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PROVINCE OF NOVA SCOTIA

DEPARTMENT OF MINES AND ENERGY

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by

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TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The rocks of the Hadrynian Fourchu Group around Louisbourg consist mainly of pyroclastic rocks such as crystal tuff, ignimbrite, breccia, tuff and ash layers and subaerial and submarine basalt, andesite, rhyodacite and rhyolite flows. Minor intrusive feeder dykes and sills cut this volcanic pile. Small gabbroic plutons are inferred to be subvolcanic. These rocks were subsequently deformed and subjected to greenschist facies metamorphism during the Late Hadrynian Cadomian Orogeny. The major, trace and rare earth element geochemistry of these igneous rocks documents that they have calc-alkalic island arc affinities erupted on thin continental crust at about 40 to 80 km above a paleo-Benioff zone. An origin by anatexis of the upper mantle and crust followed by fractionation of pyroxene, olivine, spinel and plagioclase is inferred.

INTRODUCTION

Weeks (1954) proposed the name "Fourchu Group" for the volcanic and sedimentary rocks that underlie the Eo-Lower Cambrian Morrison River Formation in southeastern Cape Breton Island. Here, the Fourchu Group is cut by granitoid plutons dated at 545±28 Ma and 548±18 Ma using the whole rock Rb/Sr isochron method (Keppie and Smith, 1978; Cormier, 1972). These rocks have generally been placed within the Avalon Zone (Fig. 1), which may be traced along the entire length of the Appalachians and is at least 500 km wide in the eastern Newfoundland-Flemish Cap area (Williams, 1978).

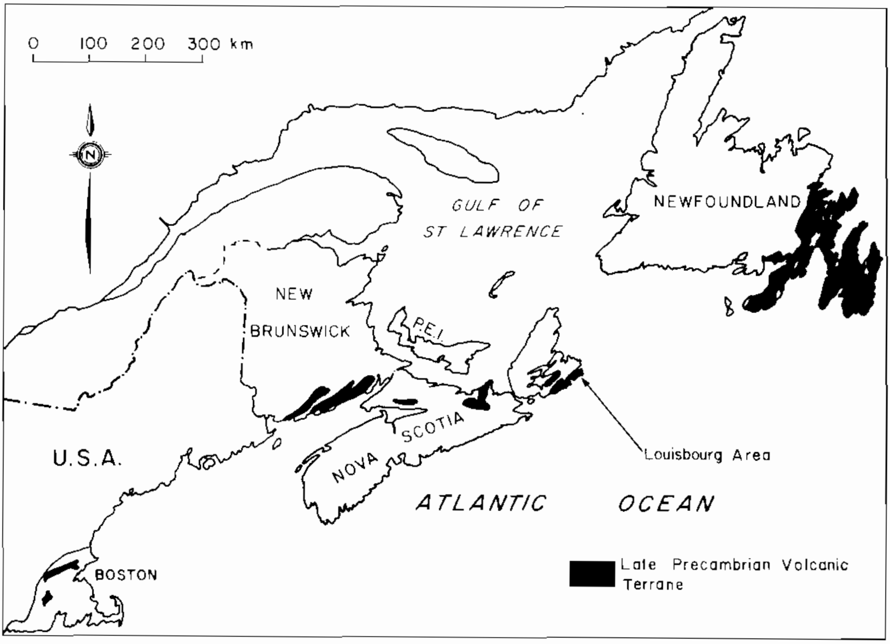

Figure 1. Map showing distribution of Late Precambrian volcanic rocks in the northern Appalachians.

The Late Precambrian rocks of the Avalon Zone have been variously interpreted as a basin-and-range type of rift zone (Papezik, 1970; Hughes and Brückner, 1971; Helmstaedt and Tella, 1973; Rast, et al., 1976) or in terms of continental extension and rifting (Rankin, 1975; Strong, et al., 1978). These regional models have generally been based either upon meagre major element geochemistry, which is of limited petrogenetic value due to the effects of alteration, or extrapolation of the results from a small area. The extent of the Avalon Zone, which is at least twice as wide as the southern Appalachians and several thousand kilometres in length, is such that many tectonic environments could be present. This can only be resolved by detailed geological mapping combined with geochemical data for the relatively "immobile" elements. This study attempts to provide such data for part of the Fourchu Group around Louisbourg in southeastern Cape Breton Island.

STRATIGRAPHY

Murphy (1977a and b) mapped the Fourchu Group around Louisbourg (Fig. 2) and subdivided it into some informal members (Fig. 3). In general, the volcanic rocks around Louisbourg pass upwards from subaerial pyroclastics in the lowest two members into shallow marine pyroclastics and hyaloclastites in all succeeding members. The general sequence from crystal tuff through ignimbrite to breccia, tuff and ash reflects the increasing volatile content of the magma leading to progressively more explosive eruptions (Peterson and Roberts, 1961). Rock types include acidic, intermediate and basic compositions. The ratio of acidic to intermediate/basic rocks in the the Louisbourg area is about 2:1. Reconnaissance of other parts of the Fourchu Group suggests that the rocks in the Louisbourg area represent a portion of the upper part of the Fourchu Group.

Kennington Cove Member

The lowest unit in the Louisbourg area is the Kennington Cove member. The lower parts of this member outcrop on White Point, and its base lies offshore. It consists of at least 2000 m of massive quartz-albite crystal tuffs interbedded with a few felsic lava flows and ashy horizons. The tuffs are composed of quartz and albite phenocrysts and rare orthoclase phenocrysts, lapilli and lithic fragments, all set in a fine grained, felsic ash matrix of similar composition. The phenocrysts are typically cracked or broken and are often embayed. Alteration is generally limited to saussuritization of plagioclase. Growth of sericite and chlorite defines two tectonic fabrics. Glass shards are rare and are altered to epidote and chlorite. Disseminated pyrite is present in minor quantities. The xenomorphic shape of the phenocrysts, the lack of sedimentary structures and the massive nature of the tuffs suggest deposition in a subaerial environment. The rhyolites are generally thin, aphanitic, green, flow banded and composed of albite microlites, quartz, minor potash feldspar, sericite, chlorite and epidote. The paucity of lapilli, lithic fragments and pumice suggests that the eruption was only mildly explosive. Initial vesiculation of the magma may have been impeded by the hydrostatic pressure of the overlying rocks (Hughes, 1973) and then clots of magma shattered before they could vesiculate to form pumice. Mild explosions caused fragmentation of the intratelluric crystals present in the magma at the time of eruption.

