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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 73-2

AGE DETERMINATIONS AND GEOLOGICAL STUDIES

K-Ar Isotopic Ages, Report 11

R. K. Wanless, R. D. Stevens,
G. R. Lachance and R. N. Delabio

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Abstract

One hundred and sixty-three new potassium-argon age determinations carried out on Canadian rocks and minerals are reported. Each age determination is accompanied by a description of the rock and mineral concentrate used; brief interpretive comments regarding the geological significance of each age are also provided. The experimental procedures employed are described in brief outline and the constants used in the calculation of ages are listed. Two geological time-scales are reproduced in tabular form for ready reference and an index of all published GSC K-Ar age determinations by primary NTS quadrangle has been prepared.

RESUME

L'auteur présente 163 nouvelles datations au potassium-argon effectuées sur des roches et des minéraux d'origine canadienne. Chaque datation est accompagnée d'une description de la roche ou du concentré minéral utilisé ainsi que d'une brève interprétation touchant l'aspect géologique. Les méthodes expérimentales qui ont servi aux datations sont aussi résumées et l'auteur joint une liste des constantes utilisées dans les calculs. Deux échelles des temps géologiques sont reproduites sous forme de tableau ce qui facilite les références et l'on a préparé, par quadrilatère du SRCN, un index de toutes les datations au potassium-argon publiées par la Commission géologique du Canada.

The age determination program is a co-ordinated effort involving the field geologists acknowledged in the accompanying text, and the scientists of the research laboratories of the Geological Survey listed below:

R. D. Stevens and R. K. Wanless	- Argon extraction, mass spectrometry, age calculation, and potassium determination using isotope dilution techniques.
G. R. Lachance	- Potassium determination using X-ray fluorescence techniques.
R. N. Delabio	- X-ray diffractometry and mineralogy of the concentrates

AGE DETERMINATIONS AND GEOLOGICAL STUDIES
K-Ar Isotopic Ages, Report 11

INTRODUCTION

This is the eleventh report of potassium-argon age measurements completed in the Geochronology Laboratories of the Geological Survey of Canada. One hundred and sixty-three new determinations are listed, bringing the total number of published ages to 1787.

The papers in this series of K-Ar age reports have not always followed a strict numerical sequence and the list below will serve to identify the complete series to the present time:-

GSC 60-17,	Report No. 1	– determinations 59-1 to 59- 98
GSC 61-17,	Report No. 2	– determinations 60-1 to 60-152
GSC 62-17,	Report No. 3	– determinations 61-1 to 61-204
GSC 63-17,	Report No. 4	– determinations 62-1 to 62-190
GSC 64-17,	Report No. 5	– determinations 63-1 to 63-184
GSC 65-17,	Report No. 6	– determinations 64-1 to 64-165
GSC 66-17,	Report No. 7	– determinations 65-1 to 65-153
GSC 67-2A,	Report No. 8	– determinations 66-1 to 66-176
GSC 69-2A,	Report No. 9	– determinations 67-1 to 67-146
GSC 71- 2,	Report No. 10	– determinations 70-1 to 70-156
This paper,	Report No. 11	– determinations 72-1 to 72-163

Many of the age determinations in these reports are plotted on GSC Map 1256A (see Douglas, 1970) which is the most recent compilation of Canadian geochronology.

Several determinations were found to be anomalously high due, it is postulated, to the presence of excess radiogenic argon-40 incorporated into the crystal lattice (see GSC 72-101, 102, 103, 104, 105 and 133). In some instances sufficient data were available to permit the application of a graphical method to establish the initial $^{40}Ar/^{36}Ar$ ratio required to correct the measured isotopic data. Thus geologically acceptable ages have been obtained from an aberrant array of 'age' data (see GSC 72-102 and 105).

Residual concentrates were on hand for a number of Appalachian samples originally analyzed some ten years ago. These have been re-analyzed and the results obtained are presented and discussed (see GSC 72-98, 110 and 113). The new data serve to confirm more recent determinations and are believed to be in better accord with the geological information currently available.

Appendix 1 comprises a new index of all published GSC K-Ar age determinations listed according to the primary NTS quadrangle to facilitate rapid retrieval.

Experimental Procedures

The concentration of potassium in mica samples was routinely determined using X-ray fluorescence methods (Lachance, *in* Wanless *et al.*, 1965, p. 4-7), and the reliability of this technique has been demonstrated (Wanless *et al.*, 1966, Table 1, p. 2). For amphibole concentrates and whole-rock

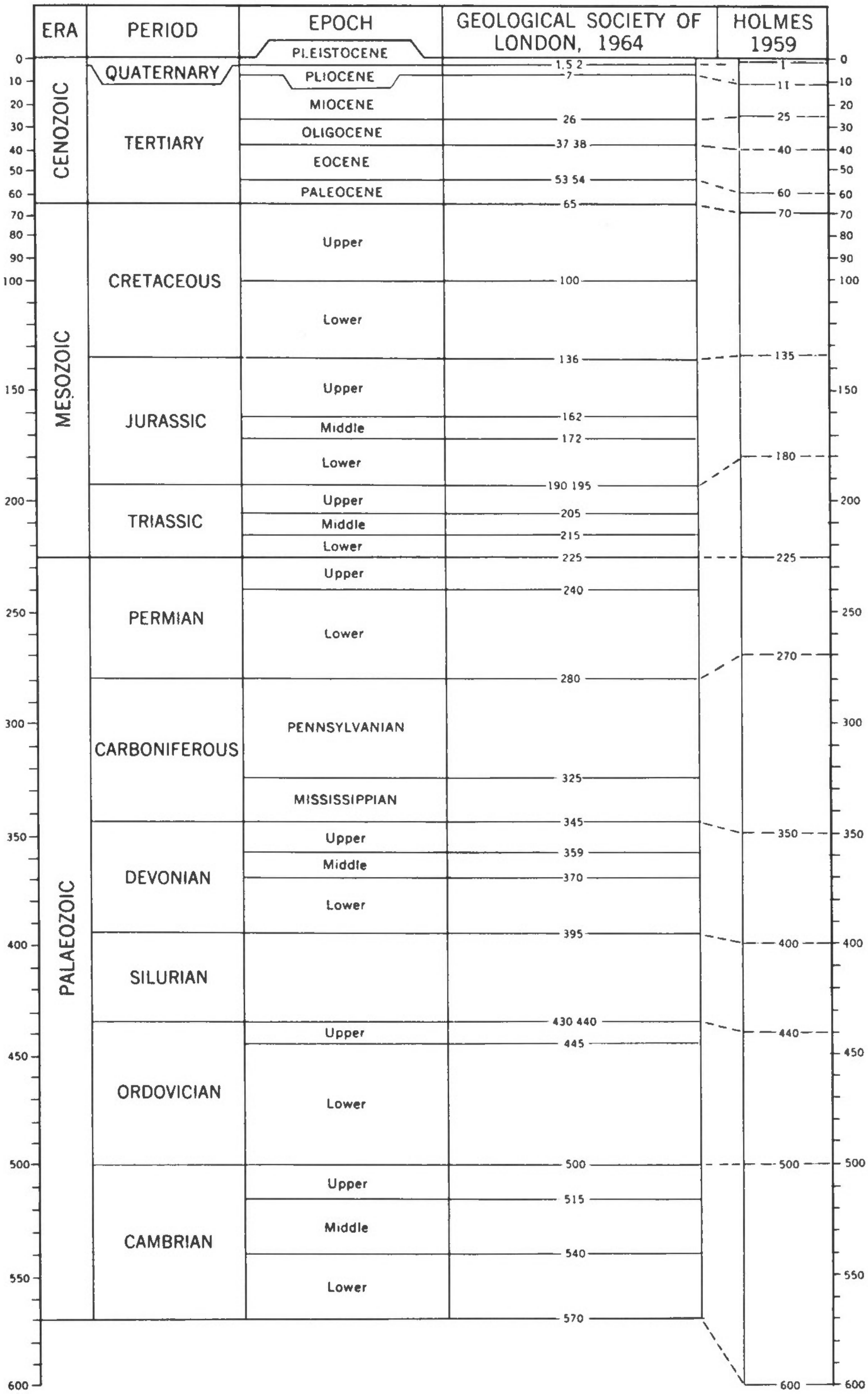

Figure 1. Phanerozoic time-scale.

