$^{40}Ar/^{39}Ar$ GEOCHRONOMETRY OF IGNEOUS ROCKS IN THE QUATSINO - PORT McNEILL MAP AREA, NORTHERN VANCOUVER ISLAND (92L/12, 11)

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INTRODUCTION

Previous geochronological studies of early Mesozoic igneous rocks on Vancouver Island have primarily used conventional K-Ar dating techniques to broadly establish an Early to Middle Jurassic age for volcanic lithologies of the Bonanza Group and intrusions of the Island Plutonic Suite. In the Cape Scott (102I) - Alert Bay (92L) area, for example, some 24 K-Ar age determinations have been made on mineral separates and whole-rocks (University of British Columbia Geochronological Database) that span a range from 184 Ma to 105 Ma or latest Early Jurassic to latest Early Cretaceous [according to the time scale of Harland *et al.* (1990) and using dates recalculated with the new decay constants recommended by Steiger and Jäger (1977)]. Even though a considerable number of samples have been dated, it is presently unclear if this spread in K-Ar dates primarily reflects substantially different ages of emplacement, partial thermal resetting of the K-Ar system or slow cooling following emplacement. Compounding these uncertainties are systematic differences between the materials that were used to date the volcanic and plutonic assemblages. All Bonanza age determinations rely exclusively on poorly characterized whole-rock samples whereas variably altered hornblende and biotite separates (commonly with impurities) have provided dates for the Island Plutonic Suite. Although there is some overlap of dates between the volcanic (105-163 Ma) and plutonic (184-148 Ma) rocks, the predominantly younger K-Ar dates obtained from the Bonanza are all considered to be minimum (cooling) ages only. This interpretation is necessary in order to reconcile fossil data which, in all but a single case (discussed later), have established an early Sinemurian to late Pliensbachian (middle Early Jurassic) age for the Bonanza Group on Vancouver Island (*c.f.* Muller *et al.*, 1974). The widely embraced concept that Jurassic volcanism is contemporaneous with plutonism on northern Vancouver Island is thus not supported by existing data.

In order to better resolve some of these uncertainties, we have begun to apply $^{40}Ar/^{39}Ar$ geochronometry to selected rock suites to try to obtain more precise data concerning the age of pluton emplacement and the late thermal history of the region. In this preliminary report,

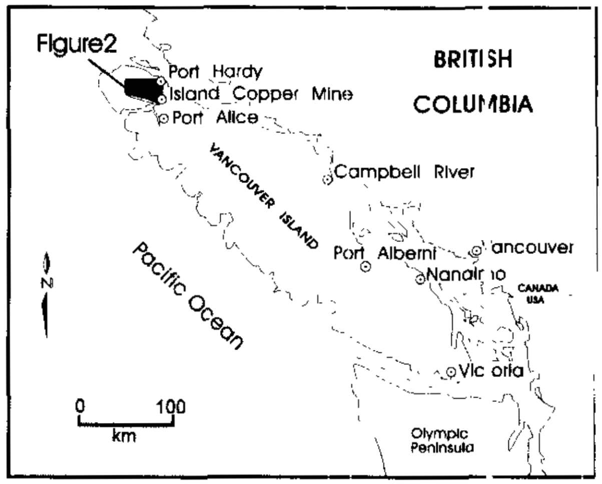

Figure 1. Location of Quatsino-Port McNeill map area.

we present $^{40}Ar/^{39}Ar$ age spectra for intrusions of the Island Plutonic Suite in the Quatsino - Port McNeill map area. The samples were collected as part of the regional mapping component of the Northern Vancouver Island integrated project (Nixon *et al.*, 1994). They represent hornblende and biotite-bearing granitoids from the Nahwitti batholith, and the Glenlion and Rupert stocks, as well as a high-level hornblende-phyric dike intruding the Bonanza Group. The $^{40}Ar/^{39}Ar$ age data reported below are combined with existing K-Ar and Rb-Sr dates, recently documented fossil occurrences and other new $^{40}Ar/^{39}Ar$ age spectra for hydrothermal minerals in acid sulphate-altered volcanic rocks of the Bonanza Group (Panteleyev *et al.*, this volume) in order to re-examine temporal relationships between Jurassic plutonism and volcanism in northern Vancouver Island.

GEOLOGICAL SETTING

The tectonic setting and regional geology of northern Vancouver Island were recently summarized by Nixon *et al.* (1994). Briefly, the oldest stratigraphic components in the Quatsino - Port McNeill area are the Upper Triassic Vancouver Group, which consists of a submarine to subaerial sequence of tholeiitic flood basalts (Karmutsen Formation) capped by thinly bedded to massive lime mudstone (Quatsino Formation) and overlain by thinly bedded and intercalated calcareous to noncalcareous siliciclastics and micritic limestone. The Upper Triassic lithologies are succeeded upwards by a thick Lower Jurassic sequence of submarine to subaerial, mafic to

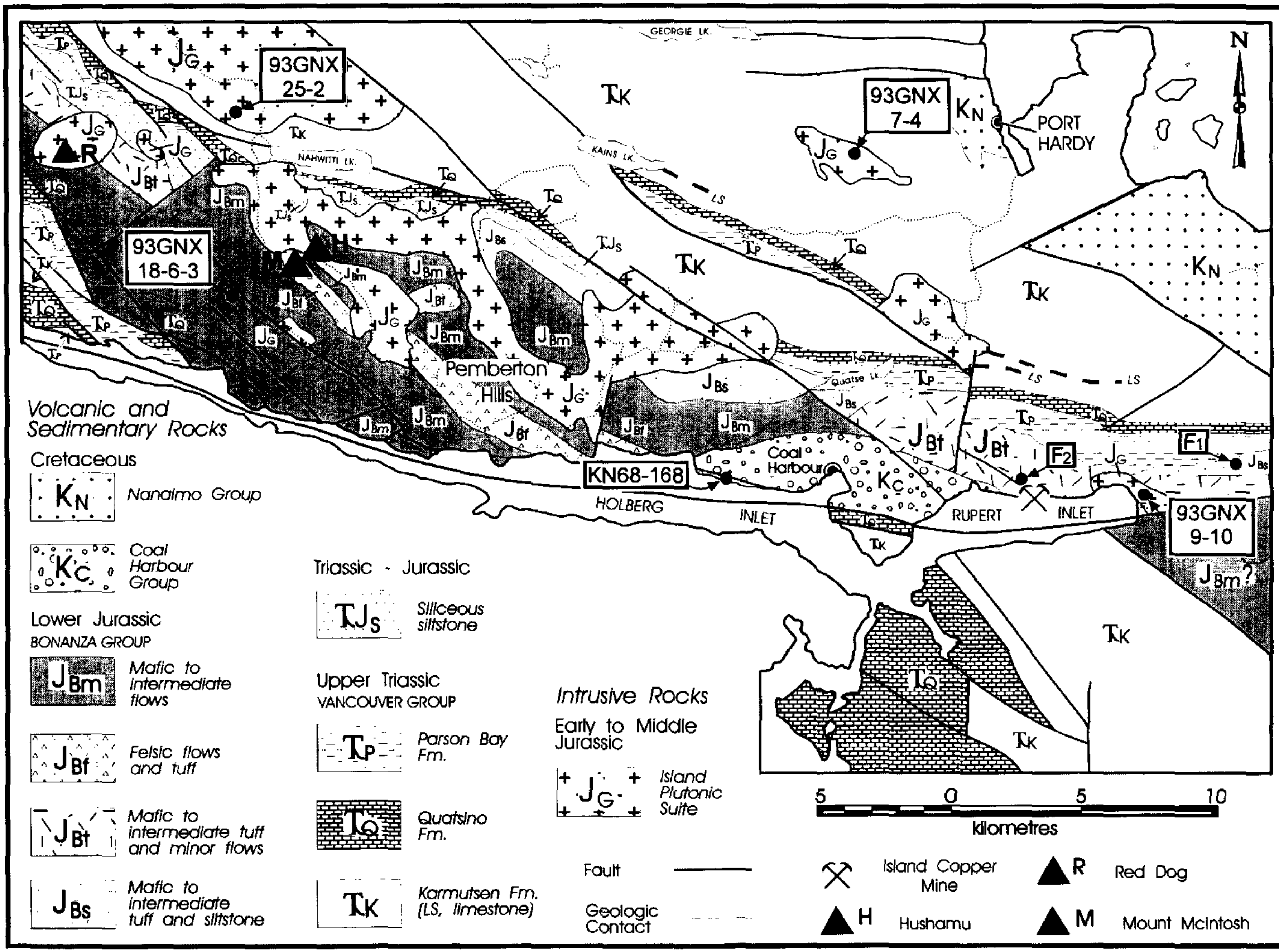

Figure 2: Generalized geology of Quatsino - Port McNeill area showing $^{40}Ar/^{39}Ar$ sample sites and other conventional K-Ar (KN68-168) and fossil (F_1, F_2) localities discussed in the text.

