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Contrasting Geology Across The Cradle Brook Thrust Zone: Subaerial vs Marine Precambrian Environments, Caledonia Highlands, New Brunswick

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Résumé de l'article

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The Cradle Brook fault zone in southern New Brunswick separates highly deformed Precambrian terranes reflecting radically different geological environments. The zone is comprised of major southward directed thrusts and is interpreted to represent, in part, the boundary between the Central and Eastern volcanic belts of the Caledonia Highlands.

The Precambrian rocks north of the fault reflect subaerial and, locally, subaqueous deposition whereas those south of the fault reflect marine deposition. In addition to the differences in Precambrian stratigraphy, extensive areas south of the fault are underlain by felsic and mafic intrusive bodies of probable late Precambrian age, and by Cambrian rocks that rest unconformably on the stratigraphy of the Eastern Volcanic Belt. Based on a limited number of chemical analyses, the volcanic piles exhibit calc-alkaline and weakly tholeiitic affinities south and north of the fault, respectively.

The structural and stratigraphic relationships imply that the subaerial rocks are older than the marine rocks and that the latter are probably near the top of the local Precambrian sequence. The abundance of intrusive rocks in the subaqueous sequence substantiate juxtaposition of very different geological regimes.

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Au nord de la faille, les roches précambriennes relèvent essentiellement d'une accumulation subaérienne et, localement, subaquatique, alors qu'au sud de la faille, elles trahissent un dépôt marin. On doit ajouter aux différences dans la stratigraphie précambrienne de vastes étendues au sud de la faille qui comprennent des appareils intrusifs felsiques et mafiques, probablement tardi-précambriens, et des assises cambriennes qui recouvrent en discordance la stratigraphie de la ceinture volcanique orientale. La prise en compte d'un nombre limité d'analyses chimiques révèle les affinités calco-alcalines et faiblement tholéiitiques des empilements volcaniques sis, respectivement, au sud et au nord de la faille. [Traduit par le journal]

INTRODUCTION

Precambrian rocks of the Caledonia Highlands, southern New Brunswick, constitute a segment of the Avalon Zone (Williams 1978) that once may have formed an extensive land mass extending from the southern Appalachians through the Canadian Appalachians to Great Britain (Rodgers 1972; Rast *et al.* 1976). More recently, Williams and Hatcher (1982) suggested that the Avalon Zone may be composite and comprised of several suspect terranes

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assembled in late Precambrian time.

Since the work of Alcock (1938), predominantly metavolcanic rocks of the Caledonia Highlands have been considered stratigraphic equivalents of the late Precambrian Coldbrook Group of the Saint John area. Giles and Ruitenberg (1977) and Ruitenberg *et al.* (1979), in a regional study of the Caledonia Highlands, divided the area into several major tectonostratigraphic belts (Fig. 1a). They envisaged the volcanic and sedimentary rocks of their Eastern Volcanic Belt to have been deposited in a large ocean basin on the flank of an extensive Precambrian land mass represented locally by their Central Volcanic Belt.

The area discussed in this paper includes the southwestern part of the Central Intrusive Belt and the western part of the Eastern volcanic Belt (Fig. 1) west of Fundy National Park. Kindle (1962) mapped part of this area and Barr and White (1986) have recently mapped the area to the east in Fundy National Park. The purpose of this paper is to summarize, in part, the results of a study undertaken to investigate the economic mineral potential of the map area (McLeod, in prep.). New detailed stratigraphic information, a brief description of plutonic rocks, and petrochemical data are presented.

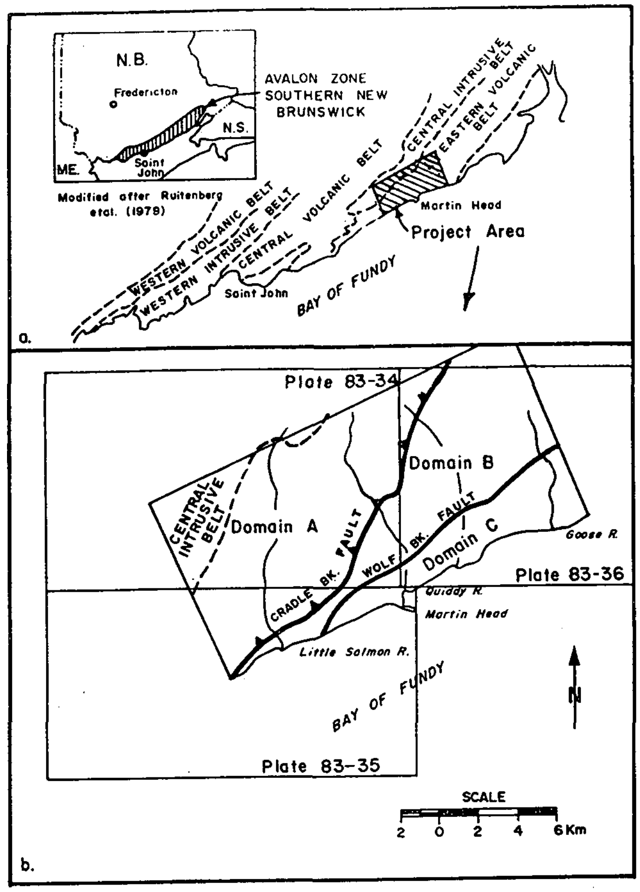

Fig. 1. (a) Location Map for southern New Brunswick showing major tectonostratigraphic belts after Ruitenberg *et al.* (1979) and the location of the study area.
(b) Outline of major domains in the study area.

