Geochemistry and tectonic setting of the late Precambrian Folly River Formation, Cobequid Highlands, Avalon Terrane, Nova Scotia: a continental rift within a volcanic-arc environment

Georgia Pe-Piper
Department of Geology, St. Mary's University, Halifax, Nova Scotia B3H 3C3, Canada

and

J. Brendan Murphy
Department of Geology, St. Francis Xavier University
Antigonish, Nova Scotia B2G 1C0, Canada

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The late Proterozoic Folly River Formation of the Cobequid Highlands, Nova Scotia, is a volcano-sedimentary sequence within the Avalon Terrane. The succession consists of interlayered mafic volcanic rocks and thinly laminated volcanogenic turbidites and is associated with abundant mafic dykes that are inferred to have fed the volcanic eruptions. The formation occurs exclusively between the Rockland Brook and Cobequid faults. The basalts and dykes are Fe- and Ti-rich, differentiated, within-plate continental tholeiites. Their emplacement is attributed to limited continental rifting. The Folly River Formation is similar in lithology, geochemistry and stratigraphy to the Clydesdale Formation in the Antigonish Highlands and is probably penecontemporaneous with arc-related volcanic sequences in both the Cobequid and Antigonish highlands. Hence it is concluded that the Folly River Formation formed in a rifting environment within a volcanic arc.

La Formation tardiprotérozoïque de Folly River (Monts Cobequid, Nouvelle-Ecosse) est une série volcano-sédimentaire au sein de la Lanière d'Avalon. La succession consiste en un interlitage de volcanites mafiques et de turbidites volcanogènes finement laminées. Lui sont associés d'abondants dykes mafiques qui auraient nourri les éruptions volcaniques. La formation ne se rencontre qu'entre les failles de Rockland Brook et de Cobequid. Les basaltes et les dykes sont des tholéiites intraplaques continentales, différenciées et riches en Fe ainsi qu'en Ti. On attribue leur emplacement à l'ouverture restreinte d'un rift continental. La Formation de Folly River ressemble, par sa lithologie, sa géochimie et sa stratigraphie, à la Formation de Clydesdale dans les Monts Antigonish. Elle est probablement pénécontemporaine des séries volcaniques reliées aux arcs des monts Cobequid et Antigonish. On conclut donc que la Formation de Folly River s'établit en régime d'ouverture à l'intérieur d'un arc volcanique.

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INTRODUCTION

The Avalon Terrane of the northern Appalachian Orogen extends from southern New England to Newfoundland and is characterised by late Precambrian volcanic and sedimentary rocks overlain by a Cambrian-Ordovician overstep sequence (Williams, 1979; Keppie, 1985). Late Precambrian sequences within the Avalon Terrane are separated from one another by younger sequences or by Paleozoic faults (Keppie, 1985).

A controversial aspect of the late Precambrian history of the Avalon Terrane is the tectonic environment that controlled its development. Despite close similarities in their late Precambrian lithostratigraphy, portions of the terrane have been variously interpreted as ensialic rifts (Strong *et al.*, 1978), ensialic volcanic arcs (Rast *et al.*, 1976), intra-cratonic troughs and small ocean basins (O'Brien *et al.*, 1983) or analogues to the Cenozoic Basin and Range Province (Krogh *et al.*, 1988). The size and extent of the Avalon Terrane suggest the possibilty that various tectonic environments may have occurred in different places at different times. In order to gain a more complete understanding of the Avalon Terrane, it is important to document the tectonic environment in each fault block. Geochemical signatures of late Precambrian volcanic rocks has provided some of the most important constraints on the interpretation of the tectonic environment in the Avalon Terrane. In this paper, we present geochemical data from the late Precambrian Folly River Formation of the Cobequid Highlands, Nova Scotia, and briefly assess the significance of the formation in the evolution of the Avalon Terrane.

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GEOLOGICAL SETTING

The Folly River Formation, together with the underlying Gamble Brook Formation and Great Village River Gneiss, comprise the Bass River Complex of the eastern Cobequid Highlands, Nova Scotia (Fig. 1) (Donohoe and Wallace, 1982). The Gamble Brook Formation predominantly consists of quartzite and pelitic schist and structurally overlies the Great Village River Gneiss which consists of orthogneiss, paragneiss and amphibolite. The contact between the Great Village River Gneiss and the Gamble Brook Formation is a ductile shear zone which obscures the original relationships (Murphy *et al.*, 1988). The Bass River Complex is thought to form part of the late Precambrian metamorphic infrastructure of the Avalon Terrane (Donohoe, 1983; Cullen, 1984).

The Folly River Formation unconformably overlies the Gamble Brook Formation and probably formed after the ca. 630 Ma deformation within the Gamble Brook Formation (Nance and Murphy, in press). It was deformed by isoclinal folds and thrusts and intruded by post-tectonic late Precambrian granite (575±22 Ma, Gaudette *et al.*, 1984) and gabbro (Murphy *et al.*, 1988; Nance and Murphy, in press). The above relationships indicate that the Folly River Formation was deposited and deformed in the latest Precambrian.

The Rockland Brook Fault separates the Folly River Formation from the late Precambrian Jeffers Group located north of the fault. The Jeffers Group consists of interlayered felsic and mafic volcanic rocks overlain by a sequence of interlayered volcanic rocks and turbidites followed by a thick sequence of turbidites (Pe-Piper, 1987).