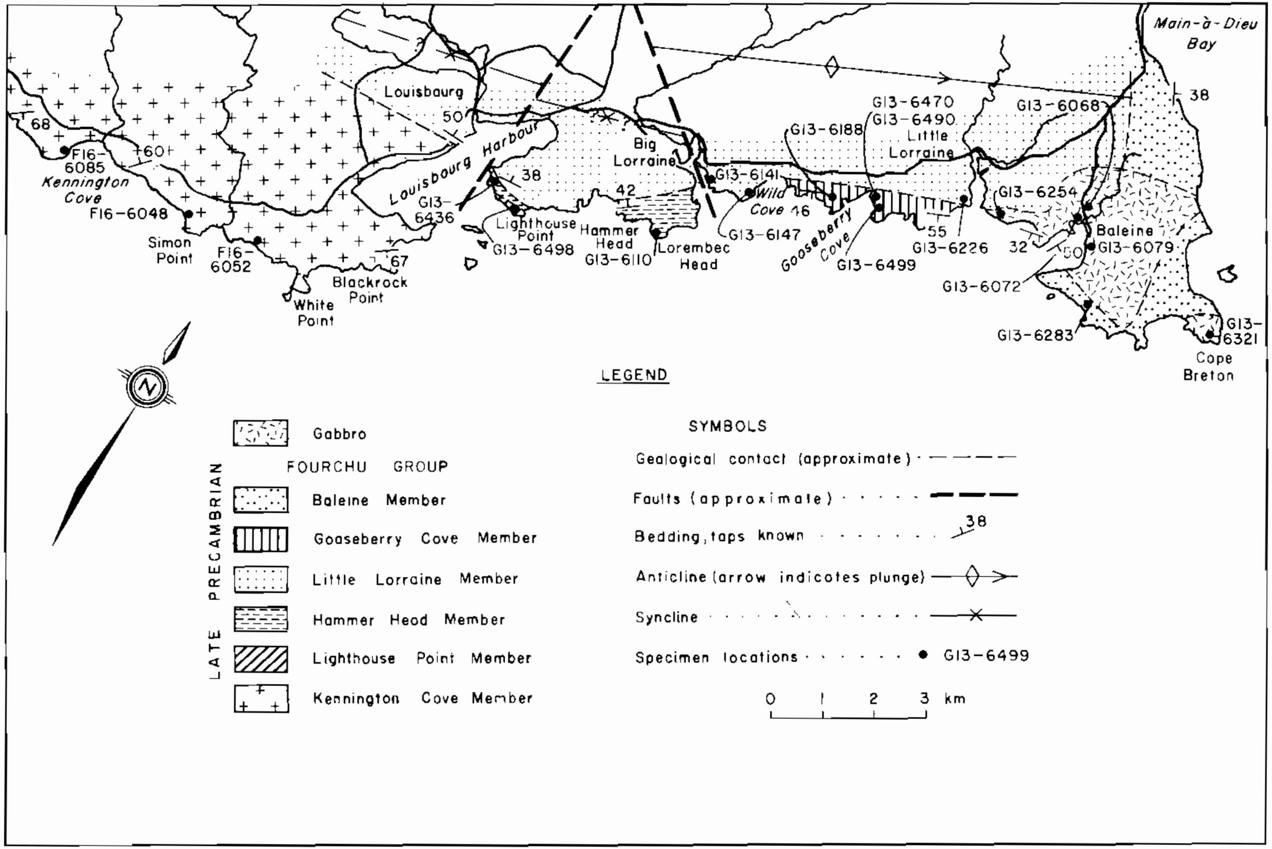

Figure 2. Geological map of the Louisbourg area, Cape Breton Island.

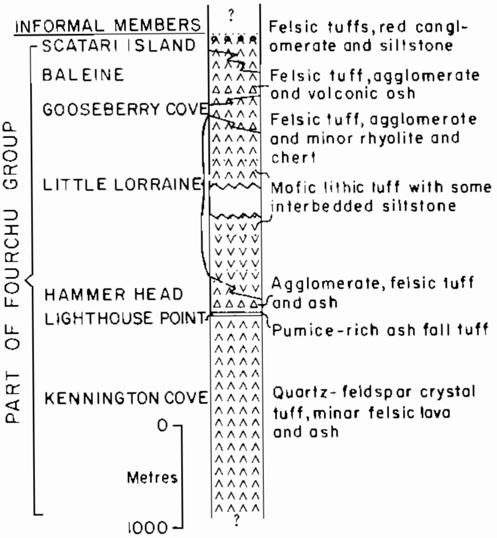

Figure 3. Stratigraphic section of the Fourchu Group in the Louisbourg area, Cape Breton Island.

