Maritime Sediments and Atlantic Geology

Vol. 22 August, 1986 No. 2

Two Rb-Sr Whole Rock Isochrons from Plutons in the Cobequid Highlands, Nova Scotia, Canada

H.V. Donohoe, A.N. Halliday**, J. Duncan Keppie****
** ***Department of Mines and Energy, P.O. Box 1087, Halifax Nova Scotia, Canada B3J 2X1*
***Scottish Universities Research and Reactor Centre East Kilbride, Glasgow, Scotland, Great Britain, G75 0QU*

Two Rb-Sr whole rock isochrons have been obtained from plutons in the Cobequid Highlands of Nova Scotia: the Debert River and Hart Lake-Byers Lake Plutons. The undeformed, unfoliated Debert River Pluton yielded an age of 596 ± 70 Ma and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7059 ± 0.0007. This age places an upper age limit on the deformation recorded in the Folly River Schist (youngest unit of the Bass River Complex), the dioritic Frog Lake Pluton, and the sedimentary rocks immediately north and east of the Debert River Pluton.

The Hart Lake-Byers Lake Pluton yielded an age of 348 ± 5 Ma and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7046 ± 0.0008. The similiarity of this age to that of the adjacent felsic volcanics of the Byers Brook Formation suggests that they are comagmatic and confirms that a Carboniferous igneous event forms an important part of the geological history of the Cobequid Highlands. The initial $^{87}Sr/^{86}Sr$ ratio and the biotite-hornblende content of the two granites suggest a mafic igneous lower crustal source or possible mantle component for the magma.

Les plutons de Debert River et Hart Lake-Byers Lake dans les monts Cobequid en Nouvelle-Ecosse ont livré deux isochrones Rb-Sr de roche globale. Ni déformé ni folié, le pluton de Debert River a donné un âge de 596 ± 70 Ma et un rapport $^{87}Sr/^{86}Sr$ initial de 0.7059 ± 0.0007. Ceci place une limite supérieure sur l'âge de la déformation enregistrée dans le schiste de Folly River (l'unité la plus jeune du complexe de Bass River), le pluton dioritique de Frog Lake et dans les roches sédimentaires jouxtant le pluton de Debert River au nord et à l'est.

Le pluton de Hart Lake-Byers Lake a produit un âge de 348 ± 5 Ma et un rapport isotopique $^{87}Sr/^{86}Sr$ initial de 0.7046 ± 0.008. Cet âge, similaire à ceux des volcanites felsiques adjacentes de la formation de Byers Brook, suggère qu'ils sont comagmatiques, signe évident qu'un épisode igné carbonifère forme l'un des faits majeurs de l'histoire géologique des monts Cobequid. Le rapport $^{87}Sr/^{86}Sr$ initial et la teneur en biotite et hornblende de ces deux granites suggèrent une genèse crustale profonde du magma avec une possible contribution mantellique.

INTRODUCTION

In this study, two plutons in the Cobequid Highlands, the Debert River Pluton and the Hart Lake-Byers Lake Pluton were chosen for Rb-Sr isotopic analysis (Fig. 1). These plutons and the geology of the Cobequid Highlands have been described by Donohoe and Wallace (1980, 1982, 1985). The age dates allow limits to be set upon the ages of various sedimentary and volcanic units and deformational events. They also provide better definition of the ages of plutonic events and the origin of the magma.

TECHNIQUES

Rb-Sr isotopic analysis were performed at the Scottish Universities

MARITIME SEDIMENTS AND ATLANTIC GEOLOGY
22, 148-154 (1986)