GEOLOGY OF THE FOLLY RIVER FORMATION

The thickness of the Folly River Formation is difficult to calculate due to structural complexities but is probably about 600 m. The formation consists of approximately equal proportions of basalt, interlayered turbidites and abundant mafic dykes. Many of the dykes clearly cut the volcanic rocks, to which they are petrologically and geochemically similar. Similar dykes also cut the Gamble Brook Formation and the Great Village River Gneiss. The most complete section of the Folly River Formation is found in the Debert River area where much of the section consists of thick mafic flows typically a few decimetres to metres in thickness. Upper parts of flows show pillowing, development of hyaloclastite breccias (Cullen, 1984), and are commonly highly vesicular. Crystal and lithic tuffs and rare agglomerate beds also occur. Most of the flows show extensive chloritization and contain epidote-rich veins.

The sedimentary rocks are generally thin-bedded, plane-laminated, fine-grained and volcaniclastic. They display rare grading and cross-bedding and are interpreted to be turbidites. Thin beds of red chert and cherty nodules are present locally. The thinly bedded character of the turbidites and the general absence of slump structures suggest either a proximal levee, back levee or distal outer fan environment.

Mafic dykes within the Folly River Formation occur as isolated sheets in zones several hundred metres in extent of almost continuous sheeted dykes. Individual dykes have chilled margins up to 3 cm in width. Textures vary from fine-grained porphyrytic to coarse-grained holocrystalline.

PETROGRAPHY OF THE FOLLY RIVER FORMATION

Flows

Mafic flows are ophitic to sub-ophitic in texture and are fine- to coarse-grained. They all have undergone low grade greenschist-facies metamorphism evidenced by the presence of chlorite, epidote, actinolite and albite, although relics of primary igneous mineralogy and texture are commonly observed. The rocks show banding or foliation defined by very fine-grained opaque minerals. Separating these foliations are pockets of epidote, actinolite and chlorite. Plagioclase (about 15%) forms fine- to medium-grained laths showing partial to complete alteration to mostly actinolite and chlorite. Actinolite (about 30%) forms medium to coarse grains in lenticular shaped pockets with chlorite and epidote, as well as scattered grains. Chlorite (about 15%) forms mostly fibrous aggregates subparallel to the opaque mineral fabric and contains inclusions of epidote. Epidote (about 20%) forms fine to coarse anhedral grains mostly in association with actinolite and chlorite. Opaque minerals (about 20%) are present as very fine-grained opaque fibers forming a discontinuous irregular foliation in the rock. Quartz, where present, forms very fine-grained patches and is a very minor constituent of the rock.

Some of the middle parts of flows and dykes are coarser grained and less metamorphosed and contain relics of primary igneous minerals such as clinopyroxene, plagioclase, and biotite in addition to secondary albite, opaque minerals and actinolite. In such rocks the clinopyroxene (about 25%) is present as fine to coarse, anhedral to subhedral grains and appears to be mostly titanoaugite. It shows various degrees of alteration to actinolite and very fine-grained opaque minerals. Plagioclase (about 30%) is present as fine to coarse laths that show varying degrees of alteration to sericite with fresh patches having labradorite (An52 to An57) and occasionally andesine (An34 to An44) compositions. Opaque minerals (about 25%) are present as medium to coarse, black anhedral to subhedral grains and as very fine-grained dusty patches, forming from alteration of clinopyroxene. Actinolite (about 20%) has formed throughout the rock as an alteration product of clinopyroxene or black opaque minerals. Biotite is a minor constituent as flakes associated with opaque phases.

Dykes

Dykes in the Folly River Formation are medium to coarse in grain size and have ophitic to subophitic textures. They contain plagioclase, clinopyroxene, actinolite, opaques, biotite, and possible hornblende. When veining is present quartz and epidote are the vein material. Plagioclase (about 40%) is present as medium- to coarse-grained laths that may show zoning and incipient to extensive alteration to sericite. Patches of fresh

