), even though it contains clasts from the stratigraphically underlying basaltic to dacitic volcanic rocks previously believed to belong to the ca. 2840 Ma Woman assemblage.

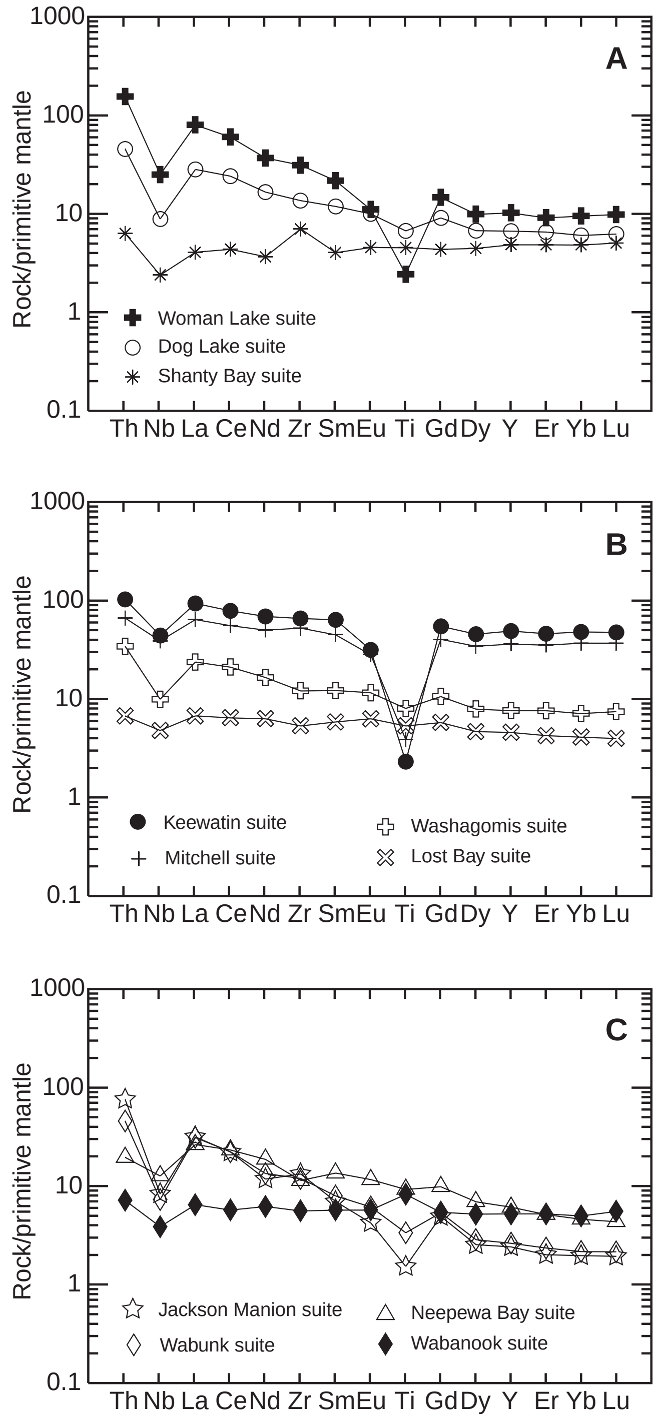

Figure 5. *Primitive mantle normalized multi-element spidergrams of mean compositions of the Confederation assemblage volcanic rocks;* ***A)*** *western Confederation belt;* ***B)*** *central Confederation belt;* ***C)*** *eastern Confederation belt. Normalization factors* after *Taylor and McLennan (1985).*