felsic arc volcanic and sedimentary rocks of the Bonanza Group. These older strata are unconformably overlain by an uppermost Jurassic(?) to Cretaceous marine and nonmarine succession of fine to coarse arc-derived clastic rocks. Intrusive rocks comprise stocks and batholiths of the Island Plutonic Suite and their associated porphyritic phases, and mafic to felsic dikes and sills of Karmutsen, Bonanza and Tertiary age. The geologic elements of Vancouver Island form the southern tip of the Wrangellia tectonostratigraphic terrane which extends northwards through the Queen Charlottes into southeastern Alaska.

SAMPLE DESCRIPTIONS

Granitoids of the Island Plutonic Suite are the focus of this dating study. Descriptions of these intrusions are provided by Carson (1973), Muller *et al.* (1974), Cargill *et al.* (1976), and Nixon *et al.* (1994). The rocks are generally medium-grained, equigranular hornblende-bearing diorite and quartz diorite, monzodiorite to quartz monzodiorite and granodiorite (nomenclature after Le Maitre, 1989). Propylitic and argillic alteration assemblages and skarn mineralization are locally well developed. Important porphyry copper-gold mineralization occurs at the Island Copper mine on Rupert Inlet and at Red Dog and Hushamu farther west (Figure 2).

Sample 93GNX25-2 comes from the southern margin of the Nahwitti batholith. This body is exposed north of Nahwitti Lake and extends to the north coast of the Island (Figure 2). It is a coarse to medium-grained (2-6 mm) equigranular hornblende-biotite quartz diorite to quartz monzodiorite containing 5% or more modal quartz and about 10 to 20% hornblende. A marginal zone up to a kilometre wide contains subequal proportions of biotite and hornblende and sparse xenoliths of feldspathic amphibolite. The plagioclase in this sample is moderately saussuritized; hornblende is weakly chloritized, unzoned and free of inclusions; and biotite is typically well chloritized with oxides accompanying chlorite along cleavages.

The Glenlion stock is exposed in roadcuts along the Holberg - Port Hardy road and in the headwaters of Glenlion Creek. It is a medium to coarse-grained, equigranular to weakly porphyritic (<7 mm) hornblende diorite with intrusion breccias (agmatites) containing xenoliths of variably pyritized and silicified Karmutsen lavas at its margins. Rare centimetre-scale modal layering of hornblende and feldspar is developed locally within the stock in zones up to several metres wide. Sample 93GNX7-4 has weakly sericitized feldspars, fresh poikilitic hornblende that includes all the other minerals, .and somewhat chloritized biotite.

The Rupert stock is a medium to coarse-grained, equigranular to porphyritic granodiorite containing up to 30% modal quartz, 60% feldspar, about 10% chloritized biotite and trace amounts of hornblende. Outcrops in the eastern part of the intrusion locally exhibit intense argillic alteration. The westnorthwest-trending quartz-feldspar porphyry dike (100-150 m wide) that hosts porphyry copper-gold mineralization at Island Copper is considered to be an offshoot of the Rupert stock. Coarsely porphyritic dikes of quartz (<1.5 cm) and plagioclase (<1 cm), rarely accompanied by hornblende (<1.5 cm) with hiatal to seriate textures are also found southwest of Quatse Lake and on Rupert Main logging road southeast of Rupert stock. Sample 93GNX9-10 contains severely altered feldspars, biotite is extensively chloritized (> 50 vol. %) and minor hornblende is altered to chlorite and carbonate.

Hornblende-bearing porphyritic dikes and sills, apophyses of Island Plutonic Suite granitoids, are widespread in the Bonanza Group and Upper Triassic sedimentary succession. Sample 93GNX18-6-[illegible] was collected from a coarsely porphyritic dike-sill complex containing large (≤2 cm) euhedral hornblende crystals set in a fine-grained quartzofeldspathic groundmass. Except for a weakly chloritized rim, the amphibole crystals are unaltered, and unzoned and free of inclusions. Soft-sediment deformation structures and, locally, a flow breccia occur at the margin of this dike-sill complex, which intrudes thinly bedded intra-Bonanza sedimentary rocks.

$^{40}Ar/^{39}Ar$ ANALYTICAL METHODS

Mineral separates were prepared using a Frantz magnetic separator, heavy organic liquids and, where appropriate, hand-picking. Samples and 15 flux monitors (standards) were irradiated with fast neutrons in position 5C of the McMaster nuclear reactor (Hamilton, Ontario) for 29 hours. The monitors were distributed throughout the irradiation container, and J-values for individual samples were determined by interpolation.

Step-heating experiments and analysis of the monitors were done in a high-purity silica tube, heated using a Lindberg tube furnace. The bakeable, ultra-high vacuum, stainless-steel argon extraction system is operated on-line to a substantially modified, A.E.I MS-10 mass-spectrometer run in the static mode. Measured mass-spectrometric ratios were extrapolated to zero time, corrected to an $^{40}Ar/^{36}Ar$ atmospheric ratio of 295.5, and corrected for neutron induced ^{40}Ar from potassium, and ^{39}Ar and ^{36}Ar from calcium. Dates and errors were calculated using formulae given by Dalrymple *et al.* (1981), and the decay constants recommended by Steiger and Jäger (1977). Inverse isochrons were calculated using the procedures of Hall (1981). The errors given in Table 1 were used to plot the age spectra shown in Figures 3 and 4. Errors represent analytical precision at the 2σ level of confidence, assuming no error in the J-value.

RESULTS

Analytical data for seven mineral separates including three hornblendes, three biotites and a plagioclase, are listed in Table 1 and shown as age spectra in Figures 3 and 4. Inverse isochrons for selected experiments are also