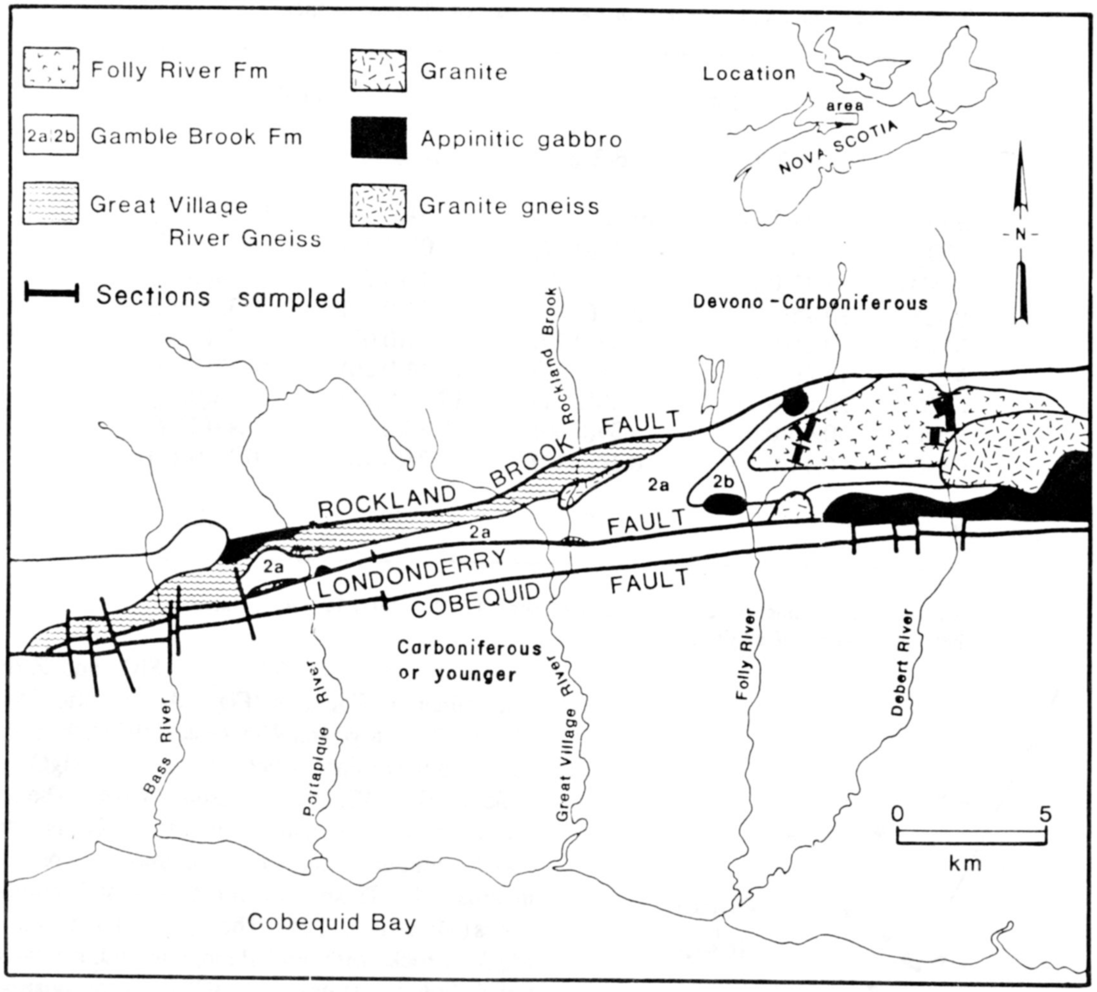

Fig. 1. Generalized Precambrian geology of the Bass River Complex (simplified after Murphy *et al.*, 1988).

plagioclase have labradorite composition (An49 to An55). Clinopyroxene (about 15%) forms anhedral to subhedral, subrounded grains and shows minor alteration to actinolite. Actinolite (about 25%) is present in the groundmass. Opaque minerals (about 20%) are fine to medium, anhedral to subhedral grains and occur throughout the rock as an alteration product together with actinolite. Biotite (about 5%) is present as tiny interstitial flakes and may have formed as an alteration product of clinopyroxene. Epidote and quartz, where present, occur as fine to medium, anhedral grains filling veinlets.

MINERAL CHEMISTRY

Relics of igneous minerals in samples from both flows and dykes were analysed by electron microprobe using the method of Clarke (1976). Our data indicate that the original plagioclase was predominantly labradorite. Of the amphiboles, hornblende with a variable TiO_2 content (0.9 to 2.8%) seemed also to have dominated. The rare biotite flakes are iron-rich (FeO_t about 24%) with high TiO_2 (around 3%). Average analyses of clinopyroxenes from representative samples are given in Table 1. A plot of Ti versus Ca+Na (Fig. 2) for individual analyses indicate that the majority of the analyses fall in the field for subalkalic basalts of Leterrier *et al.* (1982), although a substantial proportion (one third) of the analyses fall in the alkali basalt field. This diagram may indicate the transitional character of these rocks. A plot of ^{vi}Al versus ^{iv}Al for the same analyses (Fig. 3) indicates in general a low-pressure origin for the clinopyroxenes of these rocks.

GEOCHEMISTRY

Representative samples from mafic flows and dykes in the Folly River Formation were analysed in order to establish their correlation and geochemical affinities. The analyses and details of the analytical methods are given in Table 2. Locations of the analyzed samples are in Appendix A, and approximate locations are indicated on Figure 1.

The flows and dykes are chemically indistinguishable (e.g., Fig. 4). All rocks are characterized by low SiO_2 which ranges from 45 to 52 wt.% (on a volatile-free basis), high FeO_t (11 to 16 wt.%) and MgO (3.6 to 7.5 wt.%). The analyses confirm the basaltic character of the magmatism in the Folly River Formation. These rocks show wide ranges in TiO_2 (1.7 to 4.0 wt.%) and Zr (90 to 450 ppm). They show some typical magmatic trends including positive correlations between Fe, Ti, Zr and P. However, some elements, notably Na, Ca, K, Rb, Ba and Sr, have highly erratic distributions and do not display typical igneous trends. This suggests that their concentrations have been affected

Table 1. Average electron microprobe analyses of clinopyroxenes.

	LAVAS		DYKE	
	6-2-3	6-2-2	10-4-7	2-5-2
SiO_2	48.94(1.13)	49.72(1.12)	51.01(0.89)	47.56(0.99)
TiO_2	1.76(0.43)	1.35(0.39)	1.07(0.26)	1.29(0.34)
Al_2O_3	4.21(0.77)	3.36(1.09)	3.44(0.76)	3.54(0.97)
FeO*	10.75(1.25)	12.17(2.76)	9.45(0.77)	9.32(1.62)
MnO	0.26(0.04)	0.32(0.10)	0.24(0.03)	0.24(0.05)
MgO	13.46(1.09)	13.44(1.27)	15.14(0.56)	14.37(1.15)
CaO	20.07(0.73)	19.20(1.01)	19.46(0.73)	20.33(0.58)
Na_2O	0.46(0.07)	0.39(0.06)	0.38(0.03)	0.44(0.07)
Cr_2O_3	0.14(0.10)	0.10(0.12)	0.28(0.10)	0.17(0.13)
n	11	19	19	12

Standard deviations are given in parentheses; FeO* = total Fe recalculated as FeO; n=number of analyses