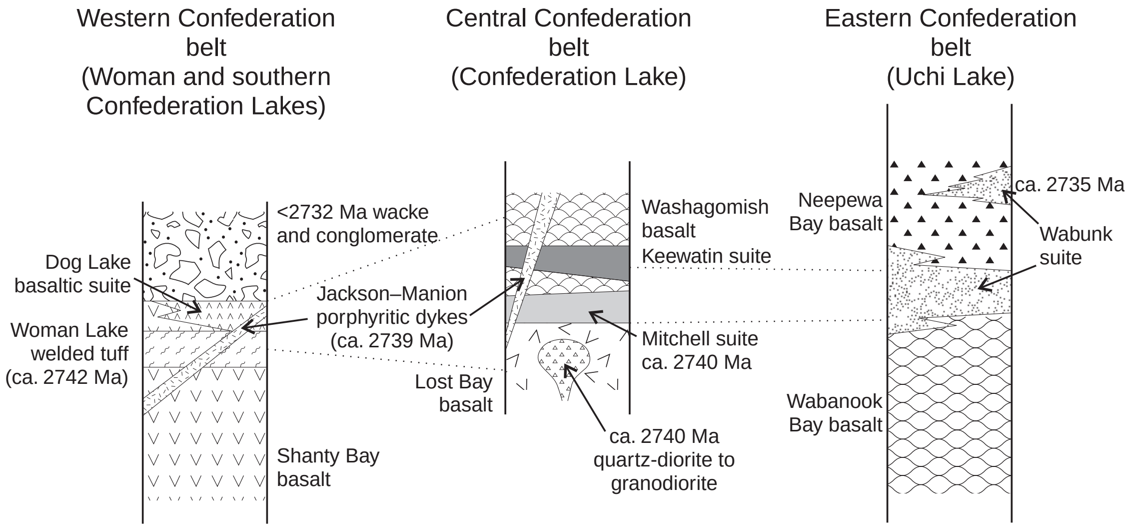

Figure 6. *Schematic sections illustrating the relative position of volcanic units from the central, eastern, and western Confederation belts.*

Supporting evidence for reinterpretation of the eastern Woman assemblage as Confederation assemblage is provided by a 2739 ± 2 Ma (V. McNicoll, unpub. data, 1999) age for a rhyolitic, quartz- and feldspar-phyric dyke within the Rowe Lake shear zone (Fig. 2; Rogers et al., 1999). Chemically and petrographically indistinguishable porphyritic dykes cut volcanic units on the northwest shore of Woman Lake, providing a minimum age for volcanism. Furthermore, the basaltic rocks from the Woman Lake area are chemically indistinguishable from ones of known Confederation age.

The expanded Confederation assemblage can be divided into three distinct, north- to northeast-trending tectonostratigraphic belts; referred to herein as the eastern, central, and western Confederation belts (Fig. 2). The belts are defined on the basis of their petrographically and chemically distinct felsic volcanic rocks (Fig. 5, Table 2). The petrographic details of the various felsic volcanic suites are discussed in Rogers et al. (1999). The western Confederation belt contains the Woman Lake tuff (pale grey to white, welded, massive or flow-banded, dacitic tuffs, often with prominent fiamme), the central belt contains the Mitchell (dark grey to black rhyolitic flows and tuffs) and Keewatin (quartz and feldspar phyric flows and tuffs) suites, and the eastern belt contains the Wabunk suite (light grey bedded tuffs and massive flows). In addition to these extrusive felsic volcanic rocks, a suite of shallow-level dykes and sills (herein called the Jackson Manion suite) cut the Woman Lake, Mitchell, and Keewatin extrusive units. At least two basaltic (to andesitic) volcanic suites, distinguished by chemical properties and stratigraphic position in relation to felsic volcanic rocks, occur within each of the belts (Fig. 5, 6, Table 2). No consistent petrographic characteristics have been recognized for these mafic volcanic suites.