Lighthouse Point Member

Although the contact is not exposed, it is inferred (Fig. 2) that the Lighthouse Point member overlies the Kennington Cove member. The Lighthouse Point member consists of at least three ignimbritic units totalling about 25 m in thickness. These ignimbrites display a distinct colour banding in which a grey, unwelded or incipiently welded sillar zone grades upwards into a purple, welded zone. The boundary between the ignimbrite units is sharp. Compaction of the pumice fragments imparts a primary, eutaxitic fabric to the ignimbrite. The ignimbrites are composed of xenomorphic fragments of quartz, plagioclase and orthoclase phenocrysts and pumice embedded in a fine grained felsic ash matrix made up of sericite, chlorite, epidote and calcite. The pumice in the welded zone shows good collapse flame structure. Lithic fragments are rare and glass shards are absent, a feature typical of Plinian ash fall tuffs. However, the presence of welded zones indicates that heat loss during extrusion was minor, thereby supporting an ignimbritic origin. Vesiculation of the magma produced pumice and led to a nuée ardente mechanism of eruption.

Hammer Head Member

The Hammer Head member unconformably overlies the Lighthouse Point member. At the contact exposed at Lighthouse Point, thick bedded felsic tuffs of the Hammer Head member lie directly upon incipiently welded ignimbrite of the Lighthouse Point member. The absence of a welded zone suggests that it has been eroded away. The Hammer Head member consists of 150 m of thinly bedded, felsic, lithic lapillistone and ash grading eastwards into agglomerate and some volcanic breccia, 350 m thick at Hammer Head. The vent is inferred to have been located near Hammer Head, with the size of the lithic fragments and the thickness of the member decreasing away from it. Grading, crossbedding, slump structures, ripple marks and penecontemporaneous faulting suggest deposition in unstable, shallow, subaqueous conditions. Current directions appear to have been mainly from southwest to northeast. The ash horizons consist of minor amounts of quartz and albite set in a matrix of volcanic dust. The lithic tuffs are composed of quartz and plagioclase crystal fragments and ash and felsic lava lithic fragments enclosed in a matrix of sericite, chlorite, epidote and calcite. The fragmental nature of this member compared to the underlying unit demonstrates the increasingly explosive nature of the eruptions predicated by the increasingly volatile content of the magma. This may have been due, in part, to access of seawater to the vent.

Little Lorraine Member

East of Louisbourg Harbour, the Little Lorraine member rests conformably to unconformably upon the Hammer Head member. West of the Louisbourg Harbour, the Little Lorraine member rests directly upon the Kennington Cove member and the intervening units are absent. The Little Lorraine member consists of at least 750 m of intermediate and basic lithic tuffs and hyaloclastites, and a few interbeds of red siltstone. The pyroclastic rocks are composed mainly of intermediate/basic lava fragments made up of aligned oligoclase laths in a palagonitic matrix with a few felsic ash fragments, and quartz and albite crystal fragments set in an altered mafic matrix made up of epidote, albite, chlorite, calcite and opaque minerals. The intermediate/basic fragments vary in shape from subrounded to angular. In places where the matrix is relatively fresh, it exhibits flow textures around the clasts. The intermediate/basic volcanic rocks vary from massive to thinly bedded, and exhibit graded bedding and ripple marks indicative of shallow marine conditions of deposition. Access of seawater to the vent is inferred to have caused the eruption to be explosive producing the lithic tuffs. Extruding submarine intermediate/basic lava reacted with the seawater and congealed. Continuing movements caused brecciation to occur which resulted in a hyaloclastite.

Gooseberry Cove Member

Between Wild Cove and Little Lorraine, the Gooseberry Cove member conformably overlies the Little Lorraine member and consists of 100 to 300 m of felsic lithic tuff, lapillistone, crystal tuff, ignimbrite, agglomerate, ash, chert and rhyodacitic flows. Lithic fragments are themselves predominantly pyroclastic. They are mainly felsic although some mafic fragments presumably derived from the Little Lorraine member also occur. They are embedded in a felsic matrix of sericite, epidote, chlorite and calcite. Crystal tuffs and ash contain quartz and plagioclase crystal fragments in a matrix of volcanic ash. The rhyodacitic lava flows contain phenocrysts of sodic plagioclase and orthoclase set in a matrix of quartz and plagioclase. The ignimbrites are similar to those in the Lighthouse Cove member, except that some cusp- and lune-shaped glass shards are present in places. Primary structures include ripple marks, grading, slump folds and penecontemporaneous faults. The environment of deposition varied from shallow submarine to subaerial. The interaction of seawater with the magma in the vent is inferred to have produced explosive volcanism.

Baleine Member

The Baleine member rests with marked angular unconformity upon the Gooseberry Cove member on the coast west of Baleine. North of Baleine, it rests unconformably upon the Little Lorraine member (Fig. 2). Lithologically, the Baleine and Gooseberry Cove members are similar. The lithic fragments in the Baleine member increase in size towards a volcanic plug outcropping southeast of Baleine, which is surrounded by massive agglomerate.

Scatari Island Member

The felsic volcanic rocks of the informal Scatari Island member are similar to those of the Baleine member except in the presence of many interbedded red siltstone, sandstone and conglomerate horizons exhibiting graded and current bedding, slump folds and ripple marks. The relationship between the Scatari Island member and those members exposed between Louisbourg and Cape Breton was not observed. It is possible that it represents a distal facies equivalent of the Baleine member.

ASSOCIATED INTRUSIVE ACTIVITY

Acidic, intermediate and basic sheets intruded and acted as feeders to the volcanic pile. The intermediate and basic sheets are inferred to be the feeders to the intermediate and basic tuffs and hyaloclastites of the Little Lorraine member because they are generally absent from stratigraphically higher units and are petrographically similar. The mafic sheet which intruded the Baleine member is an exception (Fig. 2, specimen G13-6283).

Small plutons and dykes of gabbro intruded the volcanic rocks in various parts of the area (Fig. 2). The gabbro contains oligoclase or andesine, augite, opaque minerals, apatite and quartz. The sodic nature of the plagioclase and the presence of quartz are attributed to metasomatism. These attributes suggest the gabbro has some dioritic tendencies. West and north of Louisbourg, similar volcanic rocks are intruded by granitoid plutons. Rb/Sr whole rock isochrons on the Capelin Cove and Loch Lomond plutons give ages of 545±28 Ma and 548±18 Ma respectively (Keppie and Smith, 1978). These ages provide an upper age limit for the Fourchu Group.