0711-1150/86/020148-7$2.05/0

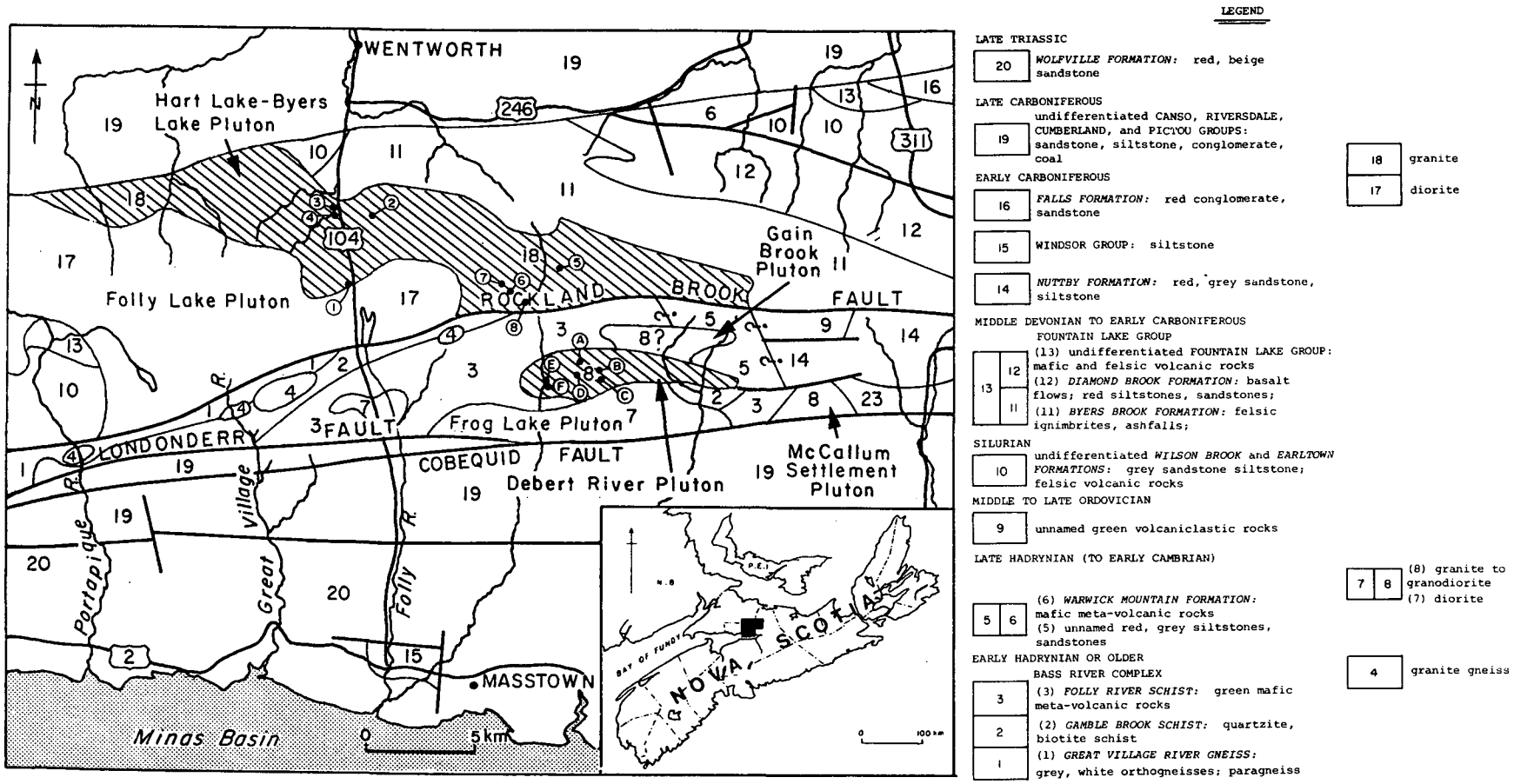

Figure 1. Geological map of the Cobequid Highlands (modified from Donohoe and Wallace, 1980) with sample locations.

Research and Reactor Centre using standard techniques described in detail elsewhere (Halliday et at., 1979, 1983). Sample powders spiked with ^{87}Rb and ^{84}Sr enriched isotopic tracers were dissolved using HF, HNO_3 and HCl acids. Rb and Sr were separated using conventional cation exchange resins. Isotopic analyses were performed on a fully automated V.G. Isomass 54E mass spectrometer. Ratios of $^{87}Sr/^{86}Sr$ are reported normalized to $^{88}Sr/^{86}Sr = 8.37521$. The average $^{87}Sr/^{86}Sr$ for NBS987 on this machine was 0.71027 ± 1 (2σ mean, N=79) at the time of analysis. Regression followed the method of York (1969). The decay constant for ^{87}Rb used is $1.42 \times 10^{-11} y^{-1}$. The uncertainty in $^{87}Rb/^{86}Sr$ is estimated to be $\pm 1.0\%$ (2σ).