The felsic volcanic rocks of the eastern and western Confederation belts are classified, by the scheme of Lesher et al. (1986), as F1 type. They exhibit steeply dipping REE patterns, have low abundances of high field-strength elements and high Zr/Y ratios, with the Wabunk suite of the eastern belt distinguished from the Woman Lake tuffs of the western belt by their lower high field-strength elements concentrations and steeper REE profiles (Fig. 5, Table 2). In contrast, the Mitchell and Keewatin suites of the central Confederation belt are both F3 type felsic volcanic rocks (Lesher et al., 1986), having relatively flat REE patterns, low Zr/Y ratios and high high field-strength elements concentrations (Fig. 5, Table 2). Furthermore, the felsic volcanic rocks of the central belt have a much smaller negative Nb anomaly than the other Confederation felsic volcanic rocks (Fig. 5). On the Pearce et al. (1984) granite-derived tectonic discrimination plots (Fig. 7) the Wabunk and Woman Lake felsic volcanic rocks plot within the arc field, whereas the Mitchell and Keewatin felsic volcanic rocks of the central Confederation belt plot in the within-plate and ocean-ridge fields. The Jackson Manion suite of porphyritic dykes is chemically very similar to the Wabunk felsic volcanic suite (Fig. 5C, 7). As the Jackson Manion dykes cut all the felsic volcanic rocks within the central and western Confederation belts (Fig. 6), the 2739 ± 2 Ma age determined for the dyke in the Rowe Lake shear zone likely provides a minimum age for felsic volcanism in these two belts.

The Shanty Bay suite of basaltic rocks dominates the western belt. These generally have a flat to slightly positively sloping REE profile, with a small to moderate negative Nb anomaly, and plot as island-arc tholeiites (IAT) on the tectonic discrimination diagrams of Wood (1980) and Cabanis and Lacolle (1989) (Fig. 5A, 8). A second suite of basalt to basaltic andesite, informally referred to herein as the Dog Lake basalt, occurs towards the stratigraphic top of the western belt. The Dog Lake basalt has a moderately steep REE pattern, a pronounced negative Nb anomaly, and plot as continental-arc basalt (CAB) on tectonic discrimination plots (Fig. 5A, 8). A similar configuration is evident in the eastern belt, where the volcanic rocks of the lower mafic volcanic

Table 2. Mean and standard deviations for whole-rock chemical analyses of the Confederation assemblage.