EON	ERA	SUB-ERA	EVENT	AGE OF BOUNDARY (m.y.) U-Pb scale	AGE OF BOUNDARY (m.y.) Rb-Sr scale (constant 1.47)	AGE OF BOUNDARY (m.y.) Rb-Sr scale (constant 1.39)
PROTEROZOIC	HADRYNIAN			Ca 1000	Ca 1010	Ca 1070
PROTEROZOIC	HELIKIAN	NEOHELIKIAN	Grenvillian Orogeny	? 1400	?	?
PROTEROZOIC	HELIKIAN	PALEOHELIKIAN	Elsonian Event	Ca 1800	? 1750	? 1850
PROTEROZOIC	APHEBIAN		Hudsonian Orogeny	Ca 2560	? 2540	? 2690
ARCHEAN			Kenoran Orogeny			

Figure 2. Precambrian time-scale, with modifications from Stockwell, 1973.

samples the potassium content was determined using isotope dilution techniques and solid-source, triple-filament mass spectrometry (Wanless et al., 1968, p. 1-6).

Radio-frequency induction heating was employed to fuse the samples in vacuo. A precisely determined quantity of enriched argon-38 was added to the liberated gas which was then purified by passage through cold-traps, hot copper oxide, and over a titanium sponge getter. Isotopic analyses were carried out in modified A. E. I. MS-10 mass spectrometers operated in the static mode.

The various factors to be considered in assigning experimental error limits to individual age determinations have been discussed in detail in Report 5 (Wanless et al., 1965, p. 1-4). All reported errors are at the 95 per cent confidence level.

Constants Employed in Age Calculations

The constants employed to calculate the ages are as follows: $\lambda_\beta = 4.72 \times 10^{-10}$ yr^{-1}; $\lambda_\epsilon = 0.585 \times 10^{-10}$ yr^{-1}; ^{40}K atomic abundance = 1.19×10^{-4}.

Geological Time-Scales

The Phanerozoic time-scales of the Geological Society of London (1964) and Holmes (1959) are summarized in tabular form in Figure 1. For appropriate stage and series names the reader is referred to the Geological Society of London publications 'The Phanerozoic Time-Scale' p. 260-262 and 'The Phanerozoic Time-Scale - A Supplement' page 7.

A revised time-scale for the Precambrian of the Canadian Shield is given in Figure 2, after Stockwell (1973), who has prepared the following explanatory notes. As in earlier publications, the close of orogeny* is chosen as the boundary between time-units of Eon, Era, and Sub-Era rank but a distinction is now made between orogenic ages and immediately following cooling ages. Precision in estimating individual age determinations is impossible because of very large analytical errors, uncertainty in decay constants, and the generally obscure effect of geological factors but, in an effort to minimize or cancel out the analytical uncertainties, average values are used here, the averages being for clusters of similar ages as determined by each method on each mineral or rock-type within a structural province chosen as a type region. On this basis, boundaries between the named time-units are placed within a narrow time interval between the latest phase of orogeny and the earliest stage of the immediately following cooling period.

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*The term "orogeny" is used here to denote a process of mountain-building accompanied by important folding that affected large segments of the crust and was commonly associated with virtually contemporaneous regional metamorphism and the emplacement of granitic bodies and pegmatite. The term "orogenic materials" is used to denote those minerals and rocks that formed in conjunction with this process.

The latest orogenic phase is given best by U-Pb methods (and with some exceptions by the Rb-Sr whole-rock isochron method), on late orogenic granitic rocks or pegmatite, while the earliest datable stage of subsequent cooling is given by K-Ar ages on orogenic amphibole and by Rb-Sr ages on orogenic muscovite.

A good example is found in the Grenville structural province which is the type region for the Grenvillian Orogeny, for the post-Grenvillian cooling period, and for the boundary between the Neohelikian and the Hadrynian. In this province, the boundary is estimated, in round numbers, at 1,000 m.y., on the U-Pb scale. It is placed within a narrow time-range between the latest phase of the orogeny, which is given by a cluster of 29 Pb^{207} Pb^{206} ages on pegmatite averaging 1,011 m.y. old (and of 16 concordant and concordia ages on pegmatite averaging 1,035 m.y.), and the earliest stage of the post-Grenvillian cooling period which is given by a cluster of 22 K-Ar ages on orogenic amphiboles averaging 963 m.y. Incidentally, the peak of igneous activity within the Grenvillian Orogeny is indicated by granitic intrusions clustering around an average of 1,074 m.y. by the 207-206 method, and of 1,104 m.y. by the concordant and concordia methods. A late stage of the cooling period is indicated by a cluster of 98 K-Ar ages on biotite averaging 924 m.y. and an intermediate stage, by a cluster of 29 K-Ar ages on muscovites averaging 943 m.y.

The presently estimated isotopic age of each boundary is subject to change as more dates become available and as their interpretation is improved, but such changes will not alter the nomenclature nor definition of the time-units because these are based on rock in type regions. In most regions of the Shield the boundaries set apart very important episodes in earth history for they lie along contacts between deeply eroded basement and unconformably overlying sedimentary and volcanic sequences.

References

Douglas, R.J.W. (Ed.)
1970: Geology and economic minerals of Canada; Geol. Surv. Can., Econ. Geol. Series No. 1, 5th ed.

Geological Society of London
1964: The Phanerozoic time-scale; Quart. J. Geol. Soc. London, v. 120 S, p. 260-262.

1971: The Phanerozoic time-scale - a supplement; Special publication No. 5, Geol. Soc. London, p. 7.

Holmes, A.
1959: A revised geological time-scale; Trans. Edinburgh Geol. Soc., v. 17, Pt. 3, p. 183-216.

Stockwell, C.H.
1973: Revised Precambrian time-scale for the Canadian Shield; Geol. Surv. Can., Paper 72-52.

Wanless, R.K., Stevens, R.D., Lachance, G.R., and Edmonds, C.M.
1968: Age determinations and geological studies, K-Ar isotopic ages, Report 8; Geol. Surv. Can., Paper 67-2, Pt. A.

Wanless, R.K., Stevens, R.D., Lachance, G.R., and Rimsaite, J.Y.H.
1965: Age determinations and geological studies, Pt. 1 - Isotopic ages, Report 5; Geol. Surv. Can., Paper 64-17, p. 1-126.

1966: Age determinations and geological studies, K-Ar isotopic ages, Report 6; Geol. Surv. Can., Paper 65-17.

ERRATA

G.S.C. Paper 63-17

Determinations GSC 62-140 and 62-141:
Co-ordinates should read 52°32'15"N; 67°41'15"W.

G.S.C. Paper 71-2

Determinations GSC 70-1, 70-2 and 70-3:
Text should indicate that interpretative comments were prepared by A. Sutherland Brown and not J.E. Reesor as stated.

Determination GSC 70-22:
"Details as for GSC 69-1629" should read "Details as for GSC 70-21".

Determinations GSC 70-120 and 70-121:
Samples should have been listed with Newfoundland results.

ISOTOPIC AGES, REPORT II

British Columbia

(GSC No. 72-1 to 72-31)

GSC 72-1 Biotite, K-Ar age 68 ± 4 m.y.

$K = 7.42\%$, $^{40}Ar/^{40}K = 0.0041$, radiogenic Ar = 73%.
Concentrate: Somewhat altered orange-brown biotite with about 7% chloritization. Some of the mica flakes contain tiny, black, opaque inclusions.

From schist.
(103 J) North side of Highway 16 in road-cut 1/4 mile east of Galloway Rapids bridge, British Columbia, 54°15'19"N, 130°15'00"W. Map-unit 3d, GSC Map 12-1966 in GSC Paper 66-33. Sample HS-60-68, collected and interpreted by W. W. Hutchison.

This sample is a coarse-grained schist composed of reddish brown biotite, muscovite, poikiloblastic kyanite, staurolite, garnet, quartz and plagioclase. Biotite is generally fresh and forms 15-20% of rock. Chlorite occurs both as distinct clasts and locally within biotite.

The schists are intruded 4 miles to the east by the Ecstall Pluton (quartz diorite-granodiorite) which has been dated at 64 ± 8 m.y. (on biotite GSC 65-31) a further 3 miles to the east. It had been thought that a significantly older age (related to time of metamorphism) might be detected for these schists. The concordance of the ages from schist and plutonic rock is consistent with the regional pattern (Hutchison, 1970) and the proposals that the results represent synmetamorphic emplacement, or thermal imprint of Ecstall Pluton on the schists, or time of regional unroofing related to uplift all remain valid. The result does not confirm that metamorphism of the schist took place prior to emplacement of Ecstall Pluton.

Reference

Hutchison, W. W.
1970: Metamorphic framework and plutonic styles in the Prince Rupert region of the Coast Mountains, British Columbia; Can. J. Earth Sci., v. 7, p. 376-405.