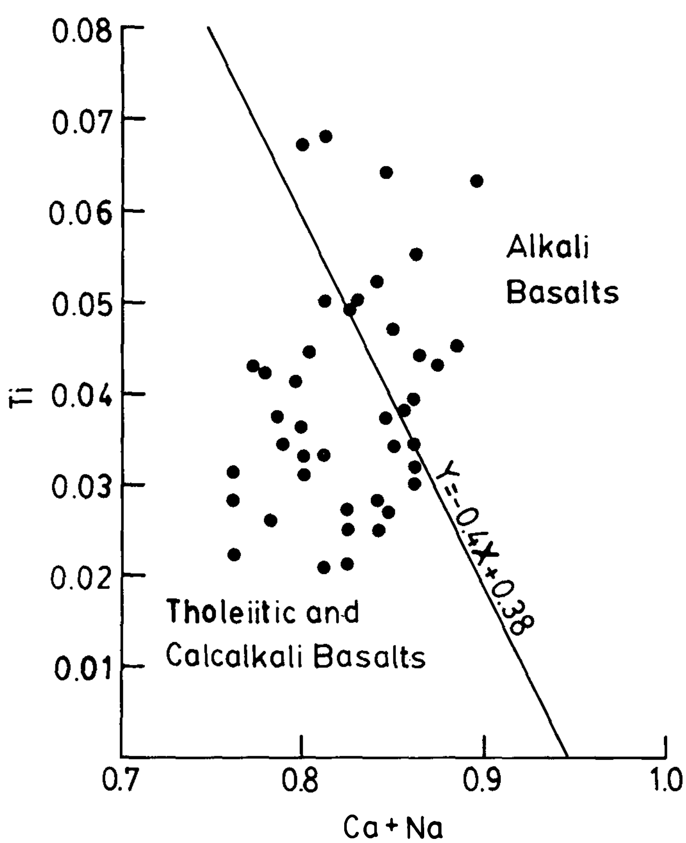

Fig. 2. Plot of Ti versus Ca+Na for pyroxenes from the Folly River Formation mafic rocks. The line separating the fields for the alkali basalts from calc-alkalic and tholeiitic basalts is from Letterrier *et al.* (1982).

by the low-grade metamorphism and alteration described above. Therefore the determination of the magmatic affinity and tectonic setting of these rocks is based mainly on discrimination diagrams involving elements that are generally least affected by secondary processes (Winchester and Floyd, 1977).

On the basis of Zr/TiO_2 vs SiO_2 and Zr/P_2O_5 vs TiO_2 discrimination diagrams (Fig. 4A, 4B, after Winchester and Floyd, 1977; Floyd and Winchester, 1975), the basalts are subalkalic and according to FeO_t versus FeO_t/MgO the basalts are tholeiitic (Fig. 4C, after Miyashiro, 1974). The apparent alkali character of some samples in Figure 2B is attributed to Ti enrichment during crystal fractionation of a primary subalkalic magma. This Ti enrichment is typical of fractionated tholeiitic suites (Miyashiro, 1974). The high FeO_t and wide range in FeO_t/MgO for rocks with limited range in SiO_2 is typical of differentiated tholeiitic suites (Fig. 4C) as is the positive correlation between Fe, Ti, P and V. The REE distribution (Fig. 5) displays moderate LREE enrichment typical of continental tholeiites (Basaltic Volcanism Study Project, 1981). The within-plate tectonic setting as shown by the Zr/Y v Zr diagram (Fig. 4D, after Pearce and Norry, 1979) is consistent with a continental tholeiitic magmatic affinity. Thus the geochemical character indicates that the rocks are within-plate continental tholeiites.

A detailed study of the petrogenesis of the Folly River mafic rocks is presently being undertaken along with other late Precambrian high-Ti mafic rocks in the Avalon Terrane (G. Pe-Piper and B. Murphy, in preparation). Therefore only a brief summary is presented here. The rocks display a wide range in Ni and Cr contents suggesting that olivine and clinopyroxene were fractionating phases. The positive correlation between Fe, Ti, P, Zr and V suggests that variations in these elements may be controlled by fractionation of titaniferous magnetite. However, wide variations in Zr/La, Zr/Y (Fig. 4d) and Zr/Nb ratios indicate that crystal-liquid fractionation cannot account for all the trends observed and require derivation from a heterogeneous or enriched source (e.g., Pearce and Norry, 1979; Le Roex *et al.*, 1983). These features are common in continental tholeiites and are attributed to the derivation of parental magmas from a heterogeneous upper mantle source (e.g., Erlank, 1986). Murphy (1988) postulated that the mantle source beneath the Antigonish Highlands may have been contaminated by dehydration of a