DEBERT RIVER PLUTON

The Debert River Pluton is located in the Bass Terrane (Keppie, 1982) between the Cobequid and Rockland Brook Faults (Fig. 1). On its west side, it is intrusive into the Folly River Schist which forms the upper part of the Bass River Complex. A minimum age for the Bass River Complex of 642 ± 15 Ma is provided by preliminary Rb-Sr data from granite gneisses intruding the Bass River Complex (Gaudette et al., 1983, 1984). On its east side, the pluton intruded and contact metamorphosed sedimentary rocks which have been correlated lithostratigraphically with the Devono-Carboniferous Nuttby Formation by Donohoe and Wallace (1980, 1982). To the south, it intruded the undated Frog Lake dioritic pluton. The undated Gain Brook Pluton intruded the Debert River Pluton along its northern margin.

The Debert River Pluton is a fresh, light grey to pale tan grey, medium to coarse grained, hypidiomorphic granular monzogranite to granodiorite. It consists of oligoclase (40-55%), quartz (20-30%), potassium-feldspar (5-30%), accessory biotite and hornblende, and traces of sphene, zircon, epidote and opaques. The pluton is not foliated although local shear zones are present. The pluton contains foliated xenoliths of green, metavolcanic rocks and quartz-biotite schist derived from the Folly River Schist and the Gamble Brook Schist respectively, both units of the Precambrian Bass River Complex. It also contains xenoliths of other plutonic rocks such as biotite monzogranite, biotite granodiorite and diorite.

Seven whole rock samples of the Debert River Pluton were analyzed for Rb-Sr and the results are given in Table 1 and plotted on a conventional isochron diagram in Figure 2. The data scatter about a best fit line corresponding to an age of 596 Ma. The "scatter error" (York, 1969) for this determination is ± 70 Ma (2σ). The initial $^{87}Sr/^{86}Sr$ so determined is 0.7059 ± 7 (2σ) (MSWD = 82).

The age of 596 ± 70 Ma is consistent with all the geological constraints described above except for its intrusive relationship with sedimentary rocks previously correlated with the Devono-Carboniferous Nuttby Formation (Donohoe and Wallace, 1980; 1982). These new data indicate that these sedimentary rocks are not correlatives of the Nuttby Formation. They may be correlatives of the (?)Late Precambrian Warwick Mountain Formation and/or Jeffers Formation, which implies that a discontinuity is present between these rocks and the dated Nuttby Formation (Fig. 1). However, the age error limits also allow the possibility that the intruded sedimentary rocks could be Cambrian in age.

The age of the Debert River Pluton agrees with the 575 ± 22 Ma age of the McCallum Settlement granite pluton (Gaudette et al., 1983, 1984) which is located just to the east (Fig. 1). The intrusive contact of the undeformed Debert River Pluton with the dioritic Frog Lake Pluton indicates an older episode of dioritic plutonism. Elsewhere in the Cobequid Highlands this episode is represented by the Jeffers Brook Diorite (K-Ar on biotite:

Table 1. Analytical and statistical data for the Debert River Pluton.

Letter on Fig. 1	Sample Number	Rb (ppm)	Sr (ppm)	Rb/Sr (Weight)	$^{87}Sr/^{86}Sr$ (atomic)	$^{87}Sr/^{86}Sr \pm 2\sigma^{M}$* (atomic)
A	JS75-46	91.00	190.4	0.4779	1.384	0.71733 ± 3
B	E11-4569	46.09	321.4	0.1434	0.4150	0.70931 ± 3
C	E11-4570	66.12	294.2	0.2247	0.6504	0.71195 ± 6
D	E11-4571	52.94	190.4	0.2781	0.8050	0.71309 ± 3
E	E11-4573	75.42	248.2	0.3039	0.8796	0.71326 ± 3
F	E11-4574	85.37	238.1	0.3586	1.038	0.71454 ± 4