GSC 72-2 Whole-rock, K-Ar age 202 ± 21 m.y.

$K = 0.122\%$, $^{40}Ar/^{40}K = 0.0125$, radiogenic Ar = 47%.
Concentrate: Crushed whole-rock.

From augite basalt.
(103 G) Small island about 4 miles north of Bonilla Island, British Columbia, 53°33'N, 130°39'39"W. Map-unit 11, Douglas Channel-Hecate Strait Map 23-1970, GSC Paper 70-41. Sample SE38-02-63, collected by J.G. Souther, interpreted by J. A. Roddick.

British Columbia

The rock is a very dark grey basalt consisting of about equal amounts of plagioclase (narrow laths) and augite which forms an ophitic texture. Chlorite forms about 10% of the rock, mainly as a fracture-filling in plagioclase rather than an alteration of the augite.

The basalt was collected from one of a group of tiny islands known as Northwest Rocks, but the same basalt also forms Bonilla Island and Bonilla Rocks to the south. As the rock is undisturbed and unmetamorphosed, it was thought to belong to the Late Miocene series in the Bella Coola-Laredo Sound map-area to the southeast (Baer, 1967), but its well-developed pillows and general appearance also suggested possible correlation with the Karmutsen Subgroup on Vancouver Island.

The 202 m.y. age obtained from the basalt has resolved the problem. The age fits precisely the known Upper Triassic age of the Karmutsen Subgroup.

The establishment of Karmutsen rocks so far north on the east side of the Insular Trough greatly extends the previously known distribution of these rocks. They are known only to be slightly farther north on the Queen Charlotte Islands (on the west side of the Insular Trough). The undisturbed nature of the Karmutsen rocks only 4 miles off the coast of Banks Island suggest that the metasediments on Banks Island (units 2b, 2d, Map 23-1970) were deformed and metamorphosed prior to Late Triassic time and supports other evidence indicating that the metasediments themselves are Paleozoic.

Although the basalt of Bonilla and associated islands was tentatively correlated with two basalt occurrences in Kitkatla Inlet on Map 23-1970, the author would now separate them and leave the Kitkatla Inlet occurrences as probable late Miocene, chiefly because they are more variable, probably not tholeiitic, and lack the pillows and general appearance of Karmutsen rocks.

References

Baer, A.J.
1967: Bella Coola-Laredo Sound map-area, B.C.; Geol. Surv. Can., Paper 66-25, Map 9-1966, 13 p.

Roddick, J.A.
1970: Douglas Channel-Hecate Strait map-area, B.C.; Geol. Surv. Can., Paper 70-41, Map 23-1970, 56 p.

GSC 72-3 Hornblende, K-Ar age 40 ± 4 m.y.

K = 0.46%, $^{40}Ar/^{40}K$ = 0.0024, radiogenic Ar = 29%.
Concentrate: Pleochroic, light green to olive-brown hornblende with approximately 5% free biotite and contamination.

From quartz diorite.
(92 H) 50 feet north of the north entrance to Ferrabee Tunnel on main Fraser Canyon Highway, British Columbia, 49°46'18"N, 121°26'06"W. Map-unit 24, GSC Paper 69-47. Sample HS68-37, collected and interpreted by W.W. Hutchison and J.A. Roddick.

See GSC 72-4 for description and interpretation.

British Columbia

GSC 72-4 Biotite, K-Ar age 44 ± 3 m.y.

K = 7.40%, $^{40}Ar/^{40}K$ = 0.0026, radiogenic Ar = 86%.
Concentrate: Light brownish coloured biotite with approximately 6% chlorite alteration.

From quartz diorite.
(92 H) Details as for GSC 72-3.

The rock is a homogeneous, grey, massive biotite-hornblende quartz diorite with minor scattered phenocrysts of plagioclase up to 1/2 inch in size. Coarser deformed flakes and fine ragged flakes of biotite form 10% of rock. Anhedral grains of hornblende form approximately 2% of rock. Plagioclase is present as euhedral crystals which exhibit delicate oscillatory zoning (with some crystals having more than 30 zones) superimposed on normal zoning. The range in composition is from An_{39}-An_{22}.

The specimen comes from the Hell's Gate pluton, which appears to be the youngest pluton in the immediate vicinity. The Hell's Gate pluton appears to cut the Scuzzy Pluton (dated as 70 m.y.; GSC 72-5) and also appears to have been emplaced after the major movement on the Fraser River fault system.

An earlier determination gave an age of 35 m.y. (Baadsgaard, Folinsbee and Lipson, 1961) on biotite only. The present determination is very slightly older with both biotite and hornblende giving roughly conjugate ages of 44 ± 3 m.y. and 40 ± 4 m.y. respectively. Regardless of which determination is more nearly correct, both indicate an event of early Tertiary age, possibly closely related to time of emplacement.

Unlike some of the central, more deeply seated parts of the Coast Mountains where plutons of different ages give the same K-Ar ages (Hutchison, 1970) and the younger higher level plutons in this part of the Coast Mountains and the Northern Cascades do indeed yield distinctly different ages. Richards and White (1970), for example, report at least 3 Tertiary plutonic events in a region 20 - 40 miles south of this sample site:

"Yale Intrusions" – 59 m.y.
Hope Plutonic Complex – 35-41 m.y.
Chilliwack Batholith – 16-29 m.y.

As suggested by Richards and White (1970), the Hell's Gate Pluton appears to be contemporaneous with the Hope Plutonic Complex.

References

Baadsgaard, H., Folinsbee, R.E., and Lipson, T.
1961: Potassium-argon dates of biotite from Cordilleran granites; Bull. Geol. Soc. Am., v. 72, p. 689-702.

Hutchison, W.W.
1970: Metamorphic framework and plutonic styles in the Prince Rupert region of the Central Coast Mountains, British Columbia; Can. J. Earth Sci., v. 7, p. 376-405.

British Columbia

Richards, T., and White, W.H.
1970: K-Ar ages of plutonic rocks between Hope, British Columbia, and the 49th parallel; Can. J. Earth Sci., v. 7, p. 12-3-1207.

GSC 72-5 Biotite, K-Ar age 70 ± 4 m.y.

K = 7.56%, $^{40}Ar/^{40}K$ = 0.0042, radiogenic Ar = 58%.
Concentrate: Brown coloured biotite with about 7% chlorite alteration. There is less than 2% muscovite contamination.

From leucocratic quartz diorite.
(92 H) Elevation 6, 905 feet, 3.15 miles northeast of triangulation point and 2.5 miles southwest of Scuzzy Mtn., British Columbia, 49°50'18"N, 121°40'36"W. Map-unit 24, GSC Paper 69-47. Sample RD68-60, collected and interpreted by J. A. Roddick and W. W. Hutchison.

The rock is a homogeneous, white weathering, coarse-grained, leucocratic quartz diorite from Scuzzy pluton. Inclusions are absent. Biotite is the only mafic mineral and forms approximately 5% of the rock. Quartz makes up roughly 25%. Plagioclase crystals are subhedral to anhedral and commonly display slight normal zoning ranging from An_{28} to An_{22}. Biotite is russet brown and commonly displays kink bands. Locally slight chlorite alteration is present. Muscovite, K-feldspar, zircon, apatite and sphene are present in minor amounts.

(For interpretation see GSC 72-8)

GSC 72-6 Hornblende, K-Ar age 73 ± 4 m.y.

K = 0.47%, $^{40}Ar/^{40}K$ = 0.0044, radiogenic Ar = 54%.
Concentrate: Clean, unaltered, pleochroic, light brown to dark green hornblende with a trace of quartz contamination.

From quartz diorite of Spuzzum pluton.
(92 H) 3.1 miles south of Spuzzum Mtn. and 4.5 miles northwest of Stout, British Columbia, 49°41'12"N, 121°28'54"W. Map-unit 19, GSC Paper 69-47. Sample HS68-34, collected and interpreted by W. W. Hutchison and J. A. Roddick.

See GSC 72-7 for description and GSC 72-8 for interpretation.

British Columbia

GSC 72-7 Biotite, K-Ar age 74 ± 4 m.y.

$K = 7.15\%$, $^{40}Ar/^{40}K = 0.0044$, radiogenic Ar = 79%.
Concentrate: Light brown biotite with about 9% chlorite alteration and less than 2% hornblende contamination.

From quartz diorite of Spuzzum pluton.
(92 H) Details as for GSC 72-6.