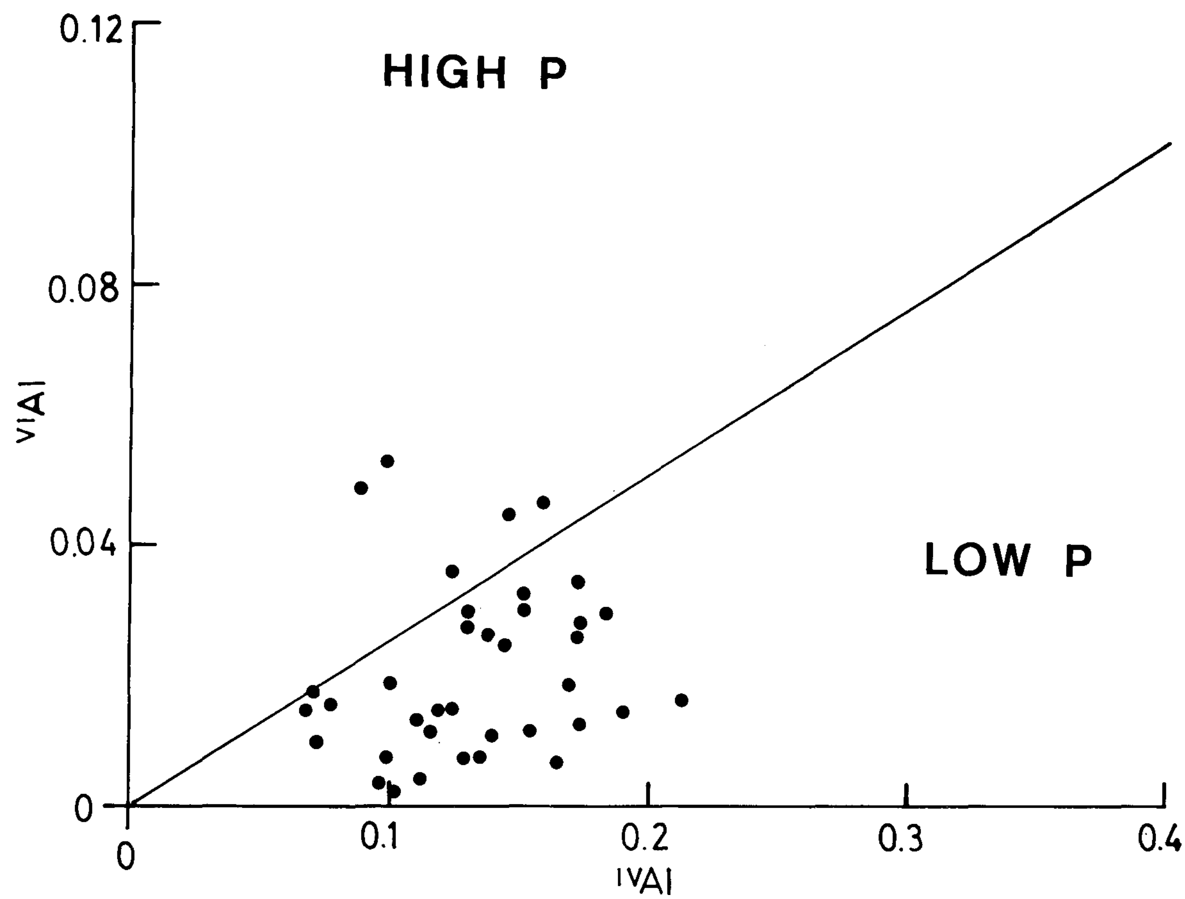

Fig. 3. Plot of ^{vi}Al versus ^{iv}Al for pyroxenes from the Folly River Formation mafic rocks. Line separates high-pressure field (upper left) from low-pressure field (lower right, after Wass, 1979).

subducting slab and it is possible that this contamination also contributed to the geochemical heterogeneities discussed above.

SUMMARY AND DISCUSSION

The Folly River Formation consists of interlayered mafic volcanic rocks and turbiditic sedimentary rocks (and abundant mafic dykes) unconformably overlying quartzites and pelitic schists of the Gamble Brook Formation. The within-plate tectonic setting inferred from the chemistry of the mafic rocks, the presence of abundant mafic dykes, and the presence of marine strata are consistent with a rift environment. The lack of MORB characteristics and the presence of continental tholeiites suggests that the rifting did not reach a stage of oceanization and that the basin was floored by thinned continental crust.

Constraints on the tectonic setting of the Folly River Formation may be obtained by comparing the formation with other late Precambrian sequences in northern mainland Nova Scotia. These sequences include the Georgeville Group in the Antigonish Highlands, the Jeffers Group in the northern and western Cobequid Highlands, and the Dalhousie Mountain Volcanics in the eastern Cobequid Highlands (Pe-Piper and Piper, 1989; Murphy *et al.*, in press).

In the southern Antigonish Highlands, the Keppoch Formation of the Georgeville Group consists of interlayered continental tholeiites, calc-alkalic basaltic andesites and felsic volcanic rocks with volcanic-arc affinities (Murphy and Keppie, 1987). The Keppoch Formation is conformably to unconformably overlain by a thick sequence of turbidites and minor interlayered continental tholeiites in the central highlands (Clydesdale Formation) and is probably laterally equivalent to the calc-alkalic basaltic andesites of the Chisholm Brook Formation in the northern Antigonish Highlands (Murphy and Keppie, 1987). The Georgeville Group has been interpreted to represent limited intra-continental rifting within a volcanic-arc setting (Murphy and Keppie, 1987; Murphy *et al.*, in press).

The Jeffers Group (Pe-Piper and Piper, 1989) and Dalhousie Mountain Volcanics (Murphy *et al.*, 1988) are remarkably similar to the Keppoch Formation and may record a similar tectonic environment.

The Folly River Formation occurs within the same fault block as the Dalhousie Mountain Volcanic rocks and is probably spatially associated. Lithologically and geochemically it resembles the Clydesdale Formation of the central Antigonish Highlands.

The similarities between late Precambrian sequences in the Antigonish and Cobequid highlands suggests that the Folly River Formation was probably deposited in an intra-continental extensional setting within a volcanic-arc environment. The environment envisaged is comparable to the narrow ensialic intra-arc basin in the Southern Andes (Saunders and Tarney, 1984) where volcanic rocks with both calc-alkalic and tholeiitic affinities are present.

Table 2. Analyses of the mafic flows and dykes in the Folly River Formation.