PRECAMBRIAN STRATIGRAPHY

The study area is divided into three major northeasterly trending fault blocks referred to as domains A, B, and C (Fig. 1b). Domain A constitutes a distinctive package of rocks that differs from those in domains B and C in both lithology and structure. Lithologic units in domains B and C are similar to each other and tentative correlations can be made across the major boundary fault.

The domains are subdivided into mappable units based on the relative proportions of dominant rock types (Fig. 2). More detail is shown on maps at a scale of 4 inches to 1 mile in McLeod (1983). The establishment of stratigraphy is hampered by numerous intrusions, complex faulting and intense cataclastic deformation that obscures primary features and depositional structures in most of the units. These factors and the repetitive nature of similar units hampers the construction of stratigraphic columns in domain A. General stratigraphic columns for domains B and C can, however, be deduced by restoring the positions of fault blocks and correlating lithologically similar units (Fig. 3). Most of the Precambrian rocks in the area have been subjected to greenschist facies metamorphism, and hence, rock types described below are now metamorphic. Numbered units referred to in the text are shown on Figure 3.

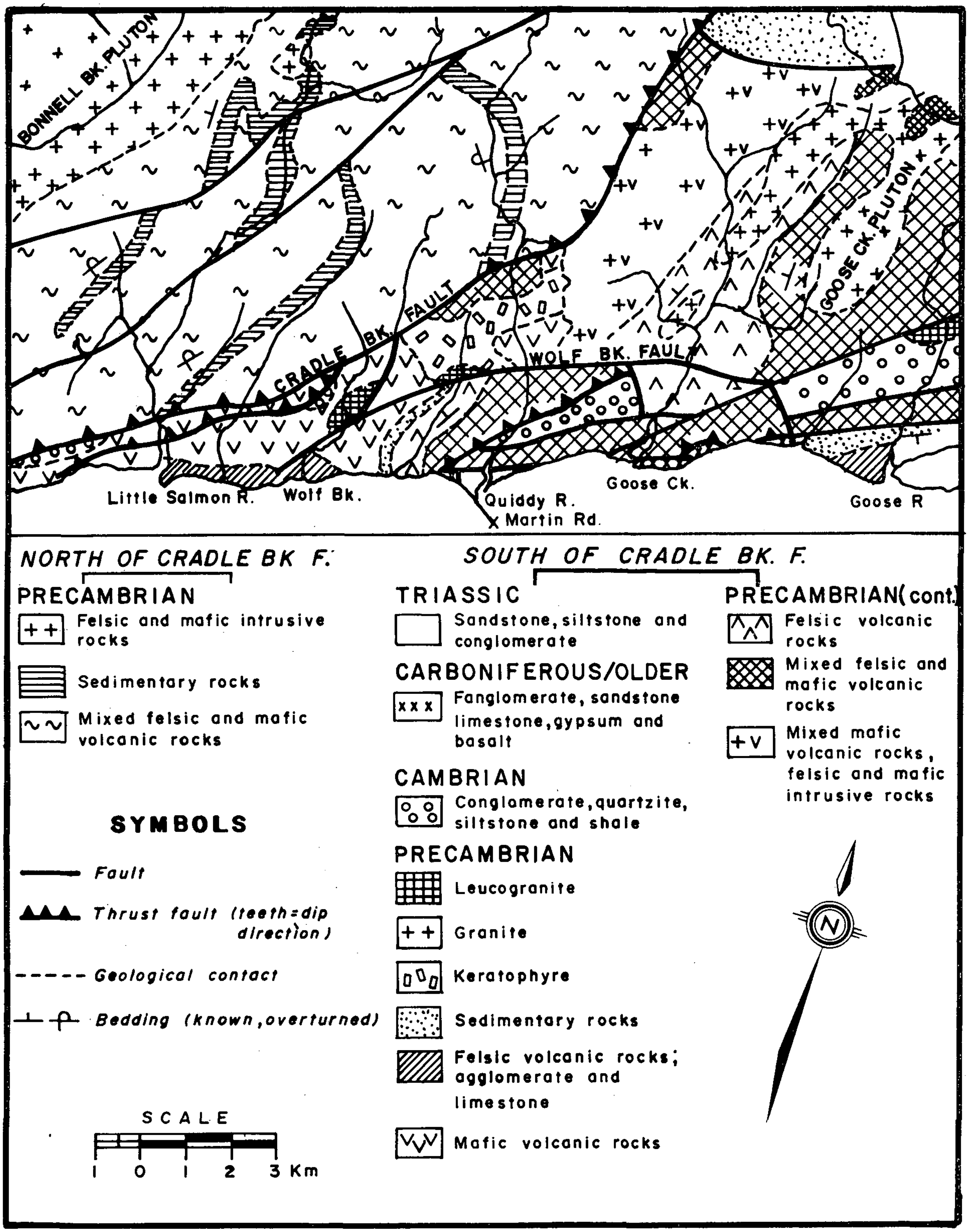

Fig. 2. General geological map of the Little Salmon River - Goose River area.