The rock is a coarse-grained, grey, homogeneous, weakly foliated hornblende-biotite quartz diorite. This is a quartz diorite typical of the Coast Mountains with approximately 20% total mafics and 10% quartz. Plagioclase forms blocky, subhedral, crystals (of andesine) which are unzoned and unaltered aside from very local saussuritization. Biotite occurs as unaltered, coarse, isolated crystals while the hornblende is partly intergrown with the plagioclase.

(For interpretation see GSC 72-8.)

GSC 72-8 Hornblende, K-Ar age 72 ± 4 m.y.

$K = 0.69\%$, $^{40}Ar/^{40}K = 0.0043$, radiogenic Ar = 42%.
Concentrate: Clean, non-pleochroic, green to brownish green hornblende with trace impurities of quartz and biotite.

From quartz diorite.
(92 H) 2.5 miles south-southeast of the Nipple, and 5.5 miles west-northwest of North Bend, British Columbia, 49°54'36"N, 121°33'54"W. Map-unit 24, GSC Paper 69-47. Sample RD68-106, collected by J. A. Roddick, interpreted by W. W. Hutchison and J. A. Roddick.

The rock is a grey, weakly foliated, medium-grained quartz diorite. Total mafic content is approximately 20% with hornblende equally as abundant as biotite. A characteristic of this particular pluton, is the common presence (1 - 2%) of garnets which occur in grains from 1/16" to 3/8" diameter.

Examination under the microscope reveals that plagioclase crystals are subhedral, most are normally zoned with a range from An_{35}-An_{28}, but a few crystals display 2 to 3 oscillatory zones. Hornblende is present as anhedral to euhedral crystals which are unaltered and appear to be slightly zoned from a brownish green core outwards to a green mantle. Biotite occurs as coarse ragged crystals which are slightly (5%) to moderately (35%) altered to chlorite. Minor amounts of garnet, sphene, apatite and zircon are also present.

The K-Ar age dates from all these plutonic rocks are essentially the same; 72 ± 4 m.y. The Scuzzy quartz diorite is presumably a leucocratic core within the Spuzzum quartz diorite which now appears to be one of the largest plutons in the Coast Mountains (50 miles x 15 miles maximum axes). If these K-Ar dates reflect time of emplacement, then the Scuzzy phase

(GSC 72-5 - 70 ± 4 m.y. on biotite) is no younger than the apparently older Spuzzum phase with its concordant biotite and hornblende dates (GSC 72-6 - 73 ± 4 m.y. on hornblende and GSC 72-7 - 74 ±4 m.y. on biotite). These dates obtained on the Spuzzum agree well with the date of 76 m.y. obtained in the valley of Sawmill Creek, 6 miles to the south (University of British Columbia Determination in Monger, 1970).

Poor field evidence suggested the Nipple Pluton is older than the Scuzzy phase but the age determination (GSC 72-8 - 72 ± 4 m.y. on hornblende) does not support this interpretation. The close proximity of the Nipple Pluton to the Scuzzy phase, along with the similar ages obtained from both, would suggest consanguinity. Yet the Nipple quartz diorite with its garnet and zoned hornblende is quite different in character from the Scuzzy quartz diorite. So two different alternatives are proposed:

1) The Scuzzy and Nipple plutonic rocks were coincidently emplaced at approximately the same geologic time but generated at two completely separate levels. Support for this would be results of Warren (1970, pers. comm.) suggesting that the Nipple garnets are of sub-crustal origin, whereas it is difficult to conceive of the extensive leucocratic Scuzzy phase as a single stage contribution from the mantle.

2) The dates do not reflect time of emplacement, but instead are related to time of regional uplift and unroofing. Evidence would suggest that this cannot be applied to this region. Richards and White (1970) report two closely spaced (6 miles apart) determinations on the Spuzzum Pluton, west of Hope, 30 miles to the south of the Nipple, of 102 m.y. and 77 m.y.

References

Monger, J.W.H.
1970: Hope map-area, west half, British Columbia; Geol. Surv. Can., Paper 69-47.

Richards, T., and White, W.H.
1970: K-Ar ages of plutonic rocks between Hope, British Columbia and the 49th parallel; Can. J. Earth Sci., v. 7, p. 1203-1207.

Warren, R.C.
1970: Electron microprobe investigations of Almandine garnets from a quartz diorite stock and adjacent metamorphic rocks, British Columbia; Trans. Amer. Geophys. Union, v. 51, p. 444.

British Columbia

GSC 72-9 Biotite, K-Ar age 110 ± 5 m.y.

$K = 7.38\%$, $^{40}Ar/^{40}K = 0.0067$, radiogenic Ar = 84%.
Concentrate: Relatively clean, greenish brown biotite with about 5% free chlorite contamination.

From granodiorite of "Pocahontas stock".
(92 F) Northeast coast of Texada Island, one mile east of Pocahontas Bay, British Columbia, 49°43'25"N, 124°24'30"W. Map 17-1968 in GSC Paper 68-50, map-unit 9. Sample MEKA 67-1, collected and interpreted by J. E. Muller. This is a duplicate-run of GSC 67-39.

See GSC 72-10 for description and GSC 72-14 for interpretation.

GSC 72-10 Hornblende, K-Ar age 114 ± 15 m.y.

$K = 1.15\%$, $^{40}Ar/^{40}K = 0.0069$, radiogenic Ar = 64%.
Concentrate: Slightly pleochroic, light green hornblende with 10 to 15% biotite impurity in the form of free flakes. The biotite content could not be further reduced.

From granodiorite.
(92 F) Details as for GSC 72-9.

The rock is medium-grained, light-grey hornblende-biotite granodiorite with modal count plagioclase 46.9%, orthoclase 7.8%, quartz 30%, hornblende 4.3%, biotite 10.3% and minor clinopyroxene, chlorite, epidote, zircon, apatite and opaques Plagioclase is subhedral, zoned, An_{20}-An_{45}, quartz and orthoclase are anhedral or interstitial. Hornblende is partly converted to biotite and chlorite, and larger biotite flakes include plagioclase.

For interpretation see GSC 72-14.

GSC 72-11 Hornblende, K-Ar age 165 ± 9 m.y.

$K = 0.56\%$, $^{40}Ar/^{40}K = 0.0101$, radiogenic Ar = 57%.
Concentrate: Clean, pleochroic, light green to olive-brown hornblende with no visible impurities.

From granodiorite "Gillies stock".
(92 F) Entrance to Prescott Pit, Texada Island, British Columbia, 49°42'15"N, 124°32'40"W, Map 17-168, in GSC Paper 68-50, map-unit 9. Sample MEKA 67-2, collected and interpreted by J. E. Muller.

The rock is medium-grained, medium grey, biotite-hornblende granodiorite, with modal count 54.4% plagioclase, 19.5% orthoclase, 10.0% quartz, 9.1% hornblende, 2.0% pyroxene, 1.3% biotite plus minor chlorite, apatite, sphene and opaques. Plagioclase is subhedral, zoned An_{30} to An_{40}. Orthoclase and quartz are interstitial, mafics partly in clusters.

For interpretation see GSC 72-14.

GSC 72-12 Hornblende, K-Ar age 155 ± 8 m.y.

$K = 0.44\%$, $^{40}Ar/^{40}K = 0.0095$, radiogenic Ar = 78%.
Concentrate: Relatively clean, pleochroic, dark green to light brown hornblende with less than 2% biotite and quartz contamination.

From "East stock" granodiorite.
(92 F) Logging road on northwest slope, 6 miles south-southeast of Northeast Point, Texada Island, British Columbia, 49°37'55"N, 124°18'10"W. See Map 17-1968 in GSC Paper 68-50. Sample MEKA 67-3, collected and interpreted by J. E. Muller.

See GSC 72-14 for description and interpretation.

GSC 72-13 Biotite, K-Ar age 106 ± 4 m.y.

$K = 6.67\%$, $^{40}Ar/^{40}K = 0.0064\%$, radiogenic Ar = 93%.
Concentrate: Impure, light brownish biotite with 20 to 25% chlorite contamination occurring both as free chlorite and as an alteration of the mica.

From granodiorite.
(92 F) Details as for GSC 72-12.

See GSC 72-14 for description and interpretation.

GSC 72-14 Biotite, K-Ar age 111 ± 6 m.y.

$K = 6.90\%$, $^{40}Ar/^{40}K = 0.0067$, radiogenic Ar = 94%.
Concentrate: Impure, light brownish green, altered biotite with about 18% chlorite occurring both as free chlorite and as an alteration of the mica.

From granodiorite.
(92 F) Details as for GSC 72-12. This determination was carried out on a second biotite concentrate from the same rock.