Sample No.	1 10-4-11	2 10-4-5	3 10-4-1	4 6-2-3	5 10-4-3	6 10-4-9	7 10-4-2	8 10-4-10	9 6-2-2	10 10-4-7	11 10-4-8	12 10-5-1	13 10-4-6	14 9-6-6
Major Elements (wt.%)														
SiO_2	46.65	47.29	47.47	47.52	47.62	47.75	47.95	48.11	48.78	49.03	49.51	50.00	51.52	45.20
TiO_2	2.24	2.27	2.13	3.41	2.18	2.29	2.56	2.21	2.73	2.77	1.76	2.56	2.97	2.86
Al_2O_3	12.68	12.78	12.65	12.51	13.31	12.64	12.94	12.46	12.70	12.56	13.13	13.48	13.93	15.31
Fe_2O_{3t}	14.71	14.76	15.07	15.00	13.16	15.15	14.42	14.36	14.64	14.50	11.13	13.05	12.83	14.20
MnO	0.22	0.26	0.25	0.23	0.23	0.24	0.29	0.23	0.38	0.33	0.23	0.24	0.23	0.31
MgO	6.45	6.77	7.02	5.22	6.55	6.30	6.16	6.54	5.45	5.28	7.21	5.03	3.66	6.67
CaO	10.94	9.88	10.00	10.07	9.25	9.49	10.37	10.17	9.51	9.10	9.89	11.68	5.33	8.15
Na_2O	2.45	2.01	2.50	2.55	3.03	2.71	2.79	2.55	2.58	2.16	3.29	0.61	2.96	2.27
K_2O	0.13	0.08	0.13	0.87	0.42	0.15	0.77	0.16	0.80	1.10	0.17	0.12	2.51	1.59
P_2O_5	0.19	0.19	0.17	0.49	0.19	0.19	0.31	0.18	0.38	0.37	0.12	0.16	0.87	0.40
L.O.I.	2.60	2.40	2.00	0.60	3.30	2.30	0.20	1.90	1.10	1.20	3.10	3.80	2.10	2.20
Total	99.26	98.69	99.39	98.47	99.24	99.21	98.76	98.87	99.05	98.40	99.54	100.73	98.91	99.16
Trace Elements (ppm)														
Ba	29	35	60	258	103	89	216	43	262	280	89	24	929	286
Rb	1	0	0	19	10	2	21	0	18	27	2	3	50	63
Sr	190	85	208	261	204	233	253	248	260	232	157	290	443	301
Y	37	40	37	38	31	41	35	36	37	37	27	30	42	32
Zr	147	151	133	240	140	153	107	144	218	222	110	187	449	201
Nb	7	4	5	16	7	3	12	8	14	13	5	13	26	11
Th	0	9	0	5	0	0	0	12	0	4	0	0	0	0
Pb	0	0	0	3	0	0	0	0	0	3	0	0	0	0
Ga	17	21	25	29	15	25	21	8	22	23	14	30	9	21
Zn	119	130	132	127	111	134	173	199	150	129	90	107	144	166
Cu	75	82	62	116	60	86	157	81	134	138	68	37	39	56
Ni	56	49	53	44	62	54	59	55	52	55	69	92	24	92
V	467	484	468	400	410	491	397	454	375	397	369	237	252	282
Cr	102	91	87	56	110	83	149	111	87	113	219	169	16	45
La	n.d.	n.d.	5.70	20.90	n.d.	n.d.	n.d.	n.d.	n.d.	19.70	n.d.	n.d.	43.20	n.d.
Ce	n.d.	n.d.	17.00	52.00	n.d.	n.d.	n.d.	n.d.	n.d.	47.00	n.d.	n.d.	96.00	n.d.
Nd	n.d.	n.d.	14.00	27.00	n.d.	n.d.	n.d.	n.d.	n.d.	27.00	n.d.	n.d.	49.00	n.d.
Sm	n.d.	n.d.	4.88	7.63	n.d.	n.d.	n.d.	n.d.	n.d.	7.10	n.d.	n.d.	11.00	n.d.
Eu	n.d.	n.d.	1.70	2.46	n.d.	n.d.	n.d.	n.d.	n.d.	2.18	n.d.	n.d.	3.10	n.d.
Tb	n.d.	n.d.	1.30	1.40	n.d.	n.d.	n.d.	n.d.	n.d.	1.40	n.d.	n.d.	1.50	n.d.
Yb	n.d.	n.d.	4.64	4.09	n.d.	n.d.	n.d.	n.d.	n.d.	4.10	n.d.	n.d.	4.59	n.d.
Lu	n.d.	n.d.	0.67	0.59	n.d.	n.d.	n.d.	n.d.	n.d.	0.60	n.d.	n.d.	0.68	n.d.