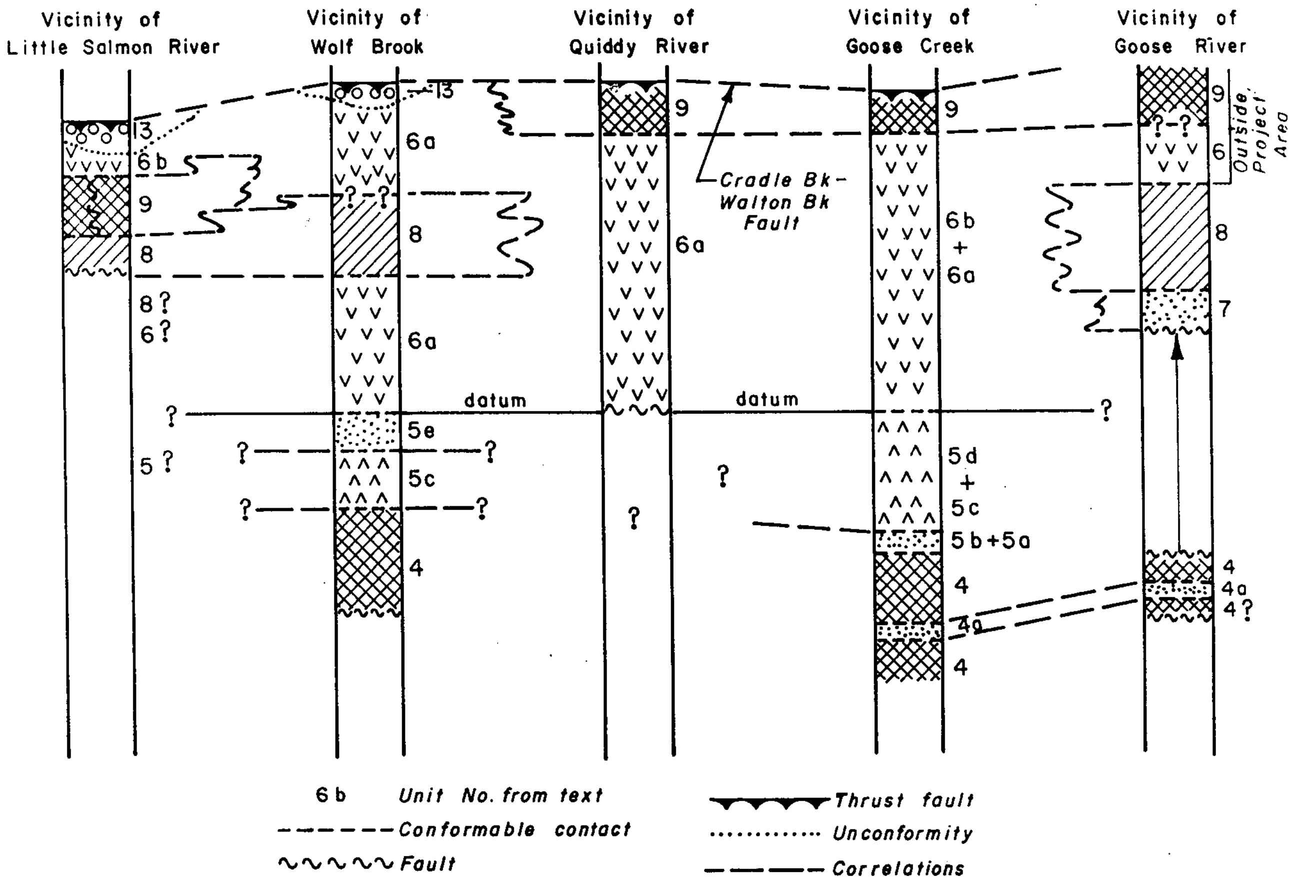

Fig. 3. Schematic stratigraphic columns and correlations for domains B and C. Unit numbers are referred to in text.

Domain A

Domain A consists of a variety of intercalated fine- and coarse-grained, felsic and mafic tuffs, basaltic flows, rhyolitic flows and minor amounts of siltstone and sandstone. Total thickness of the units comprising this domain could not be determined but is probably at least 5000 m. The stratified rocks are intruded by small bodies of granodiorite, gabbro and diabase. This domain is bounded to the north by two large intrusive bodies - the Bonnell Brook and Point Wolfe River plutons which form part of the Central Intrusive Belt of Ruitenberg *et al.* (1979). The southern boundary is marked in part by a major southward-directed thrust fault termed the Cradle Brook Fault (Fig. 2). At least one major, similarly oriented, thrust and several smaller ones with apparently relatively minor offset occur south of the main Cradle Brook Fault, and hence this area is referred to as the cradle Brook thrust zone.