CADOMIAN OROGENY

These volcanic rocks have been deformed by gently plunging, east-northeast, upright folds associated with an axial plane foliation defined by aligned chlorite and sericite. The rocks east of the fault at Big Lorraine form the southern limb of a major anticline whose hinge occurs along the coast of Main-à-Dieu Bay (Fig. 2). West of the fault at Big Lorraine the rocks lie on the southern limb of a major syncline (Fig. 2). Displacement of these major fold axial traces suggests that the movement on the fault was strike-slip, however its sense is not known. A younger, second, steeply dipping, northeast-southwest foliation is sporadically developed, but no associated major folds were identified. This deformation affects the acidic, intermediate and basic sheets and the gabbro bodies with the exception of the Blackrock Point gabbro dyke, which remains undeformed. It has also affected some of the granitoid plutons, e.g. Marie Joseph body. This deformation is Precambrian in age as is indicated by the presence in the Eo-Lower Cambrian Morrison River Formation of pebbles derived from the Fourchu Group displaying one and sometimes two tectonic fabrics. These fabrics show different orientations from one pebble to another, and are distinct from the Acadian and/or Taconian fabric in the enclosing rock. Helmstaedt and Tella (1973) noted similar features in the Boisdale Hills. This deformation and greenschist facies metamorphism are correlated with the Late Hadrynian Cadomian Orogeny.

GEOCHEMISTRY

The predominance of pyroclastic rocks in the Fourchu Group around Louisbourg limits the choice of samples to those without lithic fragments. Suitable units are lava flows, intrusive sheets and plutons. The major and trace element compositions of representative samples are given in Table 1.

The major elements were determined at Nova Scotia Technical College by atomic absorption spectroscopy. The trace elements were analyzed by X-ray fluorescence at St. Mary's University with a precision generally better than ± 10%.

The SiO_2 content (on a volatile-free basis) of the gabbros ranges from 47.0 to 55%, confirming their basic classification with some intermediate tendencies. The SiO_2 content (volatile-free basis) of the intermediate/basic sheets and acidic flows ranges from 48.4 to 62.6% and from 70.2 to 82.3%, respectively. Thus, they may be classified as basalts, andesites, rhyodacites and rhyolites.

Secondary alteration of the intermediate/mafic sheets recognized in thin section is reflected in their chemistry (Table 1) by the generally high H_2O (1.8 to 5.4%), by the K_2O and Na_2O because they plot outside the alkali based spectrum defined by Hughes (1973) (Fig. 4a) and by the low CaO values (<7%). Using the same parameters, the gabbros are less altered for, although they have rather high H_2O (1.78 to 5.36%), some do fall in the igneous spectrum using alkali parameters (Fig. 4a), and they generally have CaO values >7% and higher FeO/Fe_2O_3 ratios (1.5 to 4.15). The chemistry of the felsic flows also reflects their relatively less altered state; their volatile content is also generally low (<0.75%). The effects of alteration on the chemistry indicate that more weight should be placed on the relatively immobile elements in any analysis of their affinity and tectonic setting.

Mafic Intrusives

The subalkaline affinity of the intermediate/basic sheets and gabbros is clearly indicated by interrelationships between the relatively immobile elements (Figs. 4b and c, 5 a to c). Their calc-alkalic nature and island arc origin may be deduced using a combination of discrimination diagrams (Fig. 5). This is supported by their position on the AFM and Al_2O_3: normative plagioclase plot (Figs. 6b and c), although they fall mainly in the theoleiitic field on Miyashiro's (1974) plots of total FeO/MgO versus total FeO and SiO_2 (Figs. 6d and e). They straddle the boundary between the continental and orogenic fields on the MgO- total FeO -Al_2O_3 (Fig. 6f). Their low abundances of K, Ba, Rb, La, Ce and Zr are

Table 1. Analyses of igneous rocks from the Fourchu Group.