Sample No.	15 9-5-5	16 9-5-9	17 9-5-8	18 9-5-1	19 5-2-2	20 20-1-6	21 21-1-6	22 13-3-1	23 12-6-1	24 20-1-3	25 2-2-3	26 2-5-2	27 24-3-4	28 22-1-2	29 22-1-1
Major Elements (wt.%)															
SiO_2	48.03	48.83	49.40	49.73	44.73	46.43	47.76	48.79	48.88	48.91	45.88	47.96	48.34	48.84	48.90
TiO_2	2.14	2.06	1.93	1.96	2.59	3.86	2.89	1.48	2.21	1.57	2.68	2.76	1.32	2.10	2.14
Al_2O_3	12.47	12.93	13.02	13.12	14.38	13.00	13.54	14.47	14.01	14.70	14.06	13.15	15.35	16.06	16.11
Fe_2O_{3t}	15.15	13.24	13.84	13.00	15.82	15.37	14.11	11.69	12.89	11.79	16.75	13.70	11.12	11.46	11.84
MnO	0.29	0.24	0.22	0.22	0.28	0.42	0.36	0.19	0.35	0.17	0.32	0.26	0.17	0.34	0.35
MgO	7.30	6.70	5.97	6.43	6.51	5.37	5.26	7.10	6.41	6.37	5.66	5.92	7.28	6.22	5.94
CaO	9.62	10.68	10.23	10.40	8.29	8.55	8.76	11.40	9.13	11.68	8.17	10.35	10.54	8.44	8.35
Na_2O	2.64	2.85	2.98	3.62	2.42	2.88	2.57	2.16	2.84	2.20	3.07	3.05	2.79	2.84	2.20
K_2O	0.17	0.14	0.18	0.20	1.85	1.25	1.23	0.60	1.15	0.61	1.19	0.98	0.29	1.24	1.21
P_2O_5	0.17	0.17	0.15	0.17	0.23	0.79	0.42	0.12	0.32	0.14	0.21	0.37	0.11	0.33	0.33
L.O.I.	0.90	0.90	0.60	0.50	1.40	0.70	1.20	0.80	0.70	1.00	0.50	0.40	1.70	1.10	1.10
Total	98.88	98.74	98.52	99.35	98.50	98.62	98.10	98.80	98.89	99.14	98.49	98.90	99.01	98.97	98.47
Trace Elements (ppm)															
Ba	23	27	35	93	472	474	460	162	281	285	408	247	86	278	245
Rb	0	2	2	1	61	31	34	15	34	21	30	26	0	44	41
Sr	95	120	148	102	214	341	317	235	308	211	315	340	186	526	524
Y	32	30	30	35	39	40	41	19	35	22	31	30	28	38	39
Zr	132	131	123	143	162	289	213	92	245	109	155	183	90	191	188
Nb	5	4	4	5	12	25	18	7	16	8	10	14	4	22	21
Th	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Pb	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0
Ga	17	22	21	16	24	24	23	20	22	22	26	22	17	22	22
Zn	137	119	107	127	128	227	192	138	242	100	143	111	98	141	133
Cu	91	71	88	62	223	75	70	123	77	141	78	98	62	75	40
Ni	45	45	35	61	68	41	40	101	61	93	73	46	81	76	77
V	450	410	409	413	537	398	412	362	290	368	487	386	278	254	241
Cr	58	59	61	107	96	67	94	228	147	218	125	134	295	24	32
La	n.d.	n.d.	n.d.	n.d.	n.d.	29.50	n.d.	n.d.	n.d.	7.90	n.d.	n.d.	n.d.	n.d.	n.d.
Ce	n.d.	n.d.	n.d.	n.d.	n.d.	65.00	n.d.	n.d.	n.d.	18.00	n.d.	n.d.	n.d.	n.d.	n.d.
Nd	n.d.	n.d.	n.d.	n.d.	n.d.	39.00	n.d.	n.d.	n.d.	11.00	n.d.	n.d.	n.d.	n.d.	n.d.
Sm	n.d.	n.d.	n.d.	n.d.	n.d.	9.09	n.d.	n.d.	n.d.	3.42	n.d.	n.d.	n.d.	n.d.	n.d.
Eu	n.d.	n.d.	n.d.	n.d.	n.d.	2.91	n.d.	n.d.	n.d.	1.11	n.d.	n.d.	n.d.	n.d.	n.d.
Tb	n.d.	n.d.	n.d.	n.d.	n.d.	1.40	n.d.	n.d.	n.d.	0.70	n.d.	n.d.	n.d.	n.d.	n.d.
Yb	n.d.	n.d.	n.d.	n.d.	n.d.	4.20	n.d.	n.d.	n.d.	2.27	n.d.	n.d.	n.d.	n.d.	n.d.
Lu	n.d.	n.d.	n.d.	n.d.	n.d.	0.59	n.d.	n.d.	n.d.	0.32	n.d.	n.d.	n.d.	n.d.	n.d.

Sample locations are listed in Appendix A.

1 to 13: flows and dykes, Debert River area; 14 to 18: flows interlayered with turbidites; 19 to 24: dykes cutting Great Village River Gneiss; 25 to 26: dykes cutting the Gamble Brook Formation; 27 to 29: dykes cutting the Folly River Formation flows. Major elements and Ba-Cr trace elements were analysed by X-Ray Fluorescence at St. Mary's University on a Philips PW1400 sequential spectrometer using a Rh-anode X-ray tube. International standards with recommended values from Abbey (1983) as well as in house standards were used for calibration. Analytical precision, as determined from replicate analyses is generally better than 2%, except MgO, Na_2O and Nb which are better than 5% and Th which is better than 10%. Loss on ignition (LOI) was determined by treating the sample for 1.5 h at 1050^{o} in an electric furnace. The rare earth element concentrations were determined by neutron activation analysis at McMaster University.