Red to buff felsic and green mafic coarse tuff and lapilli-tuff with variable amounts of lithic fragments are most common and generally occur in laterally continuous thick to very thick units that are poorly sorted. The felsic coarse tuff contains variable amounts of felsic fragments, quartz, altered plagioclase and mafic fragments that together comprise up to 80% of the rock. The felsic lapilli tuff most commonly contains, in addition to altered felsic and a few mafic volcanic fragments, up to 50% quartz clasts. The matrix of these rocks consists of a microcrystalline mixture of quartz + muscovite + chlorite. These coarse tuffs and lapilli tuffs appear to be intercalated with ignimbrites at some localities. The mafic counterparts are also quite variable and generally consist of a mixture of altered mafic and minor felsic fragments, fragments and crystals of plagioclase, and minor amounts of quartz. The matrix is composed predominantly of chlorite, plagioclase and opaque minerals. Only minor amounts of felsic vitric and crystal tuffs are present.

Large areas are underlain by maroon felsic flows and/or domes that commonly exhibit contorted flow lamination and spherulitic and axiolitic structures. They usually occur in regular layers about 2 m thick, oriented parallel to the intense regional tectonic fabric, and the layering, therefore, could be a tectonic feature. Outcrop patterns indicate that some of these units truncate stratigraphy suggesting an intrusive origin. Highly vesicular mafic flows and minor amounts of highly epidotized volcanic breccia(?) occur sporatically throughout most sections.

Units of grey and greyish green siltstone and sandstone generally not more than 35 m thick are intercalated with the volcanic rocks (Fig. 2). Beds are usually thin but thicker beds (1 m and greater) of medium- to coarse-grained sandstone occur at some localities. Thin to medium-width parallel laminations are ubiquitous in the siltstone beds and normal grading occurs in the few of the thicker sandstone beds. At some localities, poorly exposed multiple Bouma a - d divisions less than 1 m thick, overlain by pelitic intervals of variable thickness, are developed within the sedimentary unit. The sandstone units are composed of feldspathic or lithic wacke and less commonly quartz wacke or arkose. The lithic wacke contains variable amounts of locally derived volcanogenic material.

Domains B and C

Domains B and C occur to the north and south of the Wolf Brook Fault respectively. These domains contain a variety of mainly fine- and some coarse-grained mafic and felsic volcanic rocks, mafic flows, hyaloclastites and hyalotuffs, detrital sedimentary rocks and minor limestones. The occurrence of pyrite is ubiquitous in most of these rocks. The total thickness of strata comprising domains B and C is at least 5000 m. Zone C is a complex sinistral wrench fault zone in which fault blocks are composed of numerous rock types of various ages (McLeod in prep.).

The intensity of the cataclastic deformation in the tuffs of these domains precludes reliable detailed descriptions of individual units. Mapping can be accomplished only by noting distinctive colour variations and rudimentary compositional variations in the tuffs, and by utilizing recognizable intervening sedimentary units as marker horizons.

The base of the section in the study area is exposed on the upper parts of Goose River, Goose Creek and on the Quiddy River. Grey and green, fine- to medium-grained mafic and commonly pyritiferous felsic tuffs with few primary structures constitute most of this unit (Unit 4, Fig. 3). One bed of arkosic sandstone that contains randomly distributed, rounded, pebble- and cobble-sized fragments of red felsic volcanic rocks provides a good stratigraphic marker (Unit 4a, Fig. 3). Thick to thin beds of dark purple and green siltstone that exhibit thin to medium laminations are particularly abundant in the lower part of the unit. Similar thin siltstone beds are intercalated with the mafic tuffaceous rocks in the upper part of the unit on the Quiddy River.

On Goose Creek, Unit 4 is conformably overlain by laterally continuous and highly sheared dark grey siltstones that are intercalated with thick beds of massive white quartzite and minor amounts of limestone (Units 5a and 5b, Fig. 3). These lithologies form the base of an extensive unit that consists primarily of dark green and orange, fine- to medium-grained felsic tuffaceous rocks (Unit 5c, Fig. 3), and are exposed on the upper part of Goose

Creek and just west of Martin Head. Minor amounts of dark grey siltstone, similar to that at the base of the unit, and dark puple siltstone occur throughout (Unit 5d, Fig. 3). Distinctive steel grey and light green siltstone and sandstone of limited extent form the top of the unit (Unit 5e, Fig. 3) west of Martin Head.