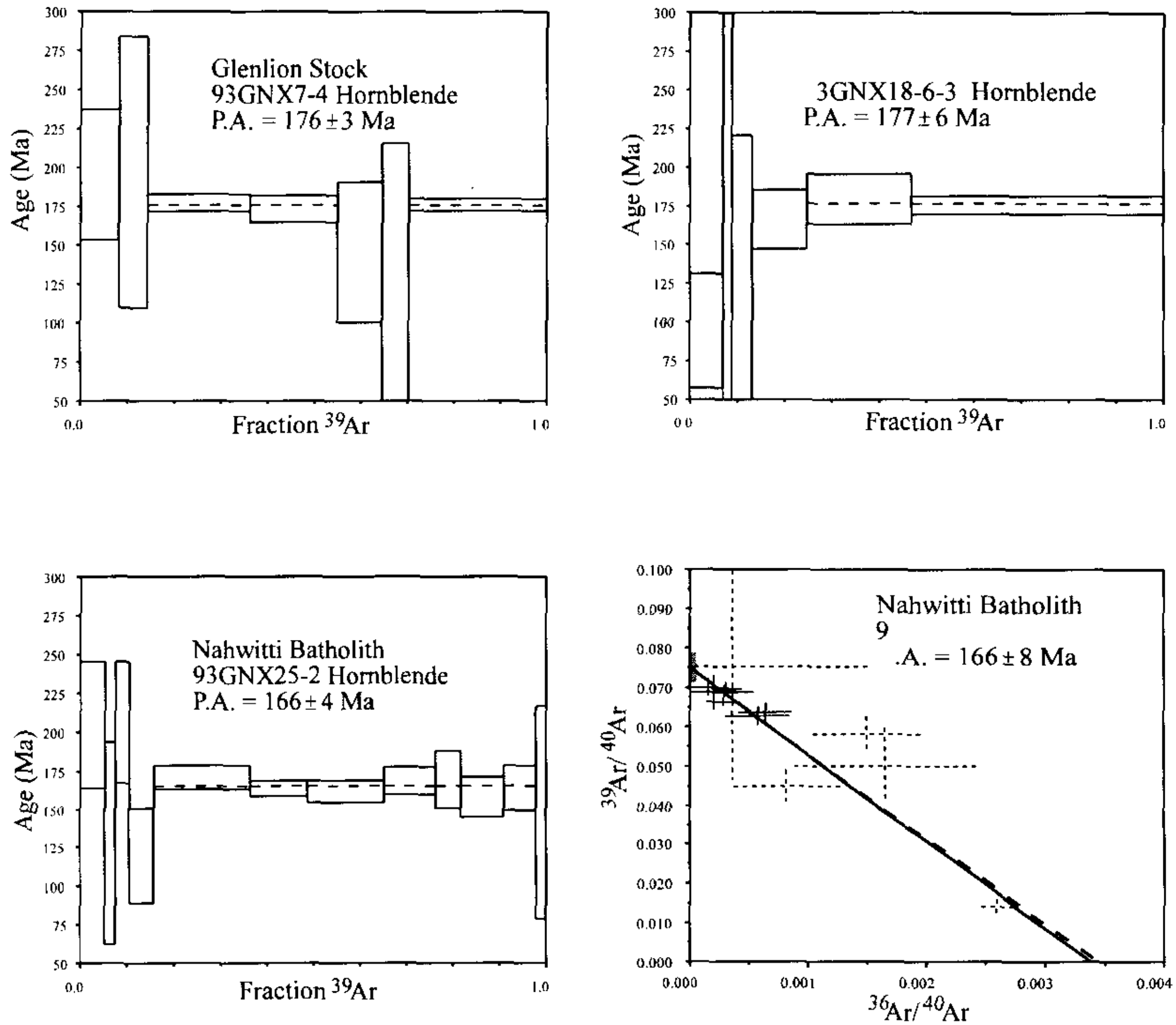

Figure 3: $^{40}Ar/^{39}Ar$ results of step heating experiments for hornblende. The horizontal, dashed line on the age spectra is the plateau segment date (see Table 1) and indicates which steps were included in the age calculation. The heavy dashed line on the $^{40}Ar/^{39}Ar$ inverse isochron plot for 93GNX25-2 hornblende is the best-fit line through the solid crosses; the size of the crosses is an indication of the 2σ error associated with the ratios for each step. Crosses with dotted lines were not included in the age calculation. The solid line connects the best-fit, inverse $^{40}Ar/^{39}Ar$ ratio to the inverse atmospheric $^{40}Ar/^{36}Ar$ ratio. The near-correspondence of the two lines indicates that this hornblende does not contain excess argon. All quoted errors are at the 2σ level of confidence.

plotted. All data are shown with 2σ error bars. Table 1 also contains the ratios used to calculate $^{40}Ar/^{39}Ar$ inverse isochron (correlation) ages.

HORNBLENDE

The three hornblende separates yield well defined plateaus or plateau segments for more than 70% of the ^{39}Ar released, in spite of their low estimated potassium abundances (<0.4% K).

Hornblende from the Glenlion stock (93GNX7-4) has an integrated date of 170±11(2σ) Ma. The three largest steps, accounting for 70% of the ^{39}Ar released, yield a plateau date of 176±3(2σ) Ma. An inverse isochron for this sample yields an identical date and reveals no anomalous initial argon. The best estimate of the cooling age for hornblende in this rock is considered to be the plateau date of 176±3(2σ) Ma.

Hornblende from the southern part of the Nahwitti batholith (93GNX25-2) has an integrated date of 165±5 Ma and a well defined, seven-step plateau for 82% of the ^{39}Ar released. The plateau date (166±4 Ma) and the inverse isochron date (166±8 Ma) agree and there is no indication of excess argon despite the low estimated potassium content (*ca.* 0.2% K). The plateau date is

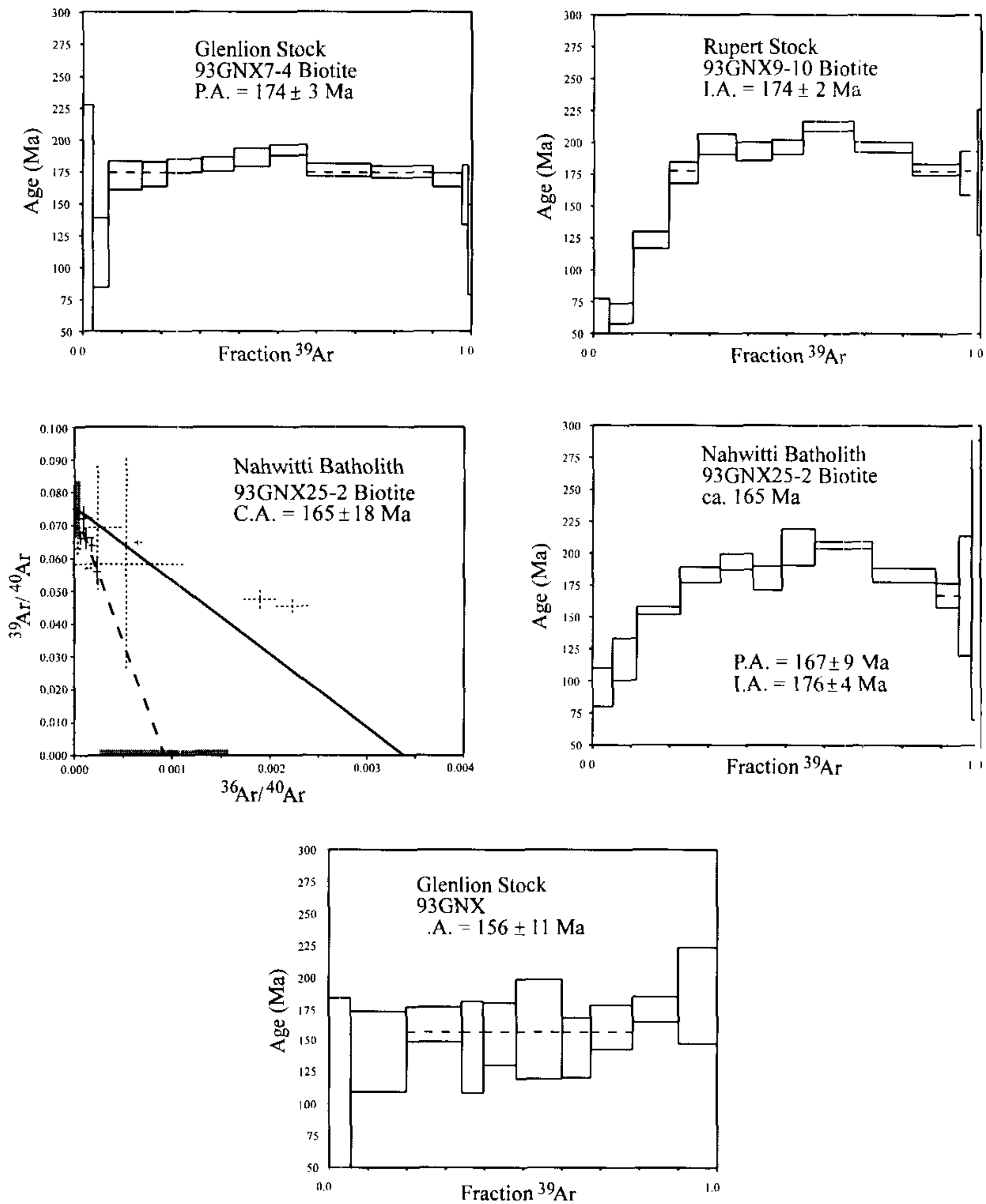

Figure 4: $^{40}Ar/^{39}Ar$ results of step heating experiments for biotite and plagioclase. The $^{40}Ar/^{39}Ar$ inverse isochron for 93GNX25-2 biotite indicates that this sample contains excess argon with an initial $^{40}Ar/^{36}Ar$ ratio much greater than atmospheric argon. Quoted errors are at the 2σ level of confidence.