*$2\sigma^{M}$ = two standard errors of the mean
Age ± 2σ *a priori* (scatter error) Ma = 596 ± 7 (70) Ma
($^{87}Sr/^{86}Sr$) Initial ± 2σ *a priori* (scatter error) = 0.70593 ± 9 (73)
SUMS = 326 (SUMS = sum of the squares of the residuals)
MSWD = 81.6 (MSWD = mean squared weighted deviates)

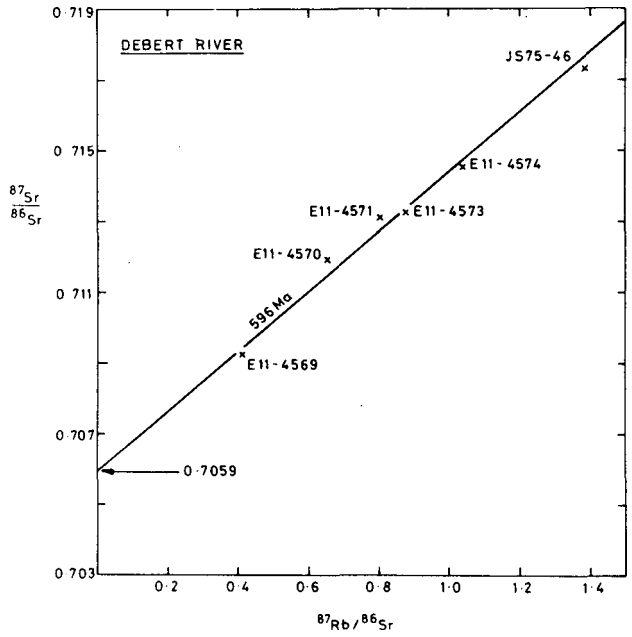

Figure 2. Rb-Sr whole rock isochron for the Debert River pluton.

544 ± 22 Ma, 564 ± 22 Ma, 585 ± 23 Ma; and K-Ar on hornblende, 616 ± 28 Ma and 628 ± 28 Ma; Wanless *et al.*, 1973, recalculated by Kepple and Smith, 1978, using the decay constants proposed by Steiger and Jager, 1977; and a Rb-Sr biotite isochron, 541 ± 25 Ma, Cormier, 1979, using $1.42 \times 10^{-11} y^{-1}$ for the ^{87}Rb decay constant).

The initial $^{87}Sr/^{86}Sr$ ratio of 0.7059 ± 0.0007 indicates that the magma had a crustal component. The mafic mineralogy suggests that the Debert River Pluton has an I-type nature and therefore that the source may have been mafic and igneous. A mantle-derived component could also be involved but its significance cannot be assessed without knowing the exact nature of the lower crust and a more complete petrologic study of the pluton.

HART LAKE-BYERS LAKE PLUTON

This granitoid pluton occurs in the Cobequid Terrane (Keppie, 1982) lying north of the Rockland Brook Fault (Fig. 1). It has intruded and contact metamorphosed the fossiliferous Silurian Wilson Brook Formation and the Devono-Carboniferous Byers Brook Formation (Donohoe and Wallace, 1982) along its northeastern contact. Felsic volcanic rocks of the Byers Brook Formation have recently yielded a whole rock Rb-Sr isochron age of 341 ± 4 Ma (Cormier, 1982). The Hart Lake-Byers Lake Pluton is also intrusive into the dioritic Folly Lake Pluton to the southwest. It is cut and mylonized by lateral movement on the Rockland Brook Fault to the south and unconformably overlain by Late Carboniferous rocks to the north.

The Hart Lake-Byers Lake Pluton is

a pale pink, hypidiomorphic granular, occasionally porphyritic, hornblende biotite syenogranite to alkali feldspar granite. It consists of potassium-feldspar (35-50%), quartz (20-35%), albite-oligoclase (10-15%), hornblende (5-10%) and traces of biotite, riebeckite, fluorite, sphene, zircon, apatite, allanite and opaques. No internal foliation was observed.

Rb-Sr isotopic analyses of eight whole rock samples from the Hart Lake-Byers Lake pluton are given in Table 2 and plotted in Figure 3. All eight samples define a reasonable linear array but sample JS76-57 plots slightly further off than the others. A best fit line for all eight samples gives an age of 355 ± 18 Ma (MSWD = 91) and exclusion of sample JS76-57 yields a better fit corresponding to an age of 348 ± 5 Ma with an initial $^{87}Sr/^{86}Sr$ of 0.7046 ± 8 (MSWD = 5.8). We accept the latter as the best estimate of the age of the pluton.