An extensive unit of mafic volcanic rocks occurs along the Fundy Bay shore in the Wolf Brook area and inland on the upper part of Goose Creek, and conformably overlies the felsic volcanic unit. The mafic unit is readily mappable throughout the area and as such provides a good marker horizon. The base of this unit is used as the datum in Fig. 3. Most of the unit is composed of thinly laminated, fine-grained and crudely bedded coarse-grained tuffaceous rocks (Unit 6a, Fig. 3). Thick beds, up to 5 m thick, of highly vesicular pillow lavas with graded beds of hyaloclastite, obviously derived from brecciation of the pillow lavas (Unit 6b, Fig. 3), are intercalated with the tuffs and are particularly abundant west of Little Salmon River. Discontinuous lenses of limestone and disrupted blocks of chert are dispersed in the hyaloclastite.

Another predominantly felsic volcanic unit (Unit 8, Fig. 3) occurs in shore sections in the Wolf Brook and Goose River areas and is, in part, a facies equivalent of the mafic volcanic unit, as is apparent in the Little Salmon River and Wolf Brook areas (Fig. 3). Lithotypes in this unit are distinctive and include a medium-grained, green felsic breccia, fine- to medium-grained, pyrite-rich felsic tuffaceous rocks, dark green siliceous siltstone and thick beds of dark grey, parallel- and cross-laminated limestone. The felsic breccia commonly contains large rounded bombs of pink vitrophyre and/or dislodged limestone fragments that exhibit normal grading in thick beds.

The top of the Precambrian sequence in domain B consists of intercalated felsic and mafic tuffs (Unit 9, Fig. 3) similar to those at the base of the section.

Rocks of unknown stratigraphic position occur in fault blocks on the upper part of the Point Wolf River in domain B and on the Bay of Fundy shore in domain C. In domain B, the unit consists of intercalated, finely laminated, maroon and grey siltstone, shale and minor limestone, and a thick succession of interbedded maroon arkosic sandstone and mafic tuffaceous rocks. In domain C, the unit is composed of a wide variety of lithotypes including fine- to medium-grained felsic and mafic tuffaceous rocks, lesser amounts of fine grained sedimentary rocks and on Goose River, a thick sequence of buff arkosic sandstone with an assortment of rounded and poorly sorted pebble-sized fragments.

Interpretation of Precambrian Stratigraphy

The rocks in domain A north of the Cradle Brook fault were deposited in a subaerial and locally subaqueous environment. Periods of intense activity produced voluminous, unsorted felsic and mafic ash and lapilli deposits, highly vesicular mafic flows and extensive felsic flows. The felsic volcanic rocks are mostly oxidized and there is little evidence of reworking of volcanic debris. Isolated basins are represented by finely laminated and commonly normally graded fine- to medium-grained sedimentary rocks that occur as discontinuous units intercalated with the volcanic deposits. These sedimentary rocks contain variable amounts of locally derived volcanic debris. This stratigraphy is considered to represent an extension of the Central volcanic Belt of Ruitenberg *et al.* (1979).

The Precambrian rocks in domains B and C, south of the Cradle Brook Fault, were deposited entirely in a marine environment. Periods of intense volcanic activity also produced voluminous felsic (commonly pyritiferous) and mafic ash deposits but these are generally finer-grained than those north of the fault and are commonly reworked, producing well sorted and laminated deposits. The volcanic flows are mafic and occur as vesicular pillow lavas and hyaloclastite. During intermittent periods of quiescence, limestone, chert, quartzite, arkose and finely laminated, fine-grained sedimentary rocks were deposited. Some of these sedimentary units are laterally extensive and correlatives exist throughout the Eastern Volcanic Belt of Ruitenberg *et al.* (1979). Equivalent rocks also exist in fault blocks north of the Cradle Brook Fault along the coast near Big Salmon River. The structural relationship (southward-directed thrusting) across the Cradle Brook Fault suggests that the rocks in domain A represent an older Precambrian terrane.

PALEOZOIC STRATIGRAPHY

Several previously unidentified units of possible Lower Cambrian rocks at least 100 meters thick occur in domains B and C (McLeod and McCutcheon 1981). Grey and maroon siltstone, sandstone and shale, quartzite, quartzite-pebble conglomerate and minor amounts of limestone crop out beneath the Cradle Brook Fault in domain B (Unit 13, Fig. 3). These rocks rest unconformably on the Precambrian rocks.

The basal conglomerate is 1 to 10 meters thick and contains abundant well rounded but poorly sorted pebbles and cobbles of maroon quartzite and quartz, and a few clasts of sedimentary and felsic volcanic rocks. A few of the volcanic fragments exhibit a pre-depositional (Precambrian) fabric. This unit is generally overlain by 1 to 5 m of maroon, parallel-laminated and cross-bedded quartzite that is in turn overlain by an undetermined thickness of highly sheared fine-grained sedimentary rocks.

Similar lithotypes of probable Cambrian age occur in fault blocks in domain C. Further descriptions and correlations of this unit are given in McLeod and McCutcheon (1981).

These Cambrian rocks reflect a major change in the depositional and tectonic environment from the preceeding Precambrian units. Similar initial Cambrian deposits (quartzite and quartzite-pebble conglomerate) are interpreted elsewhere to represent a marginal basinal facies associated with the formation of the Iapetus ocean, and the overlying shale, sandstone and limestone reflect the transgression of that ocean over the Precambrian Avalonian platform (Rast *et al.* 1976; Ruitenberg *et al.* 1977).