TABLE 1 - ANALYTICAL DATA FOR HORNBLENDE, BIOTITE AND PLAGIOCLASE MINERAL SEPARATES.

93GNX18-6-3 Hornblende 60/80

J Value: 0.007165 ± 0.000044 Volume ^{39}Ar: 18.98 x 10^{-9} cm^3 NTP Mass: 203.0 mg Approximately 0.18% K; 3.85% Ca

Integrated Age: 166.6 ± 12.6 Ma Initial $^{40}Ar/^{36}Ar$: 301.4 ± 176.9 (MSWD = 1.16, isochron between -0.41 and 3.83)

Correlation Age: 175.5 ± 6.8 Ma (86.8% of ^{39}Ar, steps marked by >) Plateau Age: 177.0 ± 6.4 Ma (75.2% of ^{39}Ar, steps marked by <)

	Volumes						Correlation Ratios							
Temp (°C)	^{40}Ar	^{39}Ar	^{38}Ar	^{37}Ar	^{36}Ar	Blank ^{40}Ar	$^{36}Ar/^{40}Ar$	$^{39}Ar/^{40}Ar$	r	Ca/K	% ^{40}Ar*	% ^{39}Ar	^{40}Ar*/^{39}K	Age ± 2σ
800	25.364 ± 0.852	1.335 ± 0.013	0.047 ± 0.389	20.623 ± 0.299	0.057 ± 0.013	4.317 ± 0.863	0.00178785 ± 0.00063146	0.062929 ± 0.003687	0.007	28.26	32.97	7.04	7.496 ± 3.001	94.4 ± 36.8
875	41.685 12.225	0.353 0.042	0.104 0.139	7.371 2.261	0.130 0.036	4.545 0.909	0.00302950 0.00000000	0.009382 0.000000	0.675	38.19	8.01	1.86	11.168 46.388	138.9 555.2
950	24.038 3.331	0.815 0.038	0.251 0.056	8.404 0.906	0.059 0.022	4.934 0.987	0.00212325 0.00000000	0.042444 0.000000	0.266	18.86	26.95	4.29	8.778 9.125	110.0 110.9
1000>	40.963 2.004	2.196 0.037	0.847 0.047	23.518 0.704	0.045 0.010	5.339 1.068	0.00058323 0.00014566	0.061322 0.002026	-0.035	19.60	67.54	11.57	13.497 1.637	166.5 19.3
<1050>	75.232 4.792	4.191 0.044	1.660 0.059	44.977 0.496	0.060 0.011	5.920 1.184	0.00041103 0.00000000	0.060149 0.000000	0.091	19.64	76.31	22.08	14.606 1.397	179.6 16.4
<1200>	154.902 2.355	10.092 0.053	4.562 0.051	112.285 0.594	0.067 0.015	9.653 1.931	0.00003911 0.00000003	0.069111 0.000000	-0.245	20.36	87.06	53.16	14.302 0.496	176.0 5.8

93GNX7-4 Hornblende 60/80

J Value: 0.007191 ± 0.000036 Volume ^{39}Ar: 33.27 x 10^{-9} cm^3 NTP Mass: 201.0 mg Approximately 0.32%K; 4.92% Ca

Integrated Age: 170.1 ± 11.5 Ma Initial $^{40}Ar/^{36}Ar$: 317.6. ± 321.6 (MSWD = 0.25, isochron between 0.18 and 2.63)

Correlation Age: 175.3 ± 16.2 Ma (84.7% of ^{39}Ar, steps marked by >) Plateau Age: 176.0 ± 3.4 Ma (70.5% of ^{39}Ar, steps marked by <)

	Volumes						Correlation Ratios							
Temp (°C)	^{40}Ar	^{39}Ar	^{38}Ar	^{37}Ar	^{36}Ar	Blank ^{40}Ar	$^{36}Ar/^{40}Ar$	$^{39}Ar/^{40}Ar$	r	Ca/K	% ^{40}Ar*	% ^{39}Ar	^{40}Ar*/^{39}K	Age ± 2σ
800>	85.963 ± 7.551	2.741 ± 0.218	1.160 ± 0.117	5.455 ± 0.635	0.145 ± 0.018	4.317 ± 0.863	0.00157919 ± 0.00026307	0.033565 ± 0.004115	0.414	3.64	50.13	8.24	15.890 ± 3.591	195.2 ± 41.8
875>	52.569 11.772	1.987 0.441	1.461 0.329	7.054 1.640	0.072 0.019	4.545 0.909	0.00114291 0.00000000	0.041323 0.000000	0.419	6.50	59.42	5.97	16.027 7.494	196.8 87.2
<950>	124.463 1.405	7.317 0.081	12.006 0.135	50.472 0.603	0.079 0.010	4.934 0.987	0.00041273 0.00000000	0.061048 0.000000	-0.094	12.62	81.13	21.99	14.383 0.469	177.6 5.5
<1000>	102.894 0.740	6.238 0.044	13.157 0.094	53.161 0.407	0.066 0.015	5.339 1.068	0.00035559 0.00007892	0.063702 0.000481	-0.144	15.60	80.81	18.75	14.049 0.733	173.6 8.6
1030	53.070 10.445	3.225 0.412	5.967 0.762	30.468 5.740	0.060 0.013	5.662 1.132	0.00070343 0.00000000	0.067736 0.000000	0.399	17.29	66.31	9.69	11.695 3.782	145.7 45.3
1060	23.668 19.583	1.873 0.587	2.782 0.872	12.869 7.333	0.048 0.030	6.063 1.213	0.00140162 0.00000058	0.106221 0.000031	0.646	12.58	39.36	5.63	5.515 11.651	70.2 45.4
<1200>	158.254 0.670	9.887 0.041	19.420 0.083	116.230 0.725	0.090 0.011	9.653 1.931	0.00018717 0.00000000	0.066152 0.000000	-0.451	21.51	83.02	29.72	14.281 0.333	176.4 3.9

93GNX7-4 Plagioclase 40/60

J Value: 0.007179± 0.000040 Volume ^{39}Ar: 32.41 x 10^{-9} cm^3 NTP Mass: 203.0 mg Approximately 0.31% K; 2.55% Ca

Integrated Age: 156.4 ± 10.1 Ma Initial $^{40}Ar/^{36}Ar$: 578.7 ± 544.2 (MSWD = 0.70, isochron between 0.29 and 2.41)

Correlation Age: 140.8 ± 36.5 Ma (67.1% of ^{39}Ar, steps marked by >) Plateau Age: 156.5 ± 11.1 Ma (58.3% of ^{39}Ar, steps marked by <)