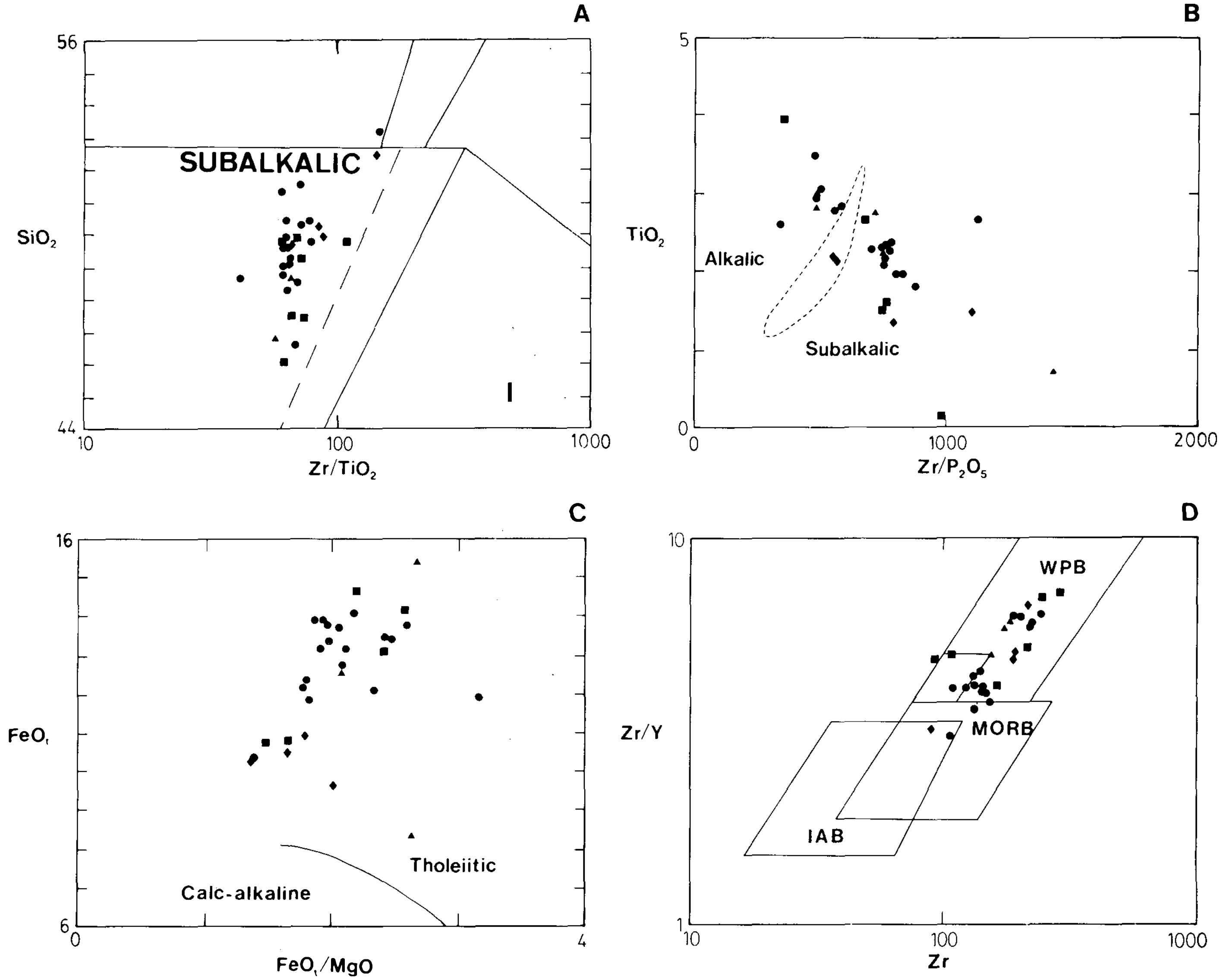

Fig. 4. Petrogenetic affinity of the mafic rocks of the Folly River Formation. (A) after Winchester and Floyd, 1977. (B) after Floyd and Winchester, 1975. (C) after Miyashiro, 1974. (D) after Pearce and Norry, 1979. Solid circles represent the volcanic rocks from the Folly River Formation in the Debert River area and those interlayered with turbidites. Triangles represent dykes cutting the Gamble Brook Formation. Squares represent dykes within the Great Village River Gneiss. Crosses represent the dykes cutting the volcanic rocks of the Folly River Formation.

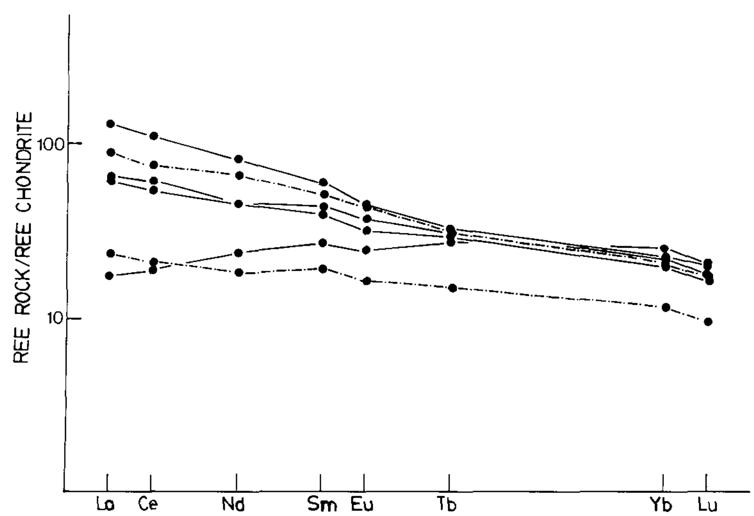

Fig. 5. REE plot for selected samples. Solid lines represent analyses from lavas. Dotted lines represent analyses from dykes in the Great Village River Gneiss.

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APPENDIX A. Location of Analysed Samples

Sample No.	Lat. °N	Long. °W	Location
10-4-11	45° 31'	63° 27'	Debert River
10-4-5	45 32	63 27	Debert River
10-4-1	45 32	63 27	Debert River
6-2-3	45 32	63 27	Debert River
10-4-3	45 32	63 27	Debert River
10-4-9	45 31	63 27	Debert River
10-4-2	45 32	63 27	Debert River
10-4-10	45 31	63 27	Debert River
6-2-2	45 31	63 27	Debert River
10-4-7	45 31	63 27	Debert River
10-4-8	45 31	63 27	Debert River
10-5-1	45 31	63 27	Debert River
10-4-6	45 31	63 27	Debert River
9-6-6	45 31	63 30	East Folly River
9-5-5	45 31	63 30	East Folly River
9-5-9	45 31	63 30	East Folly River
9-5-8	45 31	63 30	East Folly River
9-5-1	45 31	63 30	East Folly River
5-2-2	45 30	63 36	Rockland Brook
20-1-6	45 30	63 36	Rockland Brook
21-1-6	45 30	63 38	Great Village River
13-3-1	45 28	63 48	Gamble Brook
12-6-1	45 30	63 38	Great Village River
20-1-3	45 30	63 37	Rockland Brook
2-5-2	45 31	63 32	Folly River
24-3-4	45 31	63 30	East Folly River
22-1-2	45 32	63 30	Trib. East Folly River
22-1-1	45 32	63 30	Trib. East Folly River