Several units designated as Carboniferous or older, Carboniferous, and Triassic occur in small fault blocks along the coast in domain C (McLeod in prep.). The Carboniferous or older rocks consist of epidotized mafic volcanic breccia, dark red and green feldspathic wacke and siltstone, and limestone. The limestone may be a correlative of the Visean Windsor Group. The Carboniferous and Triassic rocks are primarily fluvial deposits with minor amounts of gypsum and anhydrite.

PLUTONIC ROCKS

The stratified rocks in the study area have been intruded by a variety of felsic and mafic rocks. These are particularly abundant in domains B and C but are notably lacking in domain A.

Mafic Intrusions

Deformed and undeformed porphyritic to non-porphyritic diabase dykes 1 to 5 meters wide occur throughout the study area. They are commonly deformed and generally strike parallel to the regional tectonic fabric, but massive types may be post-tectonic. A few massive dykes have intruded inferred Cambrian strata.

Massive and deformed gabbros occur throughout domains B and C as small plugs and larger bodies up to a kilometer in diameter. Only one poorly defined plug crops out in domain A.

Felsic Intrusions

The intrusive rocks that occur along the northern boundary of domain A include about equal proportions of granodiorite and monzodiorite and subordinate amounts of fine-grained felsic and mafic rocks. The margins of these plutons are deformed by the regional cataclastic deformation but interiors are relatively massive. These are part of the Bonnell Brook and Point Wolfe River Plutons of Ruitenberg *et al.* (1979). Other than these plutons, only one small stock of granodiorite and a few small stocks of very fine-grained felsic rocks have intruded domain A.

The felsic intrusions in domains B and C consist predominantly of granite, granodiorite, keratophyre porphyry, leucogranite and minor quartz diorite. These intrusions vary in width from a few meters to several kilometers and generally are elongated parallel to the regional structural trend. The margins, as well as parts of the interiors of these intrusions, are deformed by the regional tectonic fabric.

A relatively homogeneous granitic pluton, referred to as the Goose Creek sill by Ruitenberg *et al.* (1979), crops out in the northeastern part of domain B (Fig. 2). Diabase dykes intrude the granite but are volumetrically insignificant. The contacts of the pluton, where mapped in detail, cross cut the regional tectonic fabric and stratigraphy and, therefore, it cannot be considered a sill. Smaller bodies of granodiorite and quartz diorite also occur in domain B.

Several small plugs of medium- and coarse-grained leucogranite that are commonly highly fractured occur along the boundary between domains B and C (Fig. 2). The plug on Goose River contains inclusions of possible Cambrian rocks. The distribution of the leucogranites (along the Wolf Brook Fault) and their fractured appearance may indicate emplacement along zones of structural weakness. Keratophyre porphyry is most abundant in domain B on the Quiddy River where it forms fairly large, homogeneous intrusive masses but it is also abundant as smaller intrusions, dykes and sills throughout domains B and C.

Timing of Intrusive Events

The age of the intrusive rocks is not well established. The Ordovician and older? age suggested by Ruitenberg *et al.* (1979) for the large granodiorite and monzodiorite intrusions in the Caledonia Highlands is based on K-Ar dates by Ruitenberg *et al.* (1979) and Leech *et al.* (1963). One Rb-Sr whole-rock date of 530+/- 16 Ma for the Bonnell Brook Pluton indicates a Cambrian age (C. Brooks, Written Comm. 1980). Lower Cambrian conglomerates, however, contain clasts of similar granitoid rocks.

It is postulated that the majority of the intrusive rocks in the area were injected in Late Precambrian time and that absolute age dates are anomalously young, as Cormier (1963) suggested for volcanic rocks in the Coldbrook Group. Exceptions could be the leucogranites that contain xenoliths of possible Cambrian lithologies and a few massive diabase dykes which have also intruded Cambrian strata. Similar conclusions were reached by Ruitenberg *et al.* (1979).

PETROCHEMISTRY

A limited number of samples (43) were collected to assess the chemical variation within and between the major intrusive and extrusive units in the study area. The samples were analyzed at X-Ray Assay Laboratories, Don Mills, Ontario (Table 1). Analysis were by X-ray fluorescence except FeO and H_2O+ which were done by wet chemical methods. Complete analyses and data on precision and accuracy are given in McLeod (in prep.).