The rock is a medium-evenly grained, mesocratic biotite-hornblende granodiorite with modal count plagioclase 62.2%; orthoclase 7.9%, quartz 15.5%, hornblende 11.4%, biotite 1.8%, and 1.2% chlorite, sphene and opaques.

Plagioclase is euhedral, zoned, and about An_{20}-An_{45}. Quartz and orthoclase are interstitial. Subhedral hornblende contains small plagioclase and magnetite.

The following discussion (earlier published in GSC Paper 71-36) deals with GSC 72-11 hornblende from the Gillies Stock, in contact with iron-skarn at Texada Mines; GSC 67-39, GSC 72-9, GSC 72-10, duplicate biotite-runs and hornblende from the Pocahontas Stock on the Texada Island east coast and GSC 72-14, GSC 72-13 and GSC 72-12, duplicate biotite and hornblende runs from the East Stock, also on the Texada Island east coast.

Only hornblende could be extracted from biotite-hornblende-granodiorite of the Gillies Stock and yielded an age of 165 ± 9 m.y., in close agreement with that of granodiorite from many Middle Jurassic intrusions of Vancouver Island (Muller and Carson, 1969). As the orebodies and skarn replace country rock as well as the Gillies Stock (Sutherland Brown, 1965), the ore appears to have been deposited during a final stage of the intrusive episode.

The East Stock, on the east coast of Texada Island, is biotite-hornblende granodiorite, very similar to that of the Gillies Stock. It yielded ages of 155 ± 8 m.y. on hornblende and 106 ± 4 m.y., 111 ± 6 m.y. on duplicate analyses of the associated biotite. It is suggested that the original age of intrusion was the same as that of the Gillies Stock, but a more recent event at about 110 m.y. ago completely updated the biotite and had only a slight rejuvenating effect on the hornblende. This explanation is supported by the more or less concordant dates on the 'Pocahontas stock', a hornblende-biotite granodiorite, coarser grained and more quartz-rich (30% versus 10%) than the Gillies Stock. Hornblende from the 'Pocahontas stock' yielded 114 ± 15 m.y., and biotite duplicate ages of 110 ± 6 m.y. and 120 ± 6 m.y. Thus it seems probable that two intrusive pulses are represented on Texada Island and that the older pulse was responsible for the formation of the Prescott orebody. During the younger pulse, some small magnetite lenses were deposited near the 'Pocahontas stock' (McConnell, 1914). Further age determinations on post-ore dykes and on the smaller intrusive bodies associated with the worked-out copper-skarn deposits near Vanada are required to determine if there was more than one distinct pulse of mineralization of economic importance on Texada Island.

References

Carson, D.J.T., Muller, J.E., Wanless, R.K., and Stevens, R.D.
1971: Age of the contact metasomatic copper and iron deposits, Vancouver and Texada Islands, British Columbia; Geol. Surv. Can., Paper 71-36.

McConnell, R.G.
1914: Texada Island, B.C.; Geol. Surv. Can., Memoir 58.

Muller, J.E., and Carson, D.J.T.
1969: Geology and mineral deposits of Alberni map-area, British Columbia (92 F); Geol. Surv. Can., Paper 68-50.

British Columbia

Sutherland Brown, A.
1965: Texada Mines Ltd., Minister Mines Petr. Res. B.C., Ann. Rept. 1964, p. 146-157.

GSC 72-15 Hornblende, K-Ar age 173 ± 9 m.y.

$K = 0.52\%$, $^{40}Ar/^{40}K = 0.0106$, radiogenic Ar = 62%.
Concentrate: Clean, pleochroic, light green to olive-brown hornblende with no visible impurities.

From granodiorite.
(92 M) North coast of Nigei Island, small island in Cascade Harbour, British Columbia, 51°54'30"N, 127°44'25"W. GSC open-file map, 1:500,000 Vancouver Island (1971), unit Jg. Sample MEKA 68-2, collected and interpreted by J. E. Muller.

See GSC 72-16 for description and GSC 72-17 for interpretation.

GSC 72-16 Biotite, K-Ar age 153 ± 7 m.y.

$K = 7.32\%$, $^{40}Ar/^{40}K = 0.0093$, radiogenic Ar = 78%.
Concentrate: Relatively clean, light brown biotite with a trace of attached chlorite impurity.

From granite.
(92 M) Details as for GSC 72-15.

The rock is medium-grained, medium-grey hornblende-biotite granodiorite composed of plagioclase 43%, orthoclase 10%, quartz 25%, hornblende 9%, biotite 10%, magnetite 3%, and minor apatite. Plagioclase is subhedral, quartz and orthoclase anhedral and interstitial. Mafics occur in clusters.

See GSC 72-17 for interpretation.

GSC 72-17 Hornblende, K-Ar age 154 ± 8 m.y.

$K = 0.40\%$, $^{40}Ar/^{40}K = 0.0094$, radiogenic Ar = 61%.
Concentrate: Clean, pleochroic, light green to olive-brown hornblende with only a trace of quartz impurity.

From granodiorite.
(92 L) Road on east side of Nahwitti River, near Nahwitti Lake, Vancouver Island, British Columbia, 50°43'05"N, 127°52'30"W. GSC open-file map, 1:500,000 Vancouver Island (1971) unit Jg. Sample MEKA 68-3, collected and interpreted by J.E. Muller.

British Columbia

The rock is hornblende-biotite quartz diorite with plagioclase 49%, orthoclase 2%, quartz 23%, hornblende 11%, biotite 14% and minor accessories. Plagioclase subhedral, zoned up to ± An 55. Hornblende includes some plagioclase, biotite includes some magnetite and is slightly chloritized.

GSC 72-17 is part of the Nahwitti batholith at the northwest tip of Vancouver Island. It has been argued recently (Northcote and Muller, in preparation) that this and other Jurassic intrusions were comagmatic with Lower and ? Middle Jurassic Bonanza Volcanics. The maximum age of 162 m.y., at the Middle to Upper Jurassic time-boundary is a little low for this relationship. The age of plutonic and volcanic rocks could be reconciled by the assumption that the former needed several million years for cooling and/or that the latter extend in age into Middle Jurassic time.

The hornblende-biotite pair (GSC 72-15 and GSC 72-16) from granodiorite of Nigei Island, northeast of the northeast tip of Vancouver Island, gives ages of 173 ± 9 m.y. and 153 ± 7 m.y., averaging, if equally weighted, to 163 m.y. at the Middle -Late Jurassic time-boundary. This agrees with geological evidence since the granitic rocks are, a few miles to the southeast, in contact with argillite of Lower Jurassic (Sinemurian and Pliensbachian) age.

The ages of both localities are in general agreement with Early, Middle and early Late Jurassic K-Ar ages, found throughout the Island intrusions of Vancouver Island. (*See* for instance Carson, in press.)

References

Carson, D.J.T.
(in press): Petrography, chemistry, age and emplacement of the plutonic rocks of Vancouver Island; *Geol. Surv. Can.*, Paper.

Northcote, K.E., and Muller, J.E.
(in press): Volcanism and mineralization, Vancouver Island; *Can. Inst. Min. Met.*, Trans.

GSC 72-18 Phlogopite, K-Ar age $\frac{178 \pm 8 \text{ m.y.}}{181 \pm 8 \text{ m.y.}}$

$K = 7.29\%$, $^{40}Ar/^{40}K = \frac{0.0110}{0.0111}$, radiogenic Ar = $\frac{89\%}{85\%}$.

Concentrate: Relatively clean, light orange phlogopite with about 7% attached chlorite.

From skarn.

(92 L) At elevation 2,500 feet, Merry Widow Mine pit, south of Benson Lake, north Vancouver Island, British Columbia, 50°21'25"N, 127°14'58"W. Sample CT-X-3, collected and interpreted by D.J. Carson.

The phlogopite is from a skarn zone at Empire Development magnetite mine. For interpretation, *see* Carson *et al.*, 1971.

British Columbia

Reference

Carson, D.J.T., Muller, J.E., Wanless, R.K., and Stevens, R.D.
1971: Age of the contact metasomatic copper and iron deposits, Vancouver and Texada Islands, British Columbia; Geol. Surv. Can., Paper 71-36.

GSC 72-19 Biotite, K-Ar age 47 ± 3 m.y.

$K = 6.49\%$, $^{40}Ar/^{40}K = 0.0028$, radiogenic Ar = 54%.
Concentrate: Impure, orange coloured biotite with approximately 20% chlorite alteration.