	Western Confederation belt						Central Confederation belt								Eastern Confederation belt						dykes	
	Shanty Bay		Dog Lake		Woman Lake		Lost Bay		Washagomis		Mitchell		Keewatin		Wabanook Bay		Neepewa Bay		Wabunk		Jackson Manion	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	n=24		n=15		n=15		n=12		n=18		n=30		n=12		n=2		n=3		n=14		n=11	
wt%																						
SiO_2	47.58	4.88	51.69	4.21	72.42	5.98	51.48	3.84	47.06	3.09	68.44	3.85	73.43	2.32	48.49	1.43	48.92	3.16	63.29	3.57	70.30	3.24
TiO_2	0.71	0.20	1.05	0.41	0.38	0.24	1.26	0.61	0.84	0.37	0.61	0.27	0.36	0.10	1.30	0.16	1.46	0.11	0.53	0.20	0.24	0.11
Al_2O_3	15.13	2.47	14.78	1.92	12.97	2.68	15.10	1.76	16.14	1.80	11.65	0.85	10.81	0.51	17.96	0.71	13.48	1.29	15.95	2.06	14.87	0.85
Fe_2O_3t	10.97	2.59	10.45	3.43	3.19	2.03	11.32	4.13	11.03	2.25	8.00	2.06	5.19	1.62	12.93	0.23	12.15	3.28	4.80	1.54	2.28	0.85
MnO	0.17	0.04	0.22	0.15	0.07	0.05	0.17	0.06	0.26	0.36	0.14	0.05	0.09	0.03	0.20	0.05	0.14	0.01	0.07	0.02	0.03	0.01
MgO	7.07	3.40	4.77	1.68	0.99	0.88	4.50	1.82	6.88	1.69	1.00	0.44	1.19	1.29	4.09	0.13	5.51	3.04	2.59	1.46	0.89	0.62
CaO	8.83	2.94	8.01	2.77	1.09	1.03	9.40	3.37	10.43	2.53	2.83	1.18	1.15	0.70	7.88	0.02	8.93	5.89	4.03	1.46	2.17	1.33
Na_2O	2.39	1.40	2.91	1.79	2.78	2.16	2.70	1.30	2.48	1.06	4.05	0.77	2.88	1.71	3.82	0.39	2.77	1.56	4.13	0.99	4.86	0.92
K_2O	0.46	0.61	1.19	1.66	4.49	2.73	0.50	0.88	0.19	0.13	0.85	0.51	1.39	0.60	0.50	0.41	0.34	0.22	1.57	0.75	1.94	0.80
P_2O_5	0.08	0.04	0.19	0.13	0.08	0.10	0.24	0.19	0.06	0.07	0.14	0.18	0.02	0.03	0.07	0.04	0.26	0.04	0.12	0.05	0.06	0.04
LOI	6.70	3.61	4.82	3.47	1.35	0.93	3.31	1.88	4.80	2.61	2.30	1.08	3.34	2.26	2.60	0.14	5.82	3.06	2.77	1.47	2.15	1.12
Total	100.18	0.47	100.18	0.41	99.93	0.20	100.05	0.25	100.17	0.32	100.08	0.29	100.00	0.13	99.94	0.05	99.87	0.10	99.98	0.29	99.91	0.24
ppm																						
Ba	87.7	114.7	162.3	128.3	555.9	280.3	69.9	39.6	52.2	37.5	267.3	174.4	315.2	166.6	130.0	121.6	78.2	80.8	312.4	149.1	445.0	154.8
Cd	0.9	0.5	0.9	0.5	0.3	0.1	0.5	0.3	0.6	0.4	0.3	0.2	0.6	1.3			0.2		0.3	0.2	0.2	0.1
Co	51.1	6.9	40.7	15.4	7.6	6.0	47.1	13.6	56.8	10.3	4.7	5.4	1.8	1.3	42.1	7.7	49.8	9.1	16.9	9.9	5.1	3.2
Cr	349.3	312.7	249.0	162.2	153.3	58.4	180.2	104.9	298.7	124.7	106.6	60.7	155.1	21.3	215.5	169.3	237.0	85.2	212.2	58.1	144.6	56.3
Cs	0.9	1.3	1.3	1.7	1.3	1.0	0.3	0.2	0.4	0.7	0.6	0.6	1.1	0.8	0.8	0.9	0.4	0.3	2.1	3.8	1.2	0.7
Ga	14.1	3.3	14.5	5.0	17.5	6.6	14.6	1.9	14.9	3.6	20.8	3.9	20.8	3.9	15.4	3.6	16.6	0.8	15.7	2.1	17.0	3.3
Hf	1.2	0.5	2.9	1.7	6.7	2.5	2.4	1.3	1.3	0.6	11.5	2.6	13.3	2.0	1.5	0.4	2.3	0.4	2.7	0.6	3.1	1.0
Nb	1.3	0.7	4.9	1.8	13.8	6.8	5.5	2.7	2.6	1.7	21.5	5.9	24.4	5.6	2.1	0.8	7.0	1.0	4.0	2.0	4.6	1.7
Ni	171.6	125.9	104.3	60.9	21.1	24.8	91.2	58.0	171.7	61.3	9.2	18.2	3.8	3.2	69.0	42.4	129.0	50.3	54.6	40.4	14.5	14.6
Pb	4.3	2.5	3.6	2.5	8.1	4.2	5.4	5.2	1.6	0.8	3.9	2.7	3.4	2.3			4.0		5.3	3.3	6.7	4.4