	Volumes						Correlation Ratios							
Temp (°C)	^{40}Ar	^{39}Ar	^{38}Ar	^{37}Ar	^{36}Ar	Blank ^{40}Ar	$^{36}Ar/^{40}Ar$	$^{39}Ar/^{40}Ar$	r	Ca/K	% ^{40}Ar*	% ^{39}Ar	^{40}Ar*/^{39}K	Age ± 2σ
500	58.441 ± 9.993	1.807 ± 0.157	0.540 ± 0.095	4.431 ± 1.236	0.150 ± 0.025	4.037 ± 0.807	0.00249638 ± 0.00064624	0.033191 ± 0.006769	0.639	4.49	23.83	5.58	7.903 ± 6.896	99.6 ± 84.5
600	94.933 9.741	4.649 0.469	0.812 0.140	27.287 2.897	0.149 0.019	4.075 0.815	0.00141703 0.00000000	0.051048 0.000000	0.419	10.74	53.39	14.35	11.387 2.696	141.8 32.3
<700>	71.482 3.411	4.638 0.216	0.170 0.727	28.288 1.410	0.043 0.012	4.154 0.831	0.00031882 0.00000000	0.068747 0.000000	0.028	11.16	82.18	14.31	13.176 1.219	163.1 14.4
<750	32.826 3.494	1.808 0.177	0.066 0.569	9.236 1.008	0.042 0.013	4.221 0.844	0.00089159 0.00023017	0.063126 0.005040	0.152	9.35	61.95	5.58	11.668 3.056	145.1 36.5
<800>	48.879 3.282	2.727 0.181	0.079 0.744	10.690 0.750	0.053 0.014	4.317 0.863	0.00079729 0.00000000	0.061147 0.000000	0.100	7.17	67.92	8.42	12.501 2.144	155.1 25.5
<875>	48.879 3.282	2.727 0.181	0.079 0.744	10.690 0.750	0.053 0.014	4.317 0.863	0.00047717 0.00000007	0.067003 0.000004	0.203	5.29	78.08	11.83	12.820 3.340	158.8 39.6
<950	42.237 2.306	2.404 0.125	0.395 0.094	6.461 0.349	0.050 0.014	4.934 0.987	0.00085112 0.00000000	0.064456 0.000000	0.046	4.92	64.83	7.42	11.613 2.046	140.5 24.5
<1025>	57.689 3.946	3.490 0.198	0.457 0.156	9.339 0.556	0.044 0.009	5.604 1.121	0.00044257 0.00000000	0.067009 0.000000	0.067	4.90	77.11	10.77	12.972 1.540	160.6 18.3
1100>	72.104 1.230	3.825 0.059	0.509 0.173	12.320 0.206	0.063 0.010	6.752 1.350	0.00056954 0.00000000	0.058505 0.000000	-0.195	5.89	73.97	11.80	14.216 0.851	175.3 10.0
1200>	68.046 7.762	3.224 0.357	0.969 0.132	25.130 2.949	0.073 0.016	9.653 1.931	0.00058054 0.00183206	0.055020 0.060106	0.138	14.26	68.21	9.95	15.057 3.286	185.2 38.4

All volumes are x 10^{-9} cm^3 NTP. All errors are 2 x standard error.

93GNX7-4 Biotite 40/60

J Value: 0.007198 ± 0.000032 Volume ^{39}Ar: 105.13 x 10^{-9} cm^3 NTP Mass: 123.0 mg Approximately 1.67% K; 2.96% Ca

Integrated Age: 172.6 ± 3.9 Ma Initial $^{40}Ar/^{36}Ar$: 412.8 ± 223.9 (MSWD = 1.48, isochron between 0.37 and 2.26)

Correlation Age: 172.7 ± 9.3 Ma (73.7% of ^{39}Ar, steps marked by >) Plateau Age: 174.3 ± 3.4 Ma (47.5% of ^{39}Ar, steps marked by <)

	Volumes						Correlation Ratios							
Temp (°C)	^{40}Ar	^{39}Ar	^{38}Ar	^{37}Ar	^{36}Ar	Blank ^{40}Ar	$^{36}Ar/^{40}Ar$	$^{39}Ar/^{40}Ar$	r	Ca/K	% ^{40}Ar*	% ^{39}Ar	^{40}Ar*/^{39}K	Age ± 2σ
500	83.769 ± 17 288	2 727 ± 0 482	0 859 ± 0.166	2 570 ± 0.519	0.205 ± 0 067	4.037 ± 0.807	0.00239434 ± 0 00098992	0.034215 ± 0 009589	0 406	1.72	27.58	2.59	8 548 ± 9 772	107.7 ± 119 5
575	106.521 1.898	4 192 0.073	1.011 0.095	1.722 0.792	0.235 0 031	4.063 0.813	0.00215746 0 00000000	0 040947 0 000000	0.083	0.75	34.70	3 99	8.852 2 209	111.4 27 0
<650>	142 524 1.451	8 961 0.081	2 060 0 099	2.208 0.647	0 061 0.028	4.108 0.822	0 00033608 0 00000000	0 064850 0 000000	-0 023	0.45	87 19	8 52	13.889 0 939	171.9 11 1
<700>	109 969 1.496	6 677 0.063	1 493 0.186	0 878 0.261	0 056 0 017	4.154 0.831	0 00039347 0 00008368	0 063206 0 000593	-0 034	0.24	84.82	6 35	13.982 0 817	173.0 9 6
750>	150 154 0.558	9 455 0.034	2 202 0.124	1.567 0.128	0 043 0 015	4.221 0.844	0 00019274 0.00000000	0 064902 0 000000	-0 131	0.30	91.40	8 99	14.530 0.463	179.5 5.4
800>	144 400 1.720	8 513 0.084	1.978 0.103	1.523 0 330	0.067 0.012	4.317 0.863	0 00037035 0.00000002	0 060869 0 000000	-0 040	0.33	86.16	8 10	14.631 0 484	180 6 5 7
850>	156 529 1 094	9 591 0 066	2 398 0 123	2.838 0 180	0 040 0 019	4.455 0.891	0 00015854 0.00000000	0 063167 0 000000	-0 069	0.54	92.30	9 12	15.089 0 620	186.0 7.3
900	169.982 1 037	10 112 0 048	2 771 0.089	2.805 0 249	0 042 0 012	4 652 0 930	0.00015317 0.00000000	0 061256 0 000000	-0 138	0 51	92.57	9 62	15.586 0 361	191.8 4.2
<950>	272 578 0 687	17 512 0 066	7 653 0 031	18 192 0 288	0 083 0 025	4 934 0 987	0 00022912 0.00000000	0.065509 0 000000	-0 076	1 90	90.87	16 66	14.232 0 422	175.9 5.0
<1000>	251 666 0 684	16 750 0 078	13 417 0.051	39.651 0 983	0 062 0 021	5 339 1 068	0 00013588 0.00144843	0.068028 0 007942	-0 100	4 33	92.58	15 93	14.110 0 378	174.5 4.5
1050	120 731 2 356	7 994 0.121	4 298 0 090	15 171 0 467	0 045 0 008	5 920 1 184	0 00018044 0 00056195	0 069681 0.014689	-0 131	3 47	88 90	7 60	13.586 0 456	168 3 5 4
1100	30 554 0 028	1.708 0 160	1.345 0.020	6 356 0.885	0.032 0 009	6 752 1 350	0 00032231 0 00287023	0 071721 0.054759	-0 217	6 81	68.78	1.62	12.615 1 950	156 8 23 2
1200	20 812 1 197	0 938 0 037	0 964 0 051	6 133 0.584	0.043 0.008	9 653 1.931	0 00080802 0 00376582	0 083946 0 076281	-0.381	11 96	38 50	0.89	9 068 2 897	114 1 35.3

93GNX9-10 Biotite 40/60

J Value: 0.007216 ± 0.000026 Volume ^{39}Ar: 135.02 x 10^{-9} cm^3 NTP Mass: 102.0 mg Approximately 2.59% K; 1.12% Ca

Integrated Age: 173.9 ± 2.2 Ma Initial $^{40}Ar/^{36}Ar$: 239.5 ± 722.9 (MSWD = 0.06, isochron between -0.41 and 3.83)

Correlation Age: 179.3 ± 23.1 Ma (24.3% of ^{39}Ar, steps marked by >) Plateau Age: 177.4 ± 4.7 Ma (24.3% of ^{39}Ar, steps marked by <)