	MAFIC SHEETS							GABBROS							FELSIC FLOWS					
Sample No.	F16-6048	F16-6052	G13-6110	G13-6141	G13-6283	G13-6436	G13-6498	G13-6068	G13-6072	G13-6079	G13-6188	G13-6254	G13-6321	J04-6021	F16-6085	G13-6147	G13-6226	G13-6470	G13-6490	G13-6499
SiO_2 (Wt%)	49.61	55.53	50.68	50.35	46.32	61.75	53.20	48.97	48.99	48.22	52.17	48.55	51.98	43.91	75.48	69.09	73.99	72.09	76.17	81.74
TiO_2	1.23	1.31	1.09	1.01	1.15	0.81	1.41	0.81	1.14	1.17	1.18	1.43	1.04	1.38	0.31	0.60	0.36	0.48	0.34	0.29
Al_2O_3	16.62	16.28	14.10	16.51	19.36	17.63	15.34	16.80	15.71	17.47	13.81	19.05	15.28	17.06	13.00	15.63	12.82	13.22	12.31	9.91
Fe_2O_3	6.68	2.20	5.88	5.93	4.79	1.55	6.31	2.05	2.78	1.81	3.75	2.07	4.10	4.15	0.83	1.25	1.04	1.55	1.55	0.80
FeO	5.61	5.92	5.99	5.07	6.91	3.24	5.74	7.D0	6.77	7.52	7.10	8.57	6.16	6.64	0.96	2.03	0.96	1.17	1.36	0.60
MnO	0.12	0.18	0.09	0.10	0.21	0.06	0.12	0.08	0.17	0.08	0.14	0.14	0.09	0.14	0.06	0.07	0.06	0.14	0.08	0.01
MgO	5.57	4.02	5.69	4.83	6.39	2.06	4.72	7.37	5.40	6.16	4.65	6.39	5.77	7.25	0.55	0.70	0.47	0.79	0.74	0.37
CaO	5.86	3.81	4.66	6.33	6.03	3.17	3.05	11.17	10.14	9.32	5.71	1.91	7.30	7.94	2.06	1.53	1.64	2.25	0.36	0.57
Na_2O	3.51	5.36	5.09	5.61	3.75	5.89	5.43	2.01	4.02	3.32	4.46	5.32	4.58	3.45	5.70	5.26	4.86	4.96	5.26	4.39
K_2O	0.16	0.95	0.40	0.71	0.42	1.87	0.31	0.40	0.44	0.67	1.25	0.88	0.40	0.47	0.62	2.08	1.69	1.48	0.85	0.55
P_2O_5	0.40	0.59	0.19	0.28	0.20	0.31	0.32	0.15	0.17	0.15	0.25	0.24	0.22	0.60	0.05	0.12	0.04	0.15	0.07	0.04
H_2O +	3.80	3.58	3.71	2.74	4.64	1.75	3.33	3.12	3.06	3.04	2.64	5.02	1.75	5.14	0.86	1.18	0.88	1.35	1.32	1.50
H_2O -	0.22	0.10	0.12	0.03	0.13	0.03	0.12	0.11	0.10	0.07	0.09	0.15	0.03	0.22	0.11	0.05	0.03	0.04	0.04	0.05
CO_2	0.00	0.38	0.00	0.00	0.00	0.28	0.00	0.22	0.26	0.27	0.37	0.23	0.16	0.00	0.25	0.26	0.13	0.80	0.46	0.00
Σ	99.39	100.21	97.69	99.50	100.30	100.40	99.40	100.26	99.15	99.27	97.57	99.95	98.86	98.35	100.84	99.85	98.97	100.47	100.91	100.82
Rb(ppm)	2	10	12	17	13	38	7	9	15	16	21	15	14	9	20	37	39	31	26	29
Ba	71	333	120	202	108		157		103	208		448	157	159	218	651	506	532	333	209
Sr	344	112	218	204	488	308	180	208	254	282	293	74	343	452	176	112	252	153	139	85
Zr	66	98	64	91	104	155	61	80	97	108	87	112	108	144	159	163	184	164	176	169
Y	23	28	21	27	25	33	23	20	22	26	24	32	29	33				48		28
Nb	4	6	5	6	6	9	6	4	6	7	6	7	7	9	7	8	8	8	9	6
La	6	13.0	8	10	9.4	21.4	7	6.7	7	7	10.4	11	7	16	16	22	20	20	21	8
Ce	15	29.6	17	26	21.9	47.1	17	15.3	17	8	22.5	25	21	43	41	49	49	45	46	21
Yb		3.0			2.4	3.28		2.0			2.2									
Cr					27.2	2.4		331.			2.0									
Co		18.7			44.4	15.4		39.3			33.0									
Sc		35.8			40.1	22.0		37.3			41.6									
K/Rb	664	788	277	347	268	408	368	369	243	348	494	487	237	433	257	467	360	396	271	157
La/Yb		4.3			3.9	6.5		3.4			4.7									
Y/Nb	5.7	4.7	4.2	4.5	4.2	3.7	3.8	5.0	3.7	3.7	4.0	4.6	4.1	3.7				6.0		4.7
Or	1.00	5.83	2.52	4.36	2.60	11.24	1.92	2.44	2.71	4.13	7.83	5.50	2.44	2.99	3.67	12.50	10.20	8.90	5.07	3.27
Ab	31.26	47.17	46.05	43.12	33.28	50.68	48.05	17.57	34.13	29.29	39.99	47.61	40.05	30.68	48.41	45.25	41.99	42.70	44.92	37.42
An	27.88	15.69	15.45	18.43	30.02	13.95	13.66	36.81	24.57	32.11	14.80	8.38	20.63	31.96	8.09	6.92	8.05	9.60	1.34	2.59
Ne				3.32					0.76					0.41						
Q	3.18	5.11				9.93	2.56	0.80			0.81				35.08	26.14	35.70	32.56	40.65	52.83
Ol-Fo			3.81	6.94	7.22				5.34	6.51		6.54	2.00	12.50						
Ol-Fa			3.75	7.26	6.26				3.91	4.92		5.39	1.57	7.55						
Hy-En	14.60	10.41	8.01		6.40	5.52	12.29	14.00		3.13	9.43	7.51	8.40		0.89	1.77	1.19	1.76	1.85	0.93
Hy-Fs	13.45	7.52	7.15		5.05	3.50	12.18	7.60		2.15	8.88	5.63	5.98		0.44	1.86	0.43	0.30	0.81	
Di-Wo			3.33	5.12				8.11	11.20	6.31	5.64		6.41	2.63	0.77			0.32		
Di-En			1.71	2.57				4.96	6.43	3.58	2.84		3.59	1.60	0.48			0.24		
Di-Fs			1.53	2.44				2.70	4.27	2.46	2.67		2.55	0.87	0.24			0.04		
Ap	0.38	1.42	0.47	0.67	0.48	0.73	0.77	0.36	0.42	0.37	0.61	0.59	0.53	1.50	0.12	0.28	0.09	0.35	0.16	0.09
Il	2.46	2.59	2.21	1.99	2.29	1.57	2.80	1.59	2.27	2.32	2.37	2.88	2.05	2.82	0.59	1.16	0.69	0.93	0.66	0.55
C	1.02	0.94			2.36	0.90	1.35					6.81				2.27	0.11		2.27	1.16
Mt	4.17	3.32	4.02	3.78	4.03	2.29	4.41	3.07	4.00	2.73	4.12	3.17	3.80	4.50	1.20	1.84	1.54	2.29	2.27	1.14