Rb	14.4	20.4	29.7	35.9	83.3	40.6	11.3	20.4	4.6	4.5	17.5	10.9	30.1	12.3	11.1	14.0	9.0	6.3	43.6	28.2	56.7	22.7
Sc	29.9	8.9	20.3	8.5	6.5	3.2	27.2	5.7	28.1	7.3	10.2	5.3	5.5	2.5	21.5	4.9	16.7	3.5	8.3	5.4	3.5	1.4
Sn	0.9	0.7	0.9	0.7	2.1	1.3	1.5	0.7	1.0	0.6	3.8	1.5	5.6	3.5	0.3	0.0	0.8	0.7	1.0	0.6	1.4	0.7
Sr	127.0	71.1	199.0	96.1	65.4	48.4	207.8	96.9	197.8	96.1	141.8	86.3	79.7	60.6	484.5	241.7	168.9	137.9	293.8	189.2	267.6	206.5
Ta	0.1	0.0	0.3	0.1	0.9	0.5	0.3	0.2	0.1	0.1	1.8	0.8	2.6	0.8	0.1	0.0	0.3	0.0	0.3	0.1	0.5	0.3
Th	0.4	0.3	2.9	1.8	9.8	3.6	2.2	1.9	0.4	0.3	4.2	1.3	6.5	1.4	0.5	0.2	1.2	0.1	2.9	1.3	4.8	3.4
U	0.1	0.1	0.7	0.5	3.0	1.2	0.6	0.8	0.1	0.1	1.3	0.4	1.9	0.4	0.1	0.0	0.3	0.0	0.9	0.3	1.9	1.1
V	260.6	76.4	193.5	68.4	29.6	34.5	243.6	108.1	202.4	52.2	17.1	17.2	5.5	6.8	376.5	154.9	181.0	32.1	83.4	46.5	26.7	19.2
Y	16.2	5.2	22.3	9.4	34.2	13.0	25.5	14.3	15.3	8.4	121.7	28.4	164.6	29.5	17.4	3.1	20.4	2.2	8.8	2.2	8.1	5.0
Zn	88.1	28.2	101.6	32.0	41.8	24.6	103.4	38.2	74.4	13.5	128.6	40.0	242.8	424.2			129.0		63.3	16.5	44.7	17.2
Zr	57.4	80.2	111.3	57.5	255.9	73.0	98.9	47.2	43.5	19.1	430.9	93.3	541.5	118.5	45.6	11.7	93.0	7.6	97.5	20.2	108.8	27.2
La	2.20	0.90	15.39	10.52	43.61	19.30	12.90	11.46	3.65	2.46	34.96	10.56	51.02	9.90	3.50	0.71	14.33	2.52	16.94	5.95	17.20	7.02
Ce	6.16	2.83	34.29	20.10	85.51	36.09	29.87	23.09	9.09	6.05	79.14	20.59	111.71	22.37	8.05	2.05	32.93	4.47	31.61	11.44	31.41	12.76
Pr	0.77	0.28	4.35	2.69	10.92	4.90	3.95	2.96	1.36	0.84	12.39	3.50	18.38	3.76	1.28	0.27	4.50	0.73	3.91	1.59	3.75	1.46
Nd	3.84	1.43	17.47	9.73	38.85	16.90	17.39	12.03	6.61	3.92	52.87	12.81	72.78	15.99	6.50	1.84	19.67	3.06	14.08	6.05	12.38	5.68
Sm	1.37	0.53	4.07	1.56	7.42	3.33	4.16	2.30	2.00	1.14	15.42	4.07	21.88	4.44	1.95	0.35	4.63	0.68	2.71	1.22	2.37	1.00
Eu	0.58	0.20	1.29	0.52	1.43	0.47	1.49	0.64	0.81	0.44	3.64	0.63	4.07	1.15	0.74	0.01	1.50	0.35	0.79	0.30	0.54	0.23
Gd	1.97	0.63	4.11	1.50	6.64	2.76	4.79	2.30	2.61	1.45	18.30	4.34	24.92	4.69	2.45	0.62	4.46	0.39	2.42	0.82	2.22	0.95
Tb	0.39	0.14	0.69	0.32	1.04	0.41	0.84	0.43	0.43	0.24	3.61	1.02	5.35	0.93	0.47	0.15	0.67	0.05	0.35	0.15	0.31	0.15
Dy	2.50	0.81	3.80	1.55	5.58	2.17	4.45	2.35	2.62	1.38	19.43	4.23	25.77	4.27	2.91	0.88	3.90	0.51	1.60	0.42	1.43	0.87
Ho	0.58	0.18	0.78	0.31	1.16	0.47	0.91	0.53	0.57	0.30	4.33	1.06	5.69	0.99	0.67	0.18	0.74	0.09	0.31	0.08	0.27	0.19
Er	1.78	0.59	2.40	1.16	3.35	1.24	2.80	1.65	1.56	0.83	13.03	2.76	17.04	2.85	1.92	0.49	1.89	0.29	0.86	0.23	0.74	0.53
Tm	0.29	0.11	0.38	0.18	0.57	0.22	0.42	0.27	0.23	0.13	2.21	0.55	3.07	0.55	0.35	0.13	0.27	0.05	0.14	0.04	0.12	0.10
Yb	1.76	0.61	2.20	1.05	3.48	1.50	2.60	1.64	1.50	0.85	13.56	2.91	17.70	3.04	1.82	0.59	1.68	0.18	0.79	0.20	0.71	0.48
Lu	0.28	0.10	0.35	0.18	0.55	0.24	0.42	0.28	0.22	0.13	2.08	0.42	2.67	0.47	0.31	0.08	0.24	0.02	0.12	0.03	0.11	0.08