From feldspar porphyry.
(92 F) Bench at 300 feet elevation in Brynnor Mines open pit, British Columbia, 49°03'N, 125°26'W. Sample NOREX-1, collected and interpreted by D.J. Carson (Noranda Exploration).

The biotite is from a post-ore dyke at Brynnor Iron Mine. See Carson et al., 1971 for interpretation.

Reference

Carson, D.J.T., Muller, J.E., Wanless, R.K., and Stevens, R.D.
1971: Age of the contact metasomatic copper and iron deposits, Vancouver and Texada Islands, British Columbia; Geol. Surv. Can., Paper 71-36.

GSC 72-20 Hornblende, K-Ar age 129 ± 7 m.y.

$K = 0.415\%$, $^{40}Ar/^{40}K = 0.0078$, radiogenic Ar = 39%.
Concentrate: Relatively clean, non-pleochroic, light brown hornblende with a trace of chlorite contamination.

From feldspar porphyry.
(92 F) Details as for GSC 72-19. Sample NOREX-1A, collected by W.I. Nelson Jr. and interpreted by D.J. Carson (Noranda Exploration).

This determination is in agreement with a previous biotite age of 121 ± 35 m.y. (GSC 64-3) on the same dyke, but contrasts with a 47 ± 3 m.y. biotite age (GSC 72-19), also supposedly on the same dyke at a different locality in the open pit. However, it does not alter the conclusion that the Brynnor magnetite ore is older than 121 ± 35 m.y. and younger than 167 ± 10 m.y. (GSC 64-2; a biotite determination on pre-ore granodiorite).

British Columbia

GSC 72-21 Biotite, K-Ar age 38 ± 2 m.y.

K = 6.84%, $^{40}Ar/^{40}K$ = 0.0023, radiogenic Ar = 55%.
Concentrate: Light brownish orange biotite with about 10% chlorite, some of which is attached to the mica. Some of the mica flakes have split edges.

From quartz diorite.
(92 F) At 1,700 feet on the south slope of Mt. Olsen, headwaters of Corrigan Ck., Vancouver Island, British Columbia, 49°00'52"N, 124°38'55"W. Sample CT-X-4, collected and interpreted by D.J. Carson.

The rock is light grey, fresh, medium-grained hypidiomorphic granular biotite quartz diorite. It is drill core from the Corrigan Creek porphyry copper occurrence and it contains minor chalcopyrite and pyrite. The quartz diorite and associated porphyritic varieties constitute an intrusive body approximately one mile in diameter that is texturally and compositionally similar to several other Tertiary quartz diorite intrusive complexes on Vancouver Island. Included are those at Mt. Washington (35 ± 6 m.y., GSC 66-29), Zeballos (38 ± 14 m.y., GSC 65-12), Catface (48 ± 12 m.y., GSC 65-11), and Sooke (39 ± 10 m.y., GSC 65-13). Some of these also have associated porphyry copper deposits.

References

Carson, D.J.T.
1969: Tertiary mineral deposits of Vancouver Island; Can. Min. Met. Bull., v. LXXII, p. 116-125.

Muller, J.E., and Carson, D.J.T.
1969: Geology and mineral deposits of the Alberni map-area (92 F); Geol. Surv. Can., Paper 68-50.

GSC 72-22 Sericite, K-Ar age 190 ± 8 m.y.

K = 8.21%, $^{40}Ar/^{40}K$ = 0.0117, radiogenic Ar = 97%.
Concentrate: Relatively clean, clear muscovite with about 4% chlorite contamination and some slight brown staining of the mica flakes.

From copper orebody.
(92 I) Highmount copper prospect, Highland Valley area, British Columbia, 50°26.5'N, 120°58.5'W. Sample G-3181, collected and interpreted by J.F. Harris and M.J. Osatenko of Cominco Ltd.

British Columbia

The sericite forms an envelope around a quartz veinlet with minor chalcopyrite in a host rock of Skeena or Bethsaida granodiorite.

See GSC 72-24 for discussion and interpretation.

GSC 72-23 Sericite, K-Ar age 186 ± 8 m.y.

$K = 8.77\%$, $^{40}Ar/^{40}K = 0.0114$, radiogenic Ar = 92%.
Concentrate: Relatively clean, clear, muscovite with less than 5% chlorite contamination. Some of the mica flakes have split edges with brownish stain.

From copper orebody.
(92 I) Valley Copper deposit, Highland Valley area, British Columbia, 50°29'N, 121°03'W. Sample G-1627, collected and interpreted by J. F. Harris and M. J. Osatenko of Cominco Ltd.

The sericite forms an envelope around a quartz veinlet in a host rock of Bethsaida granodiorite. Chalcopyrite and bornite occur in both envelope and veinlet.

See GSC 72-24 for discussion and interpretation.

GSC 72-24 Sericite, K-Ar age 186 ± 4 m.y.

$K = 8.71\%$, $^{40}Ar/^{40}K = 0.0115$, radiogenic Ar = 93%.
Concentrate: Relatively clean, clear muscovite with about 4% chlorite contamination on flake edges.

From copper orebody.
(92 I) Valley Copper deposit, Highland Valley area, British Columbia, 50°29'N, 121°03'W. Sample G-3345, collected and interpreted by J. F. Harris and M. J. Osatenko of Cominco Ltd.

The sericite forms an envelope around a quartz veinlet in a host rock of Bethsaida granodiorite. Chalcopyrite and bornite occur in both envelope and veinlet.

The three dated samples (GSC 72-22, 23 and 24) are from copper showings in the Highland Valley area of the Guichon batholith in southern B. C. They are believed to be of hydrothermal origin, contemporaneous with the mineralization.

The mean K-Ar age for the Guichon batholith is 198 ± 8 m.y. (Northcote, 1969), so the dates of 186, 186 and 190 m.y. for the sericites recorded here presumably represent an age of mineralization just slightly younger than the host Bethsaida granodiorites. This interpretation is supported by the association of the sericite with quartz veinlets which cut the Bethsaida rocks.

British Columbia

Reference

Northcote, K. E.
1969: Geology and geochronology of the Guichon Creek batholith; B.C. Dept. Mines, Bull. 56.

GSC 72-25 Hornblende, K-Ar age 31 ± 15 m.y.

K = 0.074%, $^{40}Ar/^{40}K$ = 0.0018, radiogenic Ar = 5.7%.
Concentrate: Clean, unaltered, pleochroic bluish green to brownish green hornblende with no visible impurities.

From mineralized mafic rock.
(92 B) Willow Grouse property, Sooke Penn., British Columbia, 48°22'N, 123°41'W. Sample KQ-71-14, collected by J.T. Fyles and interpreted by R.V. Kirkham.

The rock consisted of coarse-grained, green amphibole with some chalcopyrite and iron sulphides. The amphibole occurs as an alteration product along crosscutting zones in the differentiated, mafic East Sooke intrusion.

The very low potassium content and young age of this sample have resulted in very large error limits. Nevertheless, the results are generally consistent with the 44 ± 6 m.y.* date obtained for a similar amphibole from the Sunro Mine about 18 miles to the northwest. These dates suggest a metallogenic period that possibly could have been related to Eocene volcanism in the area. The date can also be taken as a minimum age for the East Sooke intrusion.

GSC 72-26 Hornblende, K-Ar age 72 ± 3 m.y.

K = 0.561%, $^{40}Ar/^{40}K$ = 0.0043, radiogenic Ar = 42%.
Concentrate: Moderately altered, pleochroic, dark green to olive-green hornblende with about 10% chlorite impurity.

From hornblende-plagioclase porphyry.
(93 L) Near centre of a small range northwest of Smithers, British Columbia, 54°53'N, 127°53'W. Map-unit 2, B.C. Dept. of Mines Map 69-1. Sample KQ-70-203A, collected and interpreted by R.V. Kirkham.

The sample is from a light grey, fine- to medium-grained hornblende, plagioclase porphyry. The porphyry is comprised of about 10 per cent 0.1 to 5 mm hornblende phenocrysts and about 50 to 60 per cent 1 to 5 mm, strongly zoned plagioclase phenocrysts set in an aphanitic quartzo-feldspathic matrix. The rock is probably a quartz diorite porphyry. Some of the plagioclase has been partly altered to sericite and epidote but the hornblende, although it contains some inclusions, is apparently unaltered.

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*See Geol. Surv. Can., Paper 71-2 (1972), p. 22, Sample GSC 70-36.

British Columbia

This date probably indicates the time of emplacement of the pluton and petrographically similar plutons in the area. It probably also indicates the time of formation of the Jan porphyry copper and molybdenum deposit about 1 1/2 miles to the north. The Jan deposit is spatially and probably genetically related to a similar but highly altered quartz diorite porphyry.