	Volumes						Correlation Ratios							
Temp (°C)	^{40}Ar	^{39}Ar	^{38}Ar	^{37}Ar	^{36}Ar	Blank ^{40}Ar	$^{36}Ar/^{40}Ar$	$^{39}Ar/^{40}Ar$	r	Ca/ K	% ^{40}Ar*	% ^{39}Ar	^{40}Ar*/^{39}K	Age ± 2σ
500	112 008 ± 3.630	5 479 ± 0 175	2.243 ± 0.087	1.372 ± 0.638	0.289 ± 0 019	4 037 ± 0.807	0 00254705 ± 0 00019369	0 050812 ± 0 002388	0.312	0 46	23 72	4.06	4 868 ± 1 219	62 3 ± 15 3
575	160 158 3 564	8 313 0 185	2 766 0 095	2.069 0 257	0 397 0 013	4 063 0 813	0 00245656 0 00000000	0 053327 0.000000	0 397	0 46	26.58	6.16	5 140 0 632	65 7 7 9
650	213 459 3 537	12.517 0 206	3 685 0 098	1.131 0 153	0 307 0 018	4 108 0.822	0 00139939 0 00000000	0.059886 0 000000	0 175	0 17	57.38	9 27	9 793 0.531	123 2 6 5
<700>	163 377 3 113	10.075 0 183	3 395 0 104	0.898 0 353	0 068 0 020	4.154 0 831	0 00033792 0 00006272	0.063386 0 000863	0.014	0 16	87.52	7 46	14 201 0.706	176 0 8 3
750	227 869 5 746	13.345 0 332	4 399 0 133	0 827 0 140	0 041 0 016	4 221 0.844	0 00012075 0 00000000	0.059768 0 000000	0 012	0.11	94 46	9 88	16 134 0 693	198 7 8 9
800	206 914 4.996	12.405 0.299	3 693 0 142	0 709 0 301	0 042 0 011	4 317 0 863	0.00013663 0 00000001	0.061337 0 000001	0 012	0.10	93.77	9.19	15 645 0 614	193 0 7.2
850	189 092 3.265	11.036 0 190	3 724 0 095	2 561 0 158	0 044 0 010	4 455 0 891	0 00015499 0 00000000	0 059864 0 000000	-0 019	0 42	92.91	8.17	15.940 0 483	196.4 5.6
900	324 603 4.050	17 887 0 223	6 642 0 108	1 734 0 457	0 047 0 006	4 652 0 930	0 00009530 0 00000000	0.055992 0 000000	-0 033	0.18	95 60	13.25	17.357 0 329	212 9 3.8
950	333 415 4.780	20.054 0 286	6 119 0 122	2 610 0 044	0 045 0 008	4 934 0 987	0 00008530 0 00000000	0 061153 0 000000	-0 022	0 24	95 81	14 85	15 940 0 350	196 4 4 1
<1000>	249 711 4 721	16 565 0 228	4.446 0 112	3 825 0 676	0 035 0 006	5 339 1 068	0 00006702 0 00014064	0 067908 0 007679	-0 053	0.42	95 62	12 27	14 434 0.366	178.8 4 3
<1050>	97 963 2 024	6 116 0 119	1.681 0 112	4 248 0 579	0.039 0.029	5 920 1 184	0 00018928 0 00099360	0 066548 0 006717	-0 043	1.27	88 21	4 53	14 186 1 459	175 8 17 2
1200	25 344 3 217	1 227 0 110	0.922 0.095	10 081 1.275	0.029 0.012	9 653 1 931	-0 00037931 0.00408134	0 077942 0 088540	-0 310	15 04	65 71	0.91	14.268 4 199	176 8 49 6

All volumes are x 10^{-9} cm^3 NTP. All errors are 2 x standard error.

93GNX25-2 Hornblende 40/60

J Value: 0.007206 ± 0.000012 — Volume ^{39}Ar: 35.47 x 10^{-9} cm^3 NTP — Mass: 296.0 mg — Approximately 0.23% K; 3.91% Ca

Integrated Age: 165.4 ± 4.7 Ma — Initial $^{40}Ar/^{36}Ar$: 286.3 ± 151.7 (MSWD = 1.08, isochron between 0.37 and 2.26)

Correlation Age: 165.6 ± 8.1 Ma (82.2% of ^{39}Ar, steps marked by >) — Plateau Age: 165.6 ± 3.6 Ma (82.2% of ^{39}Ar, steps marked by <)

	Volumes						Correlation Ratios							
Temp (°C)	^{40}Ar	^{39}Ar	^{38}Ar	^{37}Ar	^{36}Ar	Blank ^{40}Ar	$^{36}Ar/^{40}Ar$	$^{39}Ar/^{40}Ar$	r	Ca/K	% $^{40}Ar^*$	% ^{39}Ar	$^{40}Ar^*/^{39}K$	Age ± 2σ
700	136.964 ± 4.374	1.865 ± 0.055	0.693 ± 0.084	2.395 ± 0.089	0.359 ± 0.016	4.154 ± 0.831	0.00259184 ± 0.00014786	0.014035 ± 0.000625	0.423	2.35	22.56	5.26	16.680 ± 3.499	204.8 ± 40.6
800	20.657 2.776	0.820 0.054	0.274 0.112	2.320 0.518	0.042 0.012	4.317 0.863	0.00165362 0.00000000	0.050163 0.000000	0.294	5.18	39.55	2.31	10.194 5.424	127.9 65.7
875	27.661 1.447	1.047 0.054	0.963 0.059	7.705 0.512	0.036 0.010	4.545 0.909	0.00081600 0.00000000	0.045116 0.000000	-0.019	13.47	61.25	2.95	16.820 3.346	206.4 38.8
975	35.963 2.055	1.824 0.047	2.888 0.080	16.066 0.714	0.067 0.014	4.781 0.956	0.00149954 0.00022899	0.058242 0.002250	0.134	16.12	44.85	5.14	9.562 2.532	120.2 30.8
<976>	114.591 1.144	7.300 0.069	13.629 0.133	70.019 0.713	0.066 0.015	5.119 1.024	0.00028507 0.00000000	0.066394 0.000000	-0.100	17.55	82.73	20.58	13.793 0.650	170.9 7.7
<1000>	68.459 0.659	4.385 0.040	8.234 0.083	41.835 0.387	0.047 0.005	5.339 1.068	0.00029529 0.00000003	0.069170 0.000000	-0.388	17.46	79.40	12.36	13.196 0.414	163.9 4.9
<1020>	89.152 1.316	5.855 0.086	10.843 0.164	56.907 0.905	0.059 0.010	5.547 1.109	0.00030992 0.00000000	0.069730 0.000000	-0.141	17.79	80.23	16.51	13.028 0.602	161.9 7.1
<1040>	61.499 1.082	3.918 0.067	7.081 0.124	38.568 0.670	0.038 0.009	5.786 1.157	0.00016125 0.00000000	0.070007 0.000000	-0.238	18.02	81.39	11.04	13.604 0.747	168.7 8.9
<1060>	34.472 1.272	1.965 0.040	3.550 0.075	18.774 0.616	0.031 0.009	6.063 1.213	0.00020016 0.00000000	0.068862 0.000000	-0.239	17.49	73.30	5.54	13.663 1.546	169.4 18.3
<1080>	57.504 1.327	3.272 0.051	6.438 0.103	33.297 0.754	0.063 0.011	6.383 1.277	0.00064308 0.00090425	0.063707 0.010044	-0.144	18.62	67.53	9.23	12.714 1.095	158.2 13.0
<1120>	46.274 0.347	2.468 0.018	5.632 0.046	28.385 0.220	0.054 0.010	7.178 1.436	0.00057973 0.00079419	0.062769 0.007008	-0.354	21.05	65.28	6.96	13.202 1.210	163.9 14.4
1200	19.607 3.148	0.752 0.055	1.562 0.119	7.010 1.194	0.038 0.010	9.653 1.931	0.00036365 0.00292756	0.075274 0.073336	-0.180	17.05	42.53	2.12	11.857 5.742	147.9 68.8

93GNX25-2 Biotite 40/60

J Value: 0.007214 ± 0.000028 — Volume ^{39}Ar: 125.77 x 10^{-9} cm^3 NTP — Mass: 93.0 mg — Approximately 2.64% K; 2.25% Ca

Integrated Age: 175.9 ± 3.8 Ma — Initial $^{40}Ar/^{36}Ar$: 1083.2 ± 775.0 (MSWD = 2.84, isochron between 0.18 and 2.63)

Correlation Age: 164.6 ± 18.2 Ma (48.6% of ^{39}Ar, steps marked by >) — Plateau Age: 167.4 ± 9.4 Ma (5.9% of ^{39}Ar, steps marked by <)