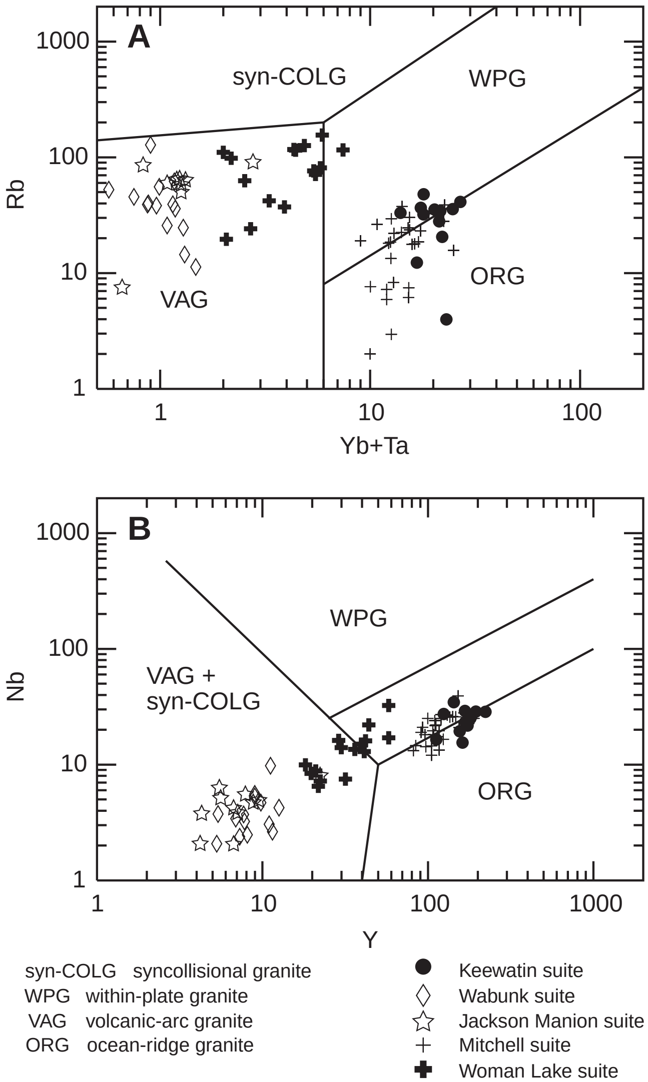

***Figure 7.** Granite-derived tectonic discrimination plots (Pearce et al., 1984). **A)** Rb vs. Ta+Yb; **B)** Nb vs. Y.*