GSC 72-27 Muscovite, K-Ar age 117 ± 5 m.y.

K = 8.01%, $^{40}Ar/^{40}K$ = 0.0070, radiogenic Ar = 91%.
Concentrate: Relatively clean, clear muscovite with less than 5% chlorite contamination. Some of the mica flakes have yellow-stained edges.

From sandstone.
(94 C) Black Canyon, British Columbia, 56°02'N, 124°14'W. See Fort Grahame E map-sheet (GSC map in prep.). Sample 70-21-1B, collected and interpreted by G.H. Eisbacher.

The micas dated in this sample are detrital and were separated from fluvial sandstones of probable Late Cretaceous - Paleogene age. The sandstone was sampled near Black Canyon along the Omineca River shortly before the outcrops were flooded by Lake Williston, behind the Peace River dam.

The Black Canyon beds probably correlate with Upper Cretaceous - Paleogene Sifton Formation which fills much of the northern Rocky Mountain Trench (Eisbacher, 1971).

Paleocurrent trends at Black Canyon suggest southeasterly directed stream flow and sandstone composition points to source area within the Wolverine Metamorphic Complex mapped by Gabrielse (1971) in the adjacent Wolverine and Butler Ranges of the Omineca Mountains.

The date of 117 m.y. suggests Early Cretaceous uplift and erosional unroofing of the Wolverine Metamorphic Complex. This suggestion seems to be supported by a biotite age of 124 m.y. from garnet-biotite-quartz-muscovite schist collected by T.N. Irvine about 100 km northwest of Black Canyon (Wanless et al., 1972, p. 11). 117 m.y. also represents a maximum age for the Black Canyon beds of the Sifton Formation. In spite of these early ages, most of the higher grade parts of the Wolverine Metamorphic Complex seem to have been uplifted as late as Eocene (see Wanless et al., 1972, p. 12-13), post-dating deposition of the Sifton Formation.

References

Eisbacher, G.H.
1971: Tectonic framework of Sustut and Sifton Basins, B.C.; in Rept. of Activities, Pt. A, GSC Paper 71-1A, p. 20-23.

Gabrielse, H.
1971: Operation Finlay, North-Central British Columbia; in Rept. of Activities, Pt. A, GSC Paper 71-1A, p. 23-26.

British Columbia

Wanless, R.K., Stevens, R.D., Lachance, G.R., and Delabio, R.N.
1972: Age determinations and geological studies K-Ar isotopic ages, Rept. 10, GSC Paper 71-2.

GSC 72-28 Muscovite, K-Ar age 49 ± 4 m.y.

$K = 8.18\%$, $^{40}Ar/^{40}K = 0.0029$, radiogenic Ar = 34%.
Concentrate: Slightly brownish stained muscovite with no visible impurities, but with a generally "altered", finely sericitic appearance.

From pegmatite.
(94 C) 1 1/2 mile south of Mt. Henri, west of L. Williston, near crest of Butler Range, British Columbia, 56°29'N, 124°44'W. Sample GA70-44, collected and interpreted by H. Gabrielse.

The rock is a pegmatite consisting of quartz, feldspar, and muscovite within regionally metamorphosed Precambrian rocks of the Ingenika Group.

See GSC 72-29 for interpretation.

GSC 72-29 Muscovite, K-Ar age 45 ± 4 m.y.

$K = 7.09\%$, $^{40}Ar/^{40}K = 0.0027$, radiogenic Ar = 54%.
Concentrate: Clean, mostly clear muscovite with less than 5% of the flakes showing slight alteration.

From pegmatite.
(94 C) Ridge crest, Wolverine Range south of Omineca River, British Columbia, 56°03 1/2'N, 124°29'W. Fort Grahame map-area. Sample GA70-2A, collected and interpreted by H. Gabrielse.

The rock, a pegmatite, is part of a regionally metamorphosed Precambrian Terrain.

K-Ar age determinations GSC 72-28 and 29 are from muscovites in the Wolverine Complex of Omineca Mountains. The results are in close agreement with those previously obtained on micas from the Wolverine Complex farther south (see GSC Map 1256A).

Geological evidence suggests that the main episode of deformation and regional metamorphism in Omineca Mountains occurred about late Middle or early Late Jurassic time. The Eocene ages indicated by the K-Ar results on micas coincide with a period of major block faulting and local emplacement of small, high-level intrusions accompanied by volcanism. The K-Ar ages therefore appear to reflect this late tectonism.

British Columbia

GSC 72-30 Phlogopite, K-Ar age 44 ± 3 m.y.

K = 6.15%, $^{40}Ar/^{40}K$ = 0.0026, radiogenic Ar = 67%.
Concentrate: Clean, light brownish orange phlogopite with no visible impurities.

From lamprophyre.
(82 M) Mine road 1/2 mile north of Hiren Lake, British Columbia, 51°06'N, 118°12'W. Sample 70320, collected and interpreted by K. L. Currie.

This determination is on phlogopite from a lamprophyre dyke, about 4 feet wide, which strikes north-northeast across the Mt. Copeland nepheline gneiss. The dyke is an ultra-alkaline variety, composed of phlogopite, kaersutite, zoned augite and olivine phenocrysts in a matrix composed of the same minerals plus plagioclase microlites and calcite. Ocelli of analcite and carbonate rich material are present, suggesting liquid immiscibility during the development of the dyke. Since nepheline syenite is known to be genetically associated with similar dykes elsewhere, it was thought the Mt. Copeland mass might be related to this dyke, but the age, 44 m.y. is compatible with that of other late intrusives in the Shuswap terrane, and is far younger than that of the nepheline gneiss, which was metamorphosed with the rest of the Shuswap complex, probably during the Jurassic. The young age emphasizes the long history of alkaline intrusive activity in the central Cordillera, which seems to have lasted from the late Paleozoic until the present.

GSC 72-31 Biotite, K-Ar age $\frac{220 \pm 8 \text{ m.y.}}{233 \pm 11 \text{ m.y.}}$

K = 7.07%, $^{40}Ar/^{40}K = \frac{0.0136}{0.0145}$, radiogenic Ar = $\frac{83\%}{84\%}$
Concentrate: Clean, very dark brown, thick biotite with no visible alteration or impurities.

From coarse nepheline-aegirine rock (ijolite).
(82 M) Northwest slope of Garnet Mtn., British Columbia, 51°12'N, 116°28 1/2'W. See field map-sheet, GSC Memoir 55. Sample 70607, collected and interpreted by K. L. Currie.

This determination is on biotite collected from massive ijolite of the Ice River complex. The rock forms part of the layered sequence in the complex, and is composed of coarse, subhedral nepheline, aegirine, and disseminated biotite, with accessory sphene and apatite. The material appears to be perfectly fresh and undisturbed, unlike some previous samples from this complex, which were collected in the vicinity of the carbonate where both mechanical deformation and alteration are extensive. The age of 226 m.y. (average of the two) is however distinctly younger than those obtained previously (360-400 m.y.), also on biotite. The geological information is sufficient only to define the emplacement of the complex as pre-Jurassic deformation. The age of emplacement of the complex is therefore not as yet determined, and awaits an isochron study, but appears to be somewhat younger than previously thought. All of these ages would be compatible with speculation that the nepheline syenites of Ice River are coeval with those of Copeland Mountain and Parry River in the Shuswap complex to the west.

Yukon Territory

(GSC No. 72-32)

GSC 72-32 Biotite, K-Ar age 98 ± 4 m.y.

$K = 6.17\%$, $^{40}Ar/^{40}K = 0.0059$, radiogenic Ar = 78%.
Concentrate: Impure, light brown coloured biotite with about 15% chlorite alteration.

From granodiorite-quartz diorite.
(105 K) Face of Faro crosscut, Anvil Mining Corp., Yukon Territory, 62°22'N, 133°23'W. Map-unit 11, GSC Map 13-1961 and GSC Paper 68-1A, p. 46. Sample TO67-459, collected and interpreted by D. Templeman-Kluit.

The rock is a medium-grained equigranular massive, fresh, biotite granodiorite. The sample, taken at the face of the crosscut across the Faro orebody, is of apparently unaltered material only ten feet away from massive quartz-pyrite-sphalerite-galena ore. It was selected to see if the proximity to the sulphide mineralization might have some effect on the K-Ar age. This is apparently not the case as the age determined for this sample conforms closely with others previously obtained for rocks of unit 11 or its equivalents near by. Related dates previously published and listed below indicate a time of consolidation of 90-95 m.y. for Anvil Batholith.