The Hart Lake and Byers Lake Plutons were previously dated by Cormier (1979), using Rb-Sr techniques,

Table 2. Analytical and statistical data for the Hart Lake-Byers Lake Pluton

Number (on Fig. 1)	Sample Number	Rb (ppm)	Sr (ppm)	Rb/Sr (Weight)	$^{87}Rb/^{86}Sr$ (atomic)	$^{87}Sr/^{86}Sr \pm 2\sigma^{M}$* (atomic)
1	JS75-22	308.7	129.8	2.378	6.900	0.73831 ± 30
2	JS75-23	286.4	19.78	14.48	42.75	0.91707 ± 3
3	JS75-32	161.8	22.71	7.122	20.80	0.80524 ± 6
4	JS75-33	207.9	113.0	1.840	5.335	0.73117 ± 3
5	JS75-37	191.8	9.811	19.55	58.15	0.99391 ± 16
6	JS75-57	225.5	35.85	6.291	18.38	0.80684 ± 3
7	JS75-58	166.1	14.33	11.59	34.08	0.87452 ± 3
8	JS75-59	234.6	23.36	10.04	29.46	0.85036 ± 4
2+	JS75-23	293	20.1	14.58	43.0	0.9127
5+	JS75-37	195	12.6	15.48	45.6	0.9179

*$2\sigma^{M}$ = two standard errors of the mean
+Data from Cormier (1979) for comparison (these data are not used in age calculations in this paper)

Suites	N[1]	Age ± 2σ a.p. (s.e) (Ma)[2]	$(^{87}Sr/^{86}Sr)_I$ ± 2σ a.p.(s.e)[2]	SUMS[3]	MSWD[4]
Hart Lake Byers Lake	8	355 ± 2 (± 18)	0.70419 ± 32 (± 306)	546	91
ditto minus 76 - 57	7	348 ± 2 (± 5)	0.70457 ± 30 (± 76)	29	5.8

1. N = number of samples used in calculations of age and intial $^{87}Sr/^{86}Sr$
2. ± 2σ a.p. (s.e.) = ± two standard errors *a priori* (scatter error)
3. SUMS = sum of the squares of the residuals
4. MSWD = mean squared weighted deviates