Samples selected for chemical analysis are the freshest available and

TABLE 1

AVERAGES AND STANDARD DEVIATIONS OF INTRUSIVE AND EXTRUSIVE ROCKS

%	Leucogranite n = 5		Granite Goose Ck. n = 5		Granodiorite Bonnell Bk. n = 4		Keratophyre n = 4		Rhyolite n = 3		Diabase and Gabbro n = 14		Mafic Volc. Domain A* n = 6		Mafic Volc. Domains B & C* n = 5	
SiO_2	77.9 ±	1.6	72.5 ±	1.0	65.8 ±	1.3	75.4 ±	2.0	73.7 ±	1.8	48.9 ±	2.7	51.5 ±	3.7	54.6 ±	1.9
TiO_2	0.05	0.00	0.31	0.11	0.47	0.07	0.28	0.07	0.26	0.10	1.20	0.39	1.22	0.28	0.82	0.31
Al_2O_3	11.5	0.58	13.3	0.1	15.2	0.4	11.8	0.6	13.0	1.3	16.1	2.1	17.3	1.4	15.1	1.9
Fe_2O_3	0.54	0.18	1.34	0.42	1.79	0.40	0.86	0.27	1.00	0.51	3.71	1.14	4.31	1.12	2.46	1.54
FeO	0.4	0.2	1.2	0.3	1.6	0.5	1.5	0.6	0.8	0.2	6.8	1.5	5.5	1.3	5.2	0.5
MnO	0.02	0.01	0.06	0.01	0.07	0.01	0.05	0.02	0.05	0.01	0.22	0.05	0.20	0.03	0.17	0.04
Mgo	0.13	0.19	0.80	0.10	1.43	0.29	1.28	0.68	0.45	0.29	6.30	2.19	5.61	1.67	6.36	1.14
CaO	0.96	0.39	2.54	0.29	3.28	1.04	1.33	0.79	1.49	0.72	8.97	1.68	7.53	1.64	5.99	0.97
Na_2O	2.96	0.74	3.50	0.51	3.91	0.44	4.53	0.85	3.67	0.19	2.33	0.85	3.04	0.63	4.32	1.01
K_2O	3.90	0.50	2.00	0.47	2.61	0.95	0.56	0.31	3.19	0.22	0.49	0.32	1.02	0.59	0.17	0.19
P_2O_5	0.01	0.00	0.07	0.00	0.13	0.02	0.27	0.38	0.06	0.03	0.17	0.13	0.20	0.08	0.09	0.05
H_2O+	1.0	1.1	1.1	0.2	1.2	0.2	0.9	0.5	0.7	0.2	2.6	0.7	2.7	**	2.7	**
Total	99.39		98.76		98.12		98.76		98.34		97.79		100.16		97.98	
ppm																
Rb	130 ±	37	60 ±	19	90 ±	42	20 ±	0	80 ±	6	20 ±	15	40 ±	22	10 ±	2
Sr	40	6	100	19	330	76	100	76	140	68	220	89	270	81	190	126
Zr	90	10	120	20	180	21	130	13	200	29	100	51	140	36	70	43

* Includes relevant analyses from Ruitenberg et al. (1979)

** Analyses from Ruitenberg et al. (1979) were not analyzed for H_2O+

only those relatively unaffected by deformation were chosen. All rocks in the project area, however, have been affected to some extent by the regional greenschist facies metamorphism. In the felsic rocks, plagioclase is intensely saussuritized, biotite is partially to totally chloritized and the matrix shows some recrystallization and development of secondary muscovite. The mafic rocks exhibit greater alteration affects. Mafic minerals are commonly chloritized and epidotized and often are totally obliterated. The matrix of these rocks is always totally chloritized.

Alteration effects are obvious in the chemical analysis. For example K_2O contents of the mafic volcanics in domains B and C are very low and consequently the samples plot outside the igneous spectrum of Hughes (1973). The following discussion of the chemistry should, therefore, be considered as preliminary, pending more detailed sampling and trace element analyses.

Mafic Intrusions

The mafic intrusions are subalkaline, contain normative orthopyroxene and quartz or olivine, and exhibit a moderately strong iron enrichment trend (Fig. 4 and 5). These features indicate that these rocks are tholeiites that are saturated or slightly undersaturated. There is no apparent systematic variation in chemical composition in the mafic intrusive rocks with respect to relative age or distribution.

Felsic Intrusions

The leucogranites and the granites-granodiorites represent two chemically distinct types of granitoid rocks in the study area. These chemical differences are readily apparent on the AFM diagram (Fig. 4) The two groups also have distinctive trace element abundances (Table 1).

The granitoid intrusions are subalkaline and exhibit typical calc-alkaline trends (Figs. 4 and 5). The leucogranites are highly differentiated with high K_2O/Na_2O and Rb/Sr ratios, and low TiO_2 contents.