Sample	Age (m.y.)	Lithology	Dated Mineral
65-41	90 ± 5	Quartz Monzonite	Biotite
65-42	79 ± 6	" "	Muscovite
65-43	87 ± 5	" "	Biotite
67-48	99 ± 5	Quartz muscovite biotite schist	Biotite
67-47	93 ± 4	" "	Muscovite
70-45	94 ± 5	Granodiorite muscovite orthogneiss	Muscovite
70-46	94 ± 5	" "	Biotite
72-32	98 ± 4	Biotite granodiorite	Biotite

The ages determined on samples GSC 67-47, 48 and GSC 70-45, 46 are on rocks within the thermal aureole of granitic rocks of unit 11 and these samples were both taken close to the Faro deposit.

District of Franklin

(GSC No. 72-33 to 72-38)

GSC 72-33 Biotite, K-Ar age 700 ± 25 m.y.

K = 5.80%, $^{40}Ar/^{40}K$ = 0.0496, radiogenic Ar = 97%.
Concentrate: Impure, altered, dark brown biotite with approximately 5% hornblende contamination and a trace of chlorite.

From diabase.
(58 C) Sill 50-100 feet below top of Aston Formation, Somerset Island, District of Franklin, 73°34'N, 94°42'W. Sample FA-DIXON, collected by R. Dixon (Ottawa University) and interpreted by W.F. Fahrig.

The sample is from a diabase sill 50' to 100' below the top of the Aston Formation, Aston Bay Area, Somerset Island. It supports the suggestion that the Aston is late Precambrian (Hadrynian) in age. The diabase may be a representative of the Franklin intrusions (Fahrig et al., 1971). If this is the case, the Franklin rocks may be slightly older than the 675 m.y. suggested by previous K-Ar age determinations.

Reference

Fahrig, W.F., Irving, E., and Jackson, G.D.
1971: Paleomagnetism of the Franklin diabases; Can. J. Earth Sci., 8, p. 455.

GSC 72-34 Whole-rock, K-Ar age 642 ± 98 m.y.

K = 0.32%, $^{40}Ar/^{40}K$ = 0.0448, radiogenic Ar = 82%.
Concentrate: Crushed whole-rock.

From diabase.
(37 G) Northeast of Pilik Lake, Baffin Island, District of Franklin, 71°14'N, 78°15'W. Sample FA-680207, collected and interpreted by W.F. Fahrig.

The rock is a massive, dark greenish black, very fine grained chilled margin of a diabase dyke. It consists mainly of plagioclase (50%), pigeonite (30%), opaques (17%), iddingsite (3%), and minor muscovite/talc and chlorite.

See GSC 72-38 for interpretation.

GSC 72-35 Whole-rock, K-Ar age 984 ± 80 m.y. / 1025 ± 80 m.y.

K = 0.245%, $^{40}Ar/^{40}K$ = 0.0755 / 0.0797, radiogenic Ar = 87% / 91%
Concentrate: Crushed whole-rock.

From porphyritic basalt.

(37 E) North-central Baffin Island, District of Franklin, 70°53'N, 75°40'W. Sample FA-5-68, collected and interpreted by W.F. Fahrig.

The basalt consists of subparallel plagioclase needles up to 1 mm long and round clinopyroxene phenocrysts up to 1/2 mm diameter in a semi-opaque devitrified matrix.

See GSC 72-38 for interpretation.

GSC 72-36 Whole-rock, K-Ar age 595 ± 90 m.y.

K = 0.33%, $^{40}Ar/^{40}K$ = 0.0410, radiogenic Ar = 79%.
Concentrate: Crushed whole-rock.

From diabase.

(37 H) Southwest of head of Cambridge Fiord, Baffin Island, District of Franklin, 71°02'N, 75°20'W. Sample FA-680148, collected and interpreted by W.F. Fahrig.

The sample is of a dark greenish black, massive, very fine grained chilled margin of a diabase dyke. It consists of labradorite (60%), pigeonite (20%), biotite (3%), olivine (2%), iddingsite (1%), magnetite (14%) and trace amounts of chlorite and amphibole.

See GSC 72-38 for interpretation.

GSC 72-37 Whole-rock, K-Ar age 577 ± 92 m.y.

K = 0.27%, $^{40}Ar/^{40}K$ = 0.0395, radiogenic Ar = 78%.
Concentrate: Crushed whole-rock.

From diabase.

(27 C) West of head of McBeth Fiord, Baffin Island, District of Franklin, 69°30'N, 70°53'W. Sample FA-680256, collected and interpreted by W.F. Fahrig.

The sample is from a massive, very fine grained, dark greenish black chilled margin of a diabase dyke. The rock consists of plagioclase (45%), pigeonite (35%), iddingsite (10%), magnetite (10%), and trace amounts of chlorite and biotite.

See GSC 72-38 for interpretation.

District of Franklin

GSC 72-38 Whole-rock, K-Ar age 546 ± 74 m.y.

K = 0.61%, $^{40}Ar/^{40}K$ = 0.0371, radiogenic Ar = 87%.
Concentrate: Crushed whole-rock.

From diabase.
(27 C) South of head of Clyde Inlet, Baffin Island, District of Franklin, 69°47'N, 70°22'W. Sample FA-680217, collected and interpreted by W.F. Fahrig.

The rock is a massive, very fine grained, dark greenish black chilled margin of a diabase dyke. It consists mainly of plagioclase (50%), pigeonite (35%), magnetite (12%), iddingsite (3%) and trace amounts of talc and chlorite.

These analyses (GSC 72-34 to 38) were all carried on chilled diabase from a swarm that trends parallel to Baffin Island (part of the Franklin diabase intrusions). They indicate a range from 546 ± 74 m.y. to 1005 ± 80 m.y. It is thought that all these intrusions are about 700 m.y.[1] old so most of the analyses suggest slight to moderate argon loss. Analysis of GSC 72-35 may suggest the presence of excess argon.

[1]Paleomagnetism of the Franklin diabases; Fahrig, W.F., Irving, E., and Jackson, G.D.; Can. J. Earth Sci., 1971, p. 455-467.

District of Mackenzie

(GSC No. 72-39 to 72-50)

GSC 72-39 Whole-rock, K-Ar age 1167 ± 39 m.y.

$K = 2.92\%$, $^{40}Ar/^{40}K = 0.0945$, radiogenic Ar = 99.9%.
Concentrate: Crushed whole-rock.

From chilled diabase.
(86 E) Terra Mine, Camsell River area, District of Mackenzie, N.W.T., 65°36'14"N, 118°06'45"W. For general geological mapping of the area see Badham (1972), the Silver Bear mine on his maps is referred to here as the Terra Mine. Sample TQ71-334, collected by R.J. Shegelski and interpreted by R.I. Thorpe.

The sample is fine grained, dark green diabase, taken from the chilled margin of a northwest striking diabase dyke about 150 feet thick. Intrusion of this dyke is one of the youngest events recognized in the area (Thorpe, 1971a); geological relationships indicate clearly that it postdates the diatreme (?) emplacement of a magnetite-apatite pipe and the intrusion of a northeast-striking quartz porphyry dyke. The age of the diabase dyke in relation to the silver-arsenide mineralization is not certain. However, the silver-bearing veins strike northeast, parallel to the trend of the quartz porphyry dyke, and it seems probable that they too are older than the diabase dyke.

The strike and K-Ar age of the dyke are in good agreement with the data for dykes of the Mackenzie swarm in the Slave and Bear structural provinces (Fahrig and Wanless, 1963; Fahrig and Jones, 1969; Leech, 1966). In view of the fact that the K-Ar age for a diabase dyke and for the diabase sill at Port Radium appear to be lower than their true ages (see discussion GSC 72-40, GSC 72-41) the date of 1167 ± 39 m.y. should probably be considered as a minimum. Since the mineralization at Terra is similar to that at Port Radium in (1) chemical and mineralogical character, (2) attitude of controlling structures, and (3) lead isotopic composition of galena occurring in the veins, it seems reasonable to place the maximum age of the diabase dyke at Terra at the time of silver-uranium mineralization at Port Radium, about 1450 m.y. (Thorpe, 1971b; Jory, 1964; Cumming *et al.*, 1955).

References

Badham, J.P.N.
1972: The Camsell River - Conjuror Bay area, Great Bear Lake, N.W.T.; *Can. J. Earth Sci.*, v. 9, no. 11, p. 1460-1468.

Cumming, G.L., Wilson, J