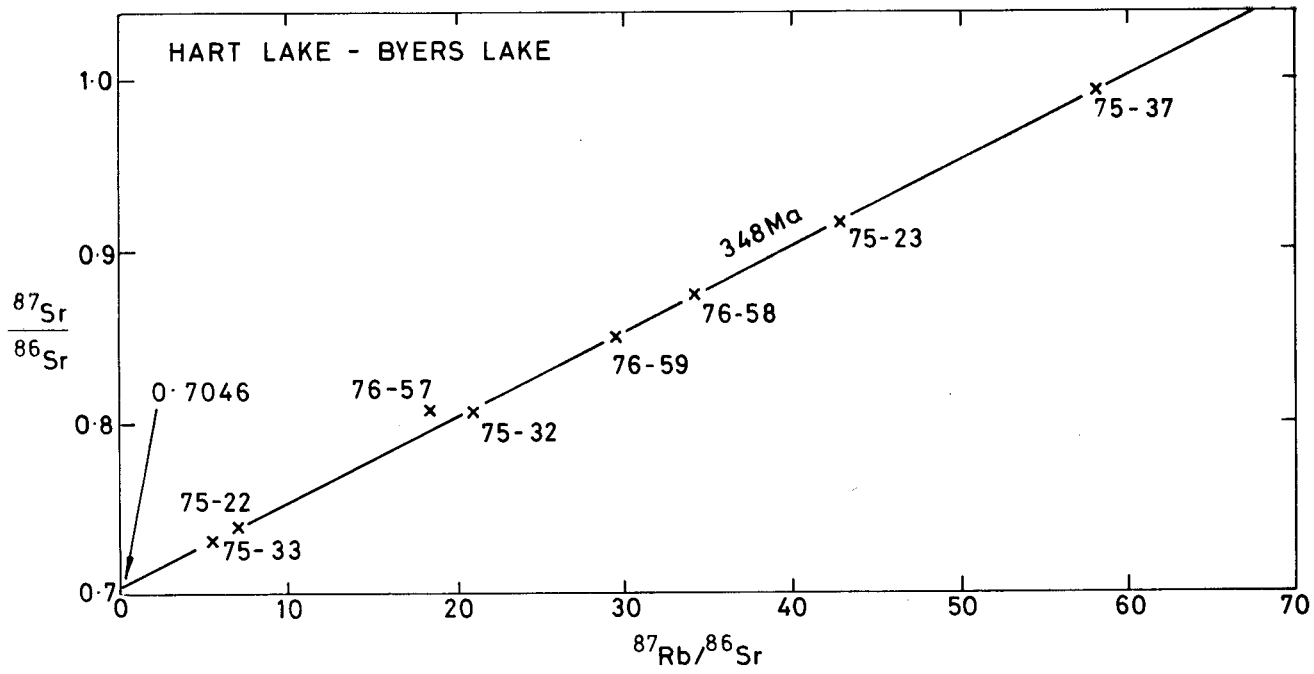

Figure 3. Rb-Sr whole rock isochron for the Hart Lake-Byers Lake pluton.

and yielded results of 331 ± 17 Ma (initial $^{87}Sr/^{86}Sr$ ratio = 0.7076 ± 0.0096) and 331 ± 27 Ma (initial $^{87}Sr/^{86}Sr$ ratio = 0.7097 ± 0.0093), respectively. The errors were sufficiently large that is was impossible to determine whether the plutonism correlates with the widespread Late Devonian (375-360 Ma) granitoid plutonism in the Meguma Terrane of Nova Scotia (Clarke and Halliday, 1980), or represents a later Carboniferous thermal event. The result from the present study (348 ± 5 Ma) suggests that the plutonism is part of a Carboniferous event.

The sample suite for this study includes two samples previously analyzed by Cormier (1979) whose results are included in Table 2 for comparison. Discrepancy between the two laboratories for sample JS75-23 is only 0.6% but is larger for the other sample (JS75-37) (8% for $^{87}Sr/^{86}Sr$, and 25% for $^{87}Rb/^{86}Sr$). Analysis of a standard (NBS987) along with these samples at the Scottish Universities Research and Reactor Centre indicates an analytical uncertainty of ± 0.1% (σ) for $^{87}Rb/^{86}Sr$ in this laboratory. Cormier (1979) does not report analyses of a standard run along with his samples so it is impossible to assess the source of the large discrepancies. Two possibilities are inaccurate analyses by Cormier (1979) or inhomogeneity in sample JS75-37. The fact that the ages and initial ratios derived from the two laboratories agrees within the reported errors may suggest than the latter possibility is more likely.

The 348 ± 5 Ma age of the Hart Lake-Byers Lake Pluton is similar to the age of 339 ± 4 Ma obtained from granitoid rocks in drill core just north of the Hart Lake-Byers Lake Pluton (Cormier, written communication, 1984). Furthermore, the similar ages of the Hart Lake-Byers Lake Pluton and the juxtaposed felsic volcanics of the Byers Brook Formation (341 ± 4 Ma, Cormier, 1982; and 343 ± 5 Ma, Cormier, written communication, 1984) suggests that they are comagmatic.

The low initial $^{87}Sr/^{86}Sr$ ratio of 0.7047 ± 0.0010 suggests a possible lower crustal or mantle source for the magma. More detailed petrologic studies of the plutonic and volcanic rocks are necessary in order to interpret their petrogenesis.

CONCLUSIONS

The 596 ± 70 Ma age of the Debert River Pluton indicates that Late Precambrian–Cambrian plutonism was more widespread in the Cobequid Highlands than formerly known (Donohoe and Wallace, 1980; 1982). It places an upper limit on the age of the rocks it intrudes and on the age of deformation observed in the Bass River Complex. In contrast, the 348 ± 5 Ma age of the Hart Lake–Byers Lake Pluton clearly documents the existence of Carboniferous plutonism in the Cobequid Highlands which corroborates the 339 ± 22 Ma age for the Cape Chignecto pluton in the western Cobequid Highlands (Cormier, 1979). This Carboniferous plutonism was synchronous with adjacent felsic volcanism suggesting that they are comagmatic.