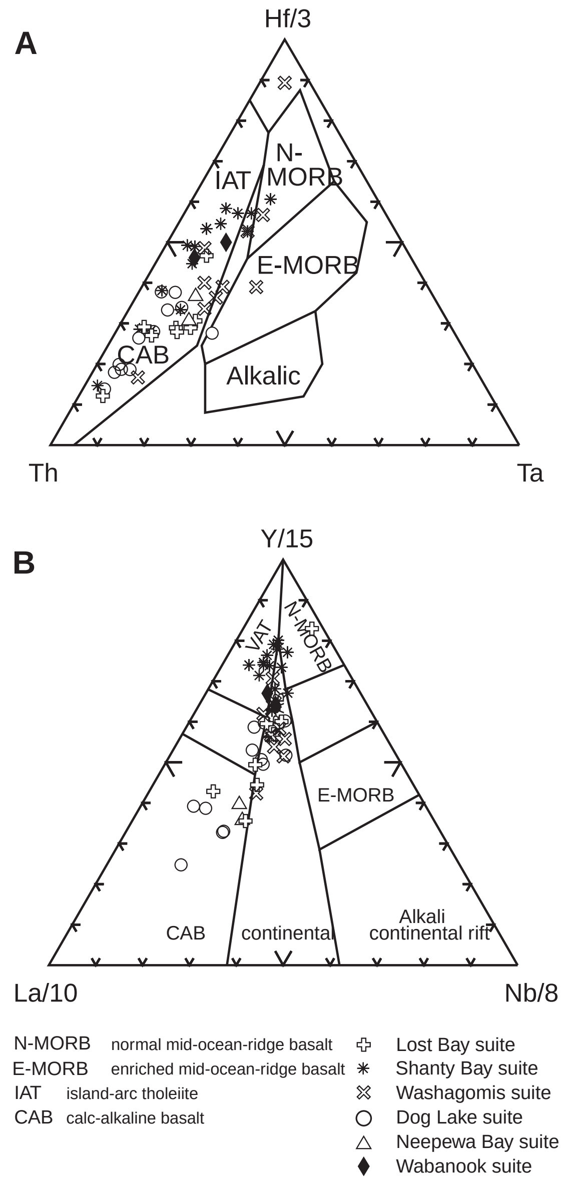

***Figure 8.** Basaltic volcanic tectonic discrimination plots. **A)** Wood (1980); **B)** Cabanis and Lecolle (1989).*

sequence (stratigraphically below the Wabunk rhyolite), referred to herein as the Wabanook Bay basalt, have a relatively flat REE profile and plot in the IAT field (Fig. 5C, 8).The upper mafic volcanic rocks (herein the Neepawa Bay basalt) have a steep REE profile and plot in the CAB field (Fig. 5C, 8). The basaltic rocks of the central Confederation belt are subdivided on the basis of whether they formed before or after the Mitchell felsic volcanic suite, referred to herein as the Lost Bay basalt and Washagomis basalt, respectively. The Lost Bay basalt is similar to the Neepewa Bay and Dog Lake suites, of the eastern and western belts, respectively, as they exhibit a moderate to steep REE pattern with a moderate to pronounced negative Nb anomaly (Fig. 5B). In contrast, the Washagomis basalt has distinctly primitive chemical characteristics with flat to very slightly sloping REE profiles and very small to no negative Nb anomalies (Fig. 5B). On the tectonic discrimination plot of Wood (1980) the Washagomis basalt samples plot between MORB and CAB compositions, whereas on the La-Y-Nb plot of Cabanis and Lecolle (1989) they plot as back-arc to continental basaltic rocks (Fig. 8). Neodymium-isotopic data is available for some of the Confederation mafic volcanic suites. Available data indicates that the Neepewa, Shanty Bay, and Washagomis suites (εNd values typically +0.7 to +1.7) interacted with small amounts of significantly older felsic crust (Balmer age or older), whereas the Dog Lake suite (εNd value of –0.6) likely incorporated a much larger amount of old crust (Tomlinson and Rogers, 1999).