The fine-grained felsic porphyries in domain B and the felsic rocks in domain A are classified as keratophyres (utilizing plots of Hughes 1973) and as

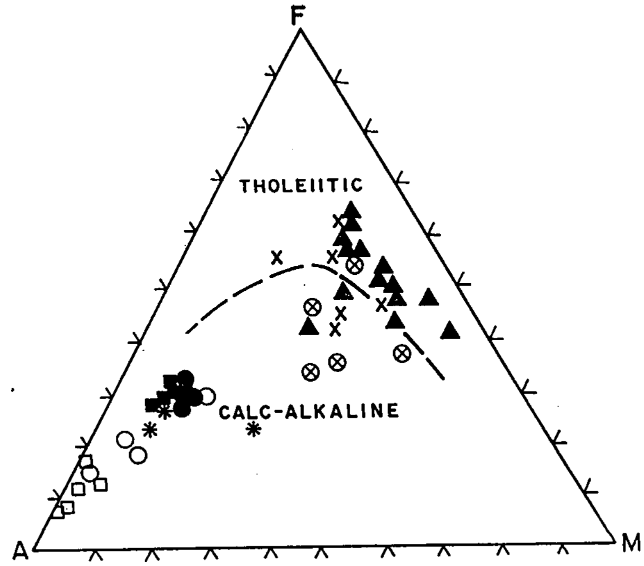

Fig. 4. AFM diagram for intrusive and extrusive rocks. Boundary line after Irvine and Baragar (1971). Open squares - leucogranite, solid squares - granite (Goose Creek), solid circles - granodiorite (Bonnell Brook), solid triangles - mafic intrusive rocks, crosses - mafic extrusive rocks. Circled crosses are mafic extrusive rocks from domains B and C, circles - keratopyre, asterisks - rhyolites.

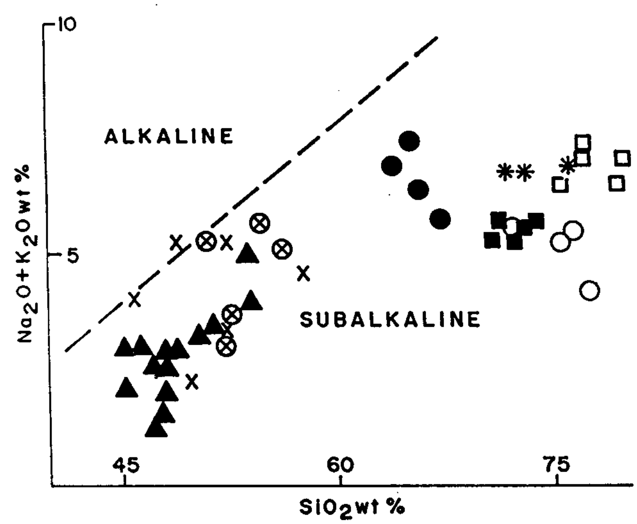

Fig. 5. Alkalies - silica diagram for intrusive and extrusive rocks. Boundary line after Irvine and Baragar (1971). Symbols as in Fig. 4.

normal rhyolites (of Carmichael *et al.* 1974), respectively. Average analyses of these keratophyres and rhyolites are shown on Table 1. Both groups are subalkaline and exhibit typical calc-alkaline trends (Figs. 4 and 5).

Mafic Flows

Ruitenberg *et al.* (1979) analyzed mafic flows from the Caledonia Highlands and concluded that they are oversaturated to slightly under-saturated tholeiitic basalts and andesites. Utilizing their data for samples collected in the study area and samples analyzed for this study it is apparent that the flows in domain A are basalts to basaltic andesites, and in domains B and C andesites or basaltic andesites. The flows in all domains are subalkaline (Fig. 5) but problems are encountered when attempting to classify these rocks further. The flows in domains B and C plot in the calc-alkaline field on Fig. 4, whereas some of those in domain A plot in the tholeiitic field and show some iron enrichment. The relatively high TiO_2 and Zr content of the northern domain samples suggests continental affiities for these rocks (Gale and Pearce 1982). These elements are lower in the mafic volcanic rocks of the southern domains.

In summary, it appears that the mafic volcanic rocks in domains B and C are calc-alkaline and that those in domain A are tholeiitic with continental affiities. This conclusion is consistent with field evidence that indicates a major division of the project area into deposits formed mainly in a subaerial environment (domain A) and a subaqueous environment (domains B and C).

CONCLUSIONS

The study area in the Caledonia Highlands of southern New Brunswick can be divided into three major fault bounded tectonostratigraphic units. Lithologic correlations can be made across faults in the two southern units (domains B and C) but these correlations cannot be extended to the northern unit (domain A) across the Cradle Brook and associated faults, a major southward directed thrust zone.

Rocks north of the fault zone were deposited in subaerial and, locally, subaqueous environments whereas south of the fault, deposition was entirely marine. This contrast in environments appears to be substantiated by the chemistry of the mafic volcanic rocks. The Cradle Brook Fault is interpreted to represent in part the boundary between the Central and Eastern Volcanic Belts of Giles and Ruitenberg (1977). Accordingly, these two belts need not be direct facies equivalents as envisaged by these authors. The structural (thrusting) and stratigraphic relationships (relics of Cambrian strata) imply that the subaerial rocks are older than the marine rocks and that the latter are probably near the top of the Precambrian sequence. The paucity of major intrusive activity within domain A, compared to domains B and C, attests to their mutually exclusive development prior to thrusting.

It appears that the majority of the intrusive rocks in the study area were injected during Precambrian time. There is evidence for several periods of mafic intrusive activity but only one period of major felsic intrusive activity. Highly differentiated leucogranites, however, may have been emplaced along major zones of structural weakness and could be much younger.

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