	Volumes						Correlation Ratios							
Temp (°C)	^{40}Ar	^{39}Ar	^{38}Ar	^{37}Ar	^{36}Ar	Blank ^{40}Ar	$^{36}Ar/^{40}Ar$	$^{39}Ar/^{40}Ar$	r	Ca/K	% $^{40}Ar^*$	% ^{39}Ar	$^{40}Ar^*/^{39}K$	Age ± 2σ
500	149.241 ± 4.588	6.596 ± 0.197	2.444 ± 0.113	5.541 ± 0.711	0.338 ± 0.022	4.037 ± 0.807	0.00222962 ± 0.00016534	0.045461 ± 0.001997	0.303	1.54	32.87	5.24	7.504 ± 1.217	95.1 ± 15.0
575	167.900 7.075	7.778 0.327	2.333 0.127	4.051 0.286	0.325 0.024	4.063 0.813	0.00189311 0.00000000	0.047523 0.000000	0.349	0.95	42.75	6.18	9.271 1.337	116.8 16.3
650	222.830 1.876	14.168 0.119	3.832 0.092	3.380 0.600	0.157 0.009	4.108 0.822	0.00065139 0.00000000	0.064886 0.000000	0.018	0.44	79.00	11.27	12.445 0.248	155.1 3.0
700>	210.259 5.420	13.155 0.217	3.907 0.103	2.092 0.392	0.052 0.007	4.154 0.831	0.00018128 0.00001847	0.063939 0.001003	0.064	0.29	92.53	10.46	14.802 0.505	183.0 5.9
750	171.871 4.083	10.550 0.250	3.049 0.131	0.967 0.235	0.021 0.004	4.221 0.844	0.00003988 0.00000000	0.063040 0.000000	-0.058	0.17	96.18	8.39	15.676 0.551	193.3 6.4
800>	144.689 5.075	9.267 0.295	2.602 0.122	1.598 0.449	0.032 0.011	4.317 0.863	0.00012012 0.00000002	0.066133 0.000001	0.009	0.32	93.31	7.37	14.584 0.799	180.5 9.4
850>	198.453 9.887	10.822 0.523	3.556 0.224	2.015 0.327	0.061 0.007	4.455 0.891	0.00023391 0.00000000	0.055866 0.000000	0.194	0.34	90.78	8.60	16.663 1.233	204.8 14.3
900	331.247 1.289	18.563 0.065	5.978 0.082	4.311 0.040	0.063 0.014	4.652 0.930	0.00014223 0.00000000	0.056924 0.000000	-0.092	0.42	94.20	14.76	16.829 0.240	206.7 2.8
950>	314.897 6.380	20.508 0.415	6.339 0.145	8.356 0.438	0.039 0.011	4.934 0.987	0.00006663 0.00000000	0.066271 0.000000	-0.005	0.75	96.11	16.31	14.792 0.462	182.9 5.4
<1000>	108.208 4.564	7.412 0.195	2.828 0.095	8.470 0.529	0.030 0.009	5.339 1.068	0.00009316 0.00048652	0.072148 0.020597	-0.036	2.09	91.67	5.89	13.479 0.788	167.4 9.3
1050	65.670 12.061	4.136 0.757	1.215 0.252	5.219 0.969	0.036 0.014	5.920 1.184	0.00023748 0.00143019	0.069299 0.111876	0.128	2.31	83.84	3.29	13.418 3.942	166.7 46.8
1200	57.891 20.397	2.813 0.984	1.007 0.373	12.596 4.426	0.061 0.026	9.653 1.931	0.00052469 0.00128759	0.058253 0.069721	0.274	8.19	68.65	2.24	14.505 9.289	179.5 109.5

All volumes are x 10^{-9} cm^3 NTP. All errors are 2 x standard error.

considered the best estimate of the time of cooling of the southern part of this batholith.

Hornblende from a hornblende-phyric dike (93GNX18-6-3) intruding the Bonanza Group has an integrated date of 167±13 Ma . However, the two highest temperature steps yield a plateau date of 177±6 Ma. The data yield an inverse isochron age of 176±6 Ma and suggest that this low-potassium amphibole contains initial argon with a non-atmospheric ratio. The plateau date of 177±6 Ma is considered the best estimate of the age of this dike.

BIOTITE

The three biotite separates contain appreciable intergrown chlorite which is believed to be responsible for their anomalously low estimated potassium contents (<3% K). The heating experiments yield distinctively hump-shaped age spectra. Following Ruffet *et al.* (1991), only the "shoulders" of the hump were used to calculate the plateau segment date which is taken as a maximum estimate of the cooling age for biotite in these rocks.

Biotite from the Glenlion stock (93GNX7-4) has an integrated date of 173±4 Ma. The plateau date and the inverse isochron date agree within analytical uncertainty at 174±3 Ma and 173±9 Ma, respectively. The 174±3 Ma plateau date for 48% of the ^{39}Ar released is believed to be the best estimate of the cooling age for this biotite.

Biotite from the Rupert stock (93GNX9-10) yields an integrated date of 174±2 Ma. This spectrum has the most pronounced hump-shape and only 24% of the ^{39}Ar released defines the shoulders of the hump. The three steps involved define a plateau date of 177±5 Ma. A poor inverse isochron date of 179±27 Ma is in agreement with the plateau date which is considered to be a maximum cooling age for biotite in this pluton.

Biotite from the southern margin of the Nahwitti batholith (93GNX25-2) yields an integrated date of 176±4 Ma. This date is 10 Ma older than the hornblende date for the same rock. The spectrum has an extreme hump-shape and only one step defines a plateau segment date of *circa* 167 Ma. The fact that biotite and hornblende in this rock show a reversal of the age discordance normally observed suggests that the biotite contains excess argon. An inverse isochron (Figure 4) for the biotite supports this conclusion and reveals two-components of initial argon. Most of the steps with dates greater than the hornblende date plot on a line with an initial $^{40}Ar/^{36}Ar$ ratio of 1099 and yield a date of 165±18 Ma. This date is analytically indistinguishable from the hornblende date of 166±4 Ma and is the preferred biotite cooling age for this part of the batholith.

PLAGIOCLASE

Plagioclase from the Glenlion stock (93GNX7-4) has an integrated date of 156±10 Ma and a plateau date of 156±11 Ma for 73% of the ^{39}Ar released. An inverse isochron (not shown) for this experiment reveals two components of initial argon and yields a poorly constrained date of 141±38 Ma. The best cooling age for this sample is regarded as the plateau date of 156±11 Ma.

SUMMARY OF RESULTS AND DISCUSSION

The $^{40}Ar/^{39}Ar$ results presented here give some insight into the thermal history of the region and place certain constraints on the age of intrusion. The hornblende separates typically yield the best plateau dates whereas the biotites give more complex argon-release spectra.

The dates for hornblende (176±3 Ma) and biotite (174±3 Ma) in the Glenlion stock are analytically indistinguishable and suggest rapid cooling *circa* 175 Ma from the closure temperature of hornblende (*ca.* 500°C; McDougall and Harrison, 1988) through the closure temperature of biotite (*ca.* 300°C; McDougall and Harrison, 1988). This is consistent with the small apparent size of this body and the relatively shallow level of emplacement. The latter observations also suggest that intrusion occurred *circa* 176 Ma. The significance of the younger plagioclase date (156±11 Ma) is not presently clear. It may indicate an episode of Late Jurassic, low-temperature thermal overprinting that would presumably reflect the zeolite to prehnite-pumpellyite facies regional metamorphism in the area, or slow cooling following emplacement through the imputed closure temperature of plagioclase (*ca.* 225°C; McDougall and Harrison, 1988, page 23).

The hornblende (166±4 Ma) and biotite (165±18 Ma) dates for the southern part of the Nahwitti batholith are concordant, but the imprecision of the biotite date precludes firm conclusions regarding the post-emplacement cooling history of this part of the intrusion. The dates are, however, consistent with the fairly rapid cooling deduced above for the Glenlion stock and neither spectrum shows evidence of later thermal overprinting. Conventional K-Ar dates on hornblende (156±8 Ma) and biotite (166±6 and 171±6 Ma) were also obtained from samples collected at the southern margin of the Nahwitti batholith (data summarized by Muller *et al.*, 1974. These determinations are comparable to ours.