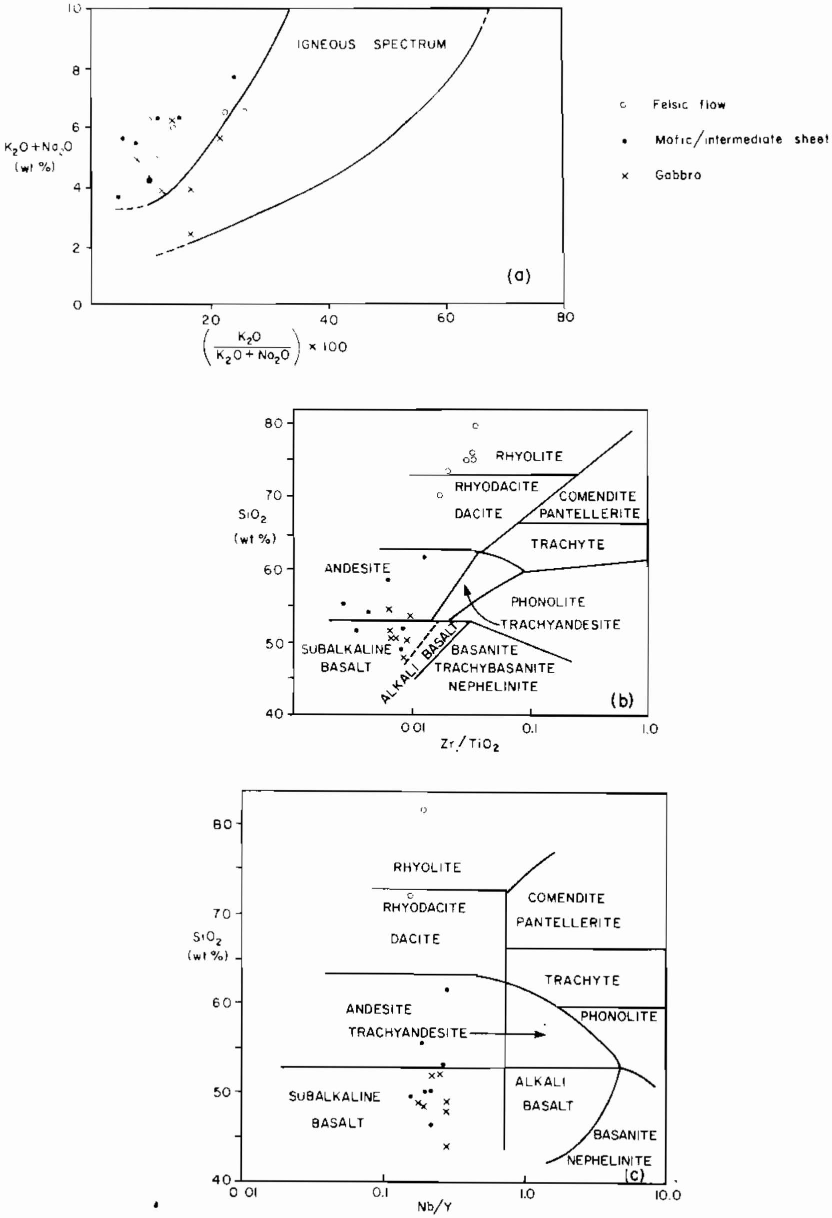

Figure 4. Rocks of the Fourchu Group plotted on (a) (K_2O+Na_2O): $[K_2O/(K_2O+Na_2O)] \times 100$ diagram (fields after Hughes, 1973); (b) SiO_2:Zr/TiO_2 diagram and (c) SiO_2:Nb/Y diagram (fields in (b) and (c) from Winchester and Floyd, 1977).