Rogers et al. (1999) correlated the stratigraphic sequences of the central and eastern Confederation belts on the basis of clast composition in a series of epiclastic breccia units that occur between the two belts and are exposed on the islands of Lost Bay (Fig. 2). Stix and Gorton (1988, 1989) initially described the stratigraphy of these breccia units as having aphyric volcanic clasts at the base of the sequence and porphyritic clasts toward the top. This clast stratigraphy mimics the overall felsic volcanic sequence of the central Confederation belt (Rogers et al., 1999). Furthermore, Stix and Gorton (1988, 1989) also noted that the aphyric felsic volcanic clasts from the epiclastic breccia units of Lost Bay form two distinct chemical groups. These groups correspond to compositions of the Mitchell and Wabunk suites, and are therefore probably derived from them. Rogers et al. (1999) inferred that the Lost Bay sequence had the form of a large north- to northeast-trending syncline, so that its clast stratigraphy would fit with the structure of the source rocks in the central Confederation belt. However, newly recognized way-up indicators clearly show that epiclastic rocks are invariably westward younging and consequently appear to be stratigraphically below their source rocks. Hence, the structure of Lost Bay has been reinterpreted as a small extensional basin, bounded, at least to the west, by penecontemporaneous normal faults.

DISCUSSION

Geochemical data from the Balmer assemblage (no basalt, LREE and Th enrichment, pronounced negative Nb anomalies, and Nd isotopic signatures derived from crustal contamination), in comparison to that of modern volcanic rocks, clearly suggests an origin within a continental arc built on significantly older basement (Wilson, 1989; Pearce, 1996). However, the Balmer assemblage consists of a series of submarine volcanic rocks deposited over at least 15 million years, with no indications of migration of volcanism, Andean-like plutonism, or rifting. Consequently, it would be imprudent to describe the Balmer assemblage as a continental arc without recognizing any supporting evidence to the chemical composition of volcanic rocks.

Initial geochemical and geochronological results from the Confederation assemblage indicate a tectonic setting that appears to be consistent with the distribution of units. It is clear from currently available geochronology and lithogeochemistry that the Confederation assemblage is made up of three distinct north- to northeast-trending belts. The chemical characteristics of the eastern and western belts suggest arc magmatism on an attenuated continental margin, with a temporal change from generally tholeiitic to calc-alkaline magmatism (Wilson, 1989; Pearce, 1996). This is consistent with the suggestion of Baker (1973) that as an arc matures, volcanism progresses from an early tholeiitic phase to dominantly calc-alkaline magmatism. The central Confederation belt has a rather different chemical stratigraphy that progresses from continental arc-like rocks at the base to back-arc-like at the top (Pearce, 1996). The relative ages of the belts are not fully constrained at this time. The ages of the central and western belts overlap within error between 2744 and 2742 Ma (V. McNicoll, unpub. data, 1999), and all units in these belts are cut by Jackson Manion porphyritic dykes, one of which is dated at 2739 ± 2 Ma (V. McNicoll, unpub. data, 1999). Chemical correlations from the synvolcanic, epiclastic deposits in Lost Bay indicate that the eastern Confederation belt contains volcanic rocks that are contemporaneous with, or predate volcanism in the central belt, however a ca. 2735 Ma date on the eastern belt (Noble, 1989) suggests that it also contains some younger volcanic rocks. This distribution of volcanic rocks and their possible timing is consistent with a modern-day rifted-arc setting, in which the western Confederation belt represents the remnant arc, with the central belt forming as the rifted-arc to back-arc section of the eastern belt active arc. A rift setting is also consistent with the epiclastic sandstone and breccia of Lost Bay that are believed to have formed in a fault-bounded, intravolcanic, extensional basin that would have been positioned between the region of active rifting and the arc.

This tectonic interpretation for the different units of volcanic rocks may have major implications for Archean tectonics, as F3-type felsic volcanic rocks (Lesher et al., 1986), like those of the central Confederation belt, only occur in the Superior Province in supracrustal sequences postdating 2750 Ma (J. Parker, pers. comm., 1999). It appears from the central Confederation belt that F3-type felsic volcanic rocks are the product of intra-arc to back-arc rifting. Hence, the lack of F3-type felsic volcanic rocks older than 2750 Ma suggests that this form of extensional tectonism did not operate until after that time. The correlation of F3 felsic volcanic rocks to an extensional setting also explains their spatial association with massive sulphide deposits (Lesher et al., 1986), as this type of mineralization is typical of intra–back-arc rifts (Lentz, 1998).

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