ACKNOWLEDGMENTS

The authors would like to thank Drs. P.S. Giles, R.F. Cormier and H.E. Gaudette for critically reviewing the manuscript, S. Saunders and B. MacDonald for typing the paper and Nova Scotia Department of Mines and Energy draftsmen for drafting the figures.

CLARKE, D.B. and HALLIDAY, A.N. 1980. Strontium isotope geology of the South Mountain Batholith, Nova Scotia. Geochimica et Cosmochimica Acta, 44, pp. 1045–1058.

CORMIER, R.F. 1979. Rubidium/Strontium isochron ages of Nova Scotia granitoid plutons. Nova Scotia Department of Mines Report 79–1, pp. 143–148.

CORMIER, R.F. 1982. Rb/Sr age data for the Fountain Lake Group volcanics. Nova Scotia Department of Mines and Energy Report 82–1, pp. 114–115.

DONOHOE, H.V., JR. and WALLACE, P.I. 1980. Structure and stratigraphy of the Cobequid Highlands, Nova Scotia; Geological Association of Canada–Mineralogical Association of Canada, Halifax '80, Field Guide to Trip 19, 64 p.

DONOHOE, H.V., JR. and WALLACE, P.I. 1982. Geological Map of the Cobequid Highlands, Nova Scotia. Scale 1:50,000. Halifax, Nova Scotia, Canada.

DONOHOE, H.V., JR. and WALLACE, P.I. 1985. Repeated orogeny, faulting, and stratigraphy in the Cobequid Highlands, Avalon Terrane of North-western Nova Scotia; Field Excursion 3. Geological Association of Canada/Mineralogical Association of Canadian Annual Meeting, University of New Brunswick, Fredericton, New Brunswick, 77 p.

GAUDETTE, H.E., OLSZEWSKI, W.J., JR. and DONOHOE, H.V., JR. 1983. Age and origin of basement rocks, Cobequid Highlands, Nova Scotia. Geological Society of America Abstracts with Programs 15, p. 136.

GAUDETTE, H.E., OLSZEWSKI, W.J., JR., and DONOHOE, H.V., JR. 1984. Rb/Sr isochrons of Precambrian age from plutonic rocks in the Cobequid Highlands, Nova Scotia. In Mines and Minerals Branch Report of Activities 1983, Nova Scotia Department of Mines and Energy Report 84–1, pp. 285–292.

HALLIDAY, A.N., AFTALION, M., VAN BREEMEN, O. and JOCELYN, J. 1979. Petrogenetic significance of Rb-Sr and U-Pb isotope systems in the c.400 Ma old British Isles granitoids and the hosts. In Harris, H.L., Holland, C.H. and Leake, B.E. (Editors). The Caledonides of the British Isles – reviewed. Special Publication of the Geological Society of London, pp. 653–661.

HALLIDAY, A.N., FALLICK, A.E., DICKIN, A.P., MACKENZIE, A.B., STEPHENS, W.E. and HILDRETH, W. 1983. The isotopic and chemical evolution of Mount St. Helens. Earth and Planetary Science Letters, 63, pp. 241–256.

KEPPIE, J.D. 1982. Tectonic Map of Nova Scotia. Scale 1:500,000. Nova Scotia Department of Mines and Energy, Halifax, Nova Scotia, Canada.

KEPPIE, J.D. and SMITH, P.K. 1978. Compilation of isotopic age data of Nova Scotia. Nova Scotia Department of Mines and Energy Report 78–4.

STEIGER, R.H. and JAGER, E. 1977. Subcommission on geochronology: convention on the use of decay constants in geo– and cosmochronology; Earth and Planetary Science Letters, 36, pp. 359–362.

WANLESS, R.K., STEVENS, R.D., LACHANGE, G.R., and DELABIO, R.N. 1973. Age determinations and geological studies: Geological Survey of Canada Paper 73–2, 139 p.

YORK, D. 1969. Least squares fitting of a straight line with correlated errors. Earth and Planetary Science Letters, 5, pp. 320–324.