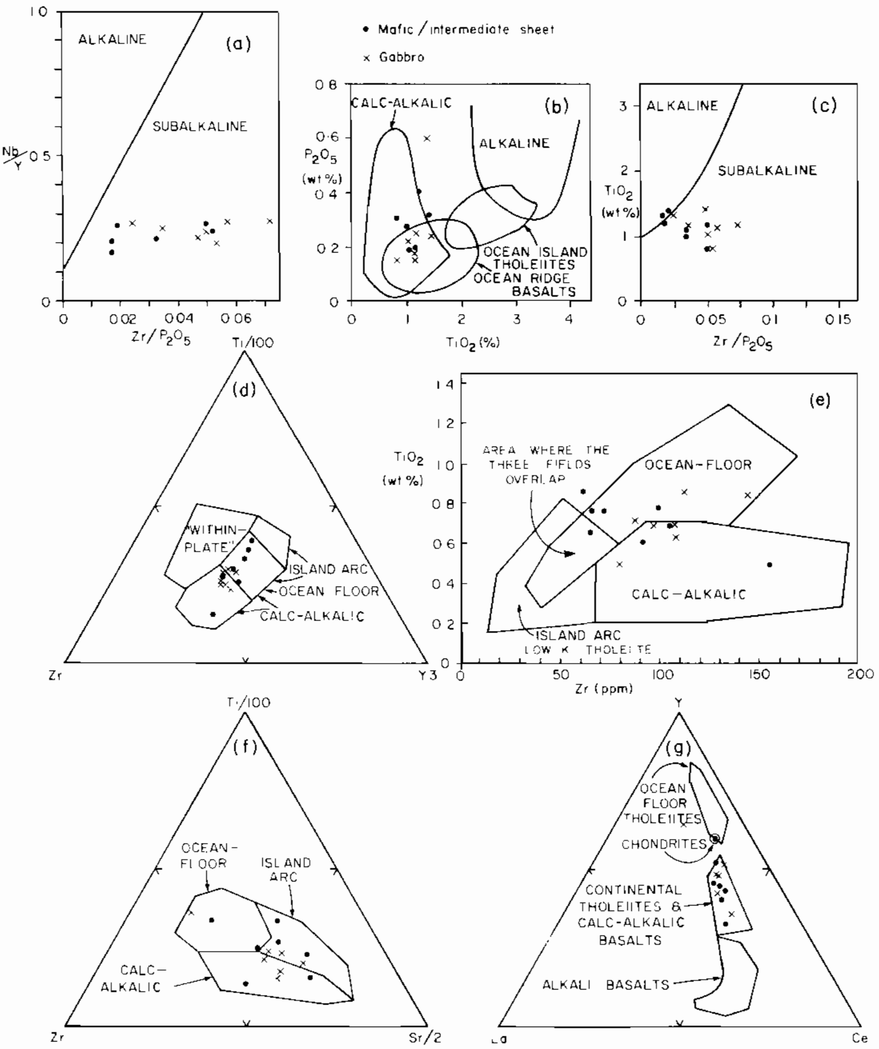

Figure 5. Petrogenetic and tectonic affinity of the mafic rocks of the Fourchu Group using trace element and REE (a) Nb/Y: Zr/P_2O_5 plot (Floyd and Winchester, 1975; Winchester and Lloyd, 1976); (b) P_2O_5 :TiO_2 plot (Sarkar, 1978); (c) TiO_2: Zr/P_2O_5 plot (Floyd and Winchester, 1975; Winchester and Floyd, 1976); (d) Zr-Ti-Y plot (e) TiO_2-Zr plot (f) Zr-Ti-Sr plot (fields in (d-f) from Pearce and Cann, 1973); (g) La-Y-Ce plot (Thorpe, 1972; Ricci and Sabatini, 1978).

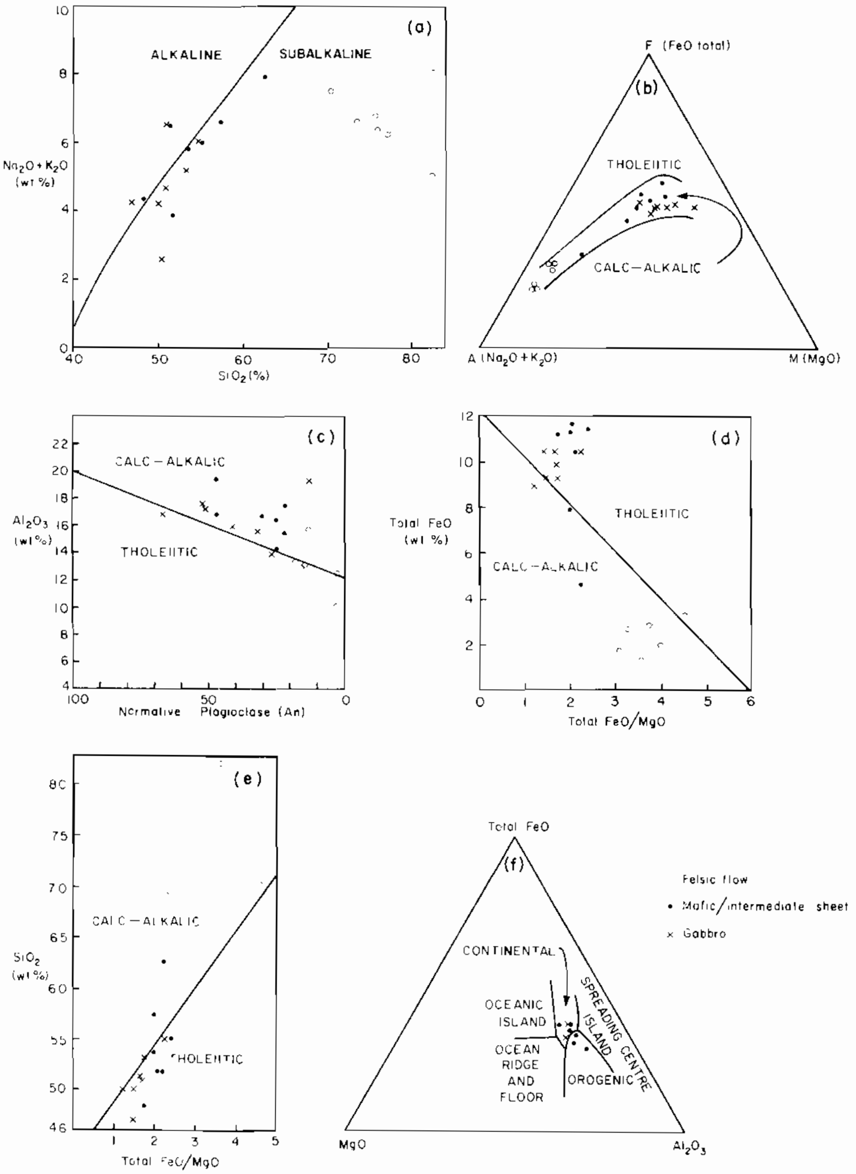

Figure 6. Petrogenetic and tectonic affinity of rocks of the Fourchu Group using major elements (a) Alkalies: SiO_2 diagram (fields from Irvine and Baragar, 1971); (b) AFM diagram (fields from Kuno, 1968): (c) Al_2O_3: normative plagioclase diagram (Irvine and Baragar, 1971); (d) Total FeO:total FeO/MgO plot; (e) SiO_2:total FeO/MgO plot (fields in (d) and (e) from Miyashiro, 1974); (f) MgO- total FeO -Al_2O_3 diagram (Pearce, et al., 1977).

similar to those of island arc calc-alkalic suites. The high K/Rb (409±156, Fig. 7) and low La/Yb (4.6±1.2) ratios are in the range of typical island arc calc-alkalic rocks (Jakes and White, 1972). The rather low abundances of lithophile and transition elements in mafic rocks are, however, also consistent with the transitional rocks between island arc tholeiitic and calc-alkalic types. Such a character is compatible with their position on the Ti-Zr-Sr discriminant plot (Fig. 5f).