The age of the Rupert stock is problematic. A previous K-Ar determination yielded an apparent biotite cooling age of 156±6 Ma, significantly younger than our date (Muller *et al.*, 1974). In addition, a Rb-Sr whole-rock isochron date of 180±20 Ma (University of British Columbia Geochronological Database) has been obtained for the quartz feldspar porphyry dike at the Island Copper mine that appears to be a lateral offshoot of the Rupert stock. Although the Rb-Sr isochron date would generally be preferred as the age of emplacement, the analytical uncertainty is considerable. The maximum cooling age of biotite (174±2 Ma), as estimated from an extremely hump-shaped age spectrum, could conceivably be of the order of 10 Ma greater than the hornblende cooling age for this rock if the $^{40}Ar/^{39}Ar$ systematics are similar to those observed for biotite in the Nahwitti batholith. These considerations would loosely constrain the age of intrusion of the Rupert stock to be between about 180 and 160 Ma.

The hornblende date (177±6 Ma) for the porphyritic dike supports the contention that these rocks are higher level equivalents of the Island Plutonic Suite. Because the hornblende porphyry was emplaced as a quickly chilled dike in thinly bedded intervolcanic sandstones prior to their complete lithification, the hornblende date is regarded as a good approximation to the age of emplacement which may well have occurred while younger strata within the Bonanza Group were still being deposited (discussed below).

In summary, in the Quatsino - Port McNeill map area, $^{40}Ar/^{39}Ar$ age spectra of mineral separates from granitoids of the Island Plutonic Suite provide evidence for two distinct ages of emplacement, *circa* 176 and 166 Ma. Biotite and hornblende dates are essentially concordant and this is consistent with rapid cooling over the approximate temperature interval 500°C to 300°C. There is no evidence in the spectra of post-Jurassic thermal overprinting and it appears that chloritization of biotite occurred soon after emplacement. In fact, a significantly younger plagioclase date (*ca.* 156 Ma) in one of the older plutons may represent the close of zeolite to prehnite-pumpellyite grade regional metamorphism. Although not conclusive, it does seem that certain dikes intruding the Bonanza Group are apophyses of some of the plutons.

Finally, it is worth noting that the $^{40}Ar/^{39}Ar$ step-heating experiments demonstrate the existance of excess argon in some samples, implying that previous K-Ar dates must be used with caution. There are several other K-Ar biotite and hornblende dates in the region. Two K-Ar determinations on biotite from Hepler Creek and the northern margin of the Wanokana batholith underlying the central part of the map area between Holberg Inlet and Nahwitti Lake, yield dates of 148±5 and 161±5 Ma, respectively (cf. Muller *et al.*, 1974). In addition, Panteleyev and Koyanagi (1994 and this volume) have reported a new K-Ar date of 168±4 Ma and a $^{40}Ar/^{39}Ar$ date of *circa* 173 Ma for hornblende from the northern margin of this batholith, as well as a $^{40}Ar/^{39}Ar$. date of *circa* 172 Ma for hornblende from the Hushamu area (Figure 2). In light of the preceding interpretations of the $^{40}Ar/^{39}Ar$ age spectra, the hornblende dates might be expected to yield the best approximation to the actual age of intrusion. Thus it would appear that emplacement of the Wanokana batholith occurred between the two ages of intrusion recognized earlier.

HOW YOUNG IS BONANZA VOLCANISM?

We alluded earlier to the fact that Jurassic granitoids seem to be younger than the volcanics based on the disparate ages provided by isotopic dates for the Island Plutonic Suite (*ca.* 184-103 Ma; Toarcian to mid-Cretaceous) on the one hand, and paleontological control in sedimentary rocks of the Bonanza Group (Sinemurian-Pliensbachian; 203-187 Ma) on the other. This discrepancy may be more apparent than real, as discussed below.

Recently, Haggart and Tipper (1994) identified marine fossils from the Bonanza Group that were collected in a quarry east of Rupert Inlet (Figure 2). Outcrop in this area is scarce, but regional mapping reported by Nixon *et al.* (1994) and Hammack *et al.* (1995) places this locality near the base of the Bonanza succession (and possibly within it). The succession totals some several tens of metres of noncalcareous siltstone, shale and mudstone intercalated, in the lower part of the quarry, with crystal tuffs, and in the upper part of the quarry, with lithic and crystal lithic tuffs with lapilli-size clasts of predominantly mafic to intermediate volcanic lithologies. The fauna they identified were collected from the lower part of the succession and include ammonites and bivalves that indicate a middle early Sinemurian age (*ca.* 200 Ma).

Within the basal part of the Bonanza sequence exposed in the pit of the Island Copper mine, marine sedimentary rocks intercalated with lithic-rich tuffs and minor flows(?) have yielded trigoniid bivalves of Aalenian age (Poulton, 1980; Poulton and Tipper, 1991). These marine fossil occurrences are the youngest presently known in the Bonanza Group and clearly indicate that the basal part of the tuff-sediment sequence extends into the earliest Middle Jurassic.

In the vicinity of the Pemberton Hills (Figure 2), the subaqueously deposited basal Bonanza tuffs and sediments are overlain by a thick succession of mafic to felsic subaerial flows and tuffs with minor intercalated sedimentary strata (Nixon *et al.*, 1994). Although stratigraphic continuity has been disrupted by intrusion of the composite Wanokana batholith, rhyolitic flow-dome complexes and ash-flow tuffs exposed in the Pemberton Hills appear towards the top of the succession (Figure 2; Nixon *et al.*, 1994). This rhyolitic unit can be traced east to the shores of Holberg Inlet where a "Bonanza andesite" collected by K. E. Northcote yielded a whole-rock K-Ar date of 163±6 Ma (Bathonian). This "andesite" is a finely crystalline hornblende-bearing rock with fairly fresh feldspars, and although associated with silicic volcanics, contact relationships were not observed so that it could be a dike (K. E. Northcote, personal communication 1994). This Middle Jurassic sample was considered to have been reset by a later thermal overprint (University of British Columbia Geochronological Database). However, as discussed previously, there is no evidence for such an event in the $^{40}Ar/^{39}Ar$ age spectra studied to date. While argon loss remains a possibility, this date fits stratigraphic assignments and may indeed be valid. If this rock is in fact part of a dike, it would place a minimum age limit only on this part of the Bonanza Group.

Panteleyev *et al.* (1995) also provide evidence for the apparent youth of the Bonanza Group in the form of new $^{40}Ar/^{39}Ar$ dates for alunites that formed during acid sulphate alteration of the Pemberton Hills rhyolite unit. The alunite age spectra are complex. Two alunites gave maximum plateau ages ranging from *circa* 167 to 160 Ma (latest Bajocian to earliest Callovian), and two gave significantly younger maximum ages of *circa* 145-150 Ma (earliest Cretaceous). The oldest dates are considered to represent primary hydrothermal alunite that formed as a replacement of feldspar phenocrysts and as euhedral crystals in vugs, whereas the younger alunites are all interpreted to be supergene. Geological considerations suggest that the acid sulphate alteration occurred penecontemporaneously with extrusion of rhyolitic hostrocks, and may also be linked to emplacement of certain members of the Island Plutonic Suite (Panteleyev and Koyanagi, 1994; Nixon *et al.*, 1994). Although the $^{40}Ar/^{39}Ar$ systematics of alunite age spectra are not well known, the primary alunite maximum plateau date is consistent with a Middle Jurassic age for the upper part of the Bonanza succession.

From the preceding discussion, it is evident that the younger, predominantly subaerial part of the Bonanza Group in the Quatsino - Port McNeill area is younger than Aalenian. The available stratigraphic, paleontological and geochronological data currently suggest that Bonanza volcanism began in the early Lower Jurassic (Sinemurian-Pliensbachian) and extended well into the Middle Jurassic (Bathonian or younger). Accordingly, the upper part of the Bonanza Group would be equivalent in age to the youngest members of the Island Plutonic Suite in the area (*ca.* 166 Ma). Samples of rhyolitic lavas and ash-flow tuffs in the Bonanza Group are currently being prepared for U-Pb zircon geochronometry in order to further test these inferences.

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