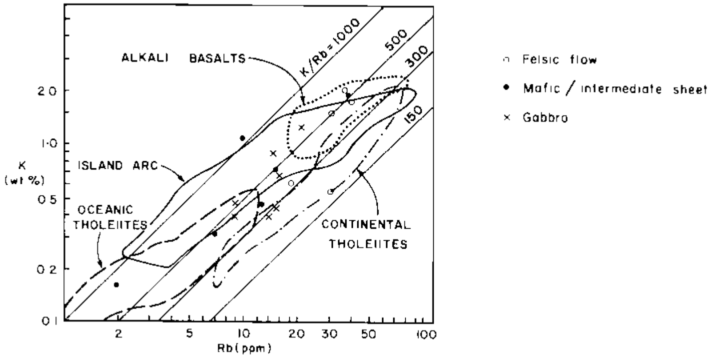

Figure 7. Rocks of the Fourchu Group plotted on the K/Rb plot (fields after Albuquerque, 1979).

Although K, Rb, Ba, Sr, Al, Fe and Mg may have been partly redistributed by postmagmatic alternation there is no compelling evidence that the averages for these elements were significantly affected. Therefore it may be possible to apply the Rb/Sr crustal thickness index of Condie (1973) and the K and Sr abundances to indicate the depth to the paleo-Benioff zone (Dickinson, 1975; Palacios and Oyarzun, 1975). These indices suggest that the Fourchu Group was emplaced in thin continental crust (<20 km) and that the depth to the Paleo-Benioff zone was 40 to 75 km using the more reliable Sr, or 40 to 100 km using K (cf. Lopez-Escobar, et al., 1977; Dostal, et al., 1977).

Variation trends exhibited by the major and trace elements in the basic/intermediate sheets and their spatial association suggest that they are genetically related and were derived from the same or similar parental magmas by fractional crystallization. Pyroxene fractionation was dominant as is indicated by the positive correlation of the La/Yb ratio with the total FeO/MgO ratio, and is consistent with the observed negative correlation of Sc and Co with the total FeO/MgO ratio. The interrelation between Al, Ca and Sr suggests that plagioclase also played a role during the evolution of these rocks. The low abundances of transition elements imply that the magma also underwent fractional crystallization of olivine and spinel (Nicholls and Ringwood, 1973). Several recent studies (Ringwood, 1974; Noble, et al., 1975) have demonstrated that calc-alkalic basalts cannot be generated by partial melting of subducted oceanic lithospere and are probably the result of upper mantle anatexis. If such upper mantle has chondritic REE abundances, then the low La/Yb ratios suggest that garnet did not participate significantly in the genesis of these rocks.

Felsic Rocks

The felsic volcanic rocks are characteristically depleted in K_2O and are peraluminous with mol. $Na_2O+K_2O>Al_2O_3$. According to Murphy (1977b) the low K_2O/Na_2O ratios are of primary magmatic origin. Their low normative orthoclase (<12.5%) and normative anorthite (<18.4%) mean that they plot in the low pressure one feldspar field on the Ab-Or-An ternary diagram (Fig. 8a). However, they do not show any obvious differentiation trends towards a ternary minimum (Fig. 8a & b). The felsic flows are low in Rb with an average K/Rb ratio of 318. They also have low abundances of La, Ce, Zr and Nb.

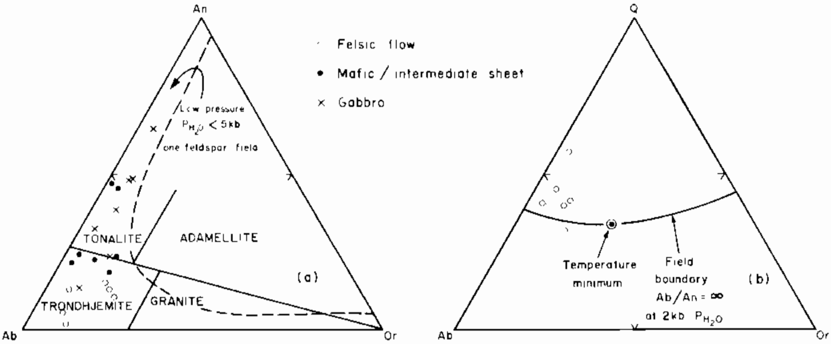

Figure 8. Rocks of the Fourchu Group plotted on the normative plots: (a) Ab-An-Or (fields from O'Conner, 1965); and (b) Ab-Q-Or.

Two models for the origin of the felsic rocks of the Fourchu Group are fractional crystallization of mafic magma and partial melting of the crustal rocks. The close spatial and temporal association of the mafic, intermediate and felsic rocks suggests a parent-daughter relationship. This is supported by the variation trends of many of the major and trace elements (Figs. 4 to 6 and 8). However, if the 2:1 volumetric proportion of felsic to intermediate/basic rocks in the Louisbourg area is representative of the Fourchu Group as a whole, then it is probable that anatexis of the crust also took place. Furthermore, the low abundances of incompatible elements in the felsic rocks are significantly lower than those expected during extensive fractional crystallization of basic magma with a composition similar to that of analyzed mafic rocks. Therefore, anatexis of crustal rocks is more plausible and may be related to the rise of mafic magma.

CONCLUSIONS

The volcanic rocks of the Fourchu Group consist of subaerial and submarine mafic, intermediate and felsic pyroclastic rocks and flows. Geochemically, they have calc-alkalic affinities and were erupted as part of an ensialic island arc on thin continental crust at about 40 to 80 km above the paleo-Benioff zone. Their generation was terminated by the late Hadrynian Cadomian Orogeny which produced greenschist facies metamorphism, polyphase deformation and extensive plutonism. Their geochemistry is consistent with the orogenic tectonic setting. An origin by anatexis of the upper mantle and crust accompanied by fractionation of pyroxene, olivine, spinel and plagioclase is most plausible.

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Paper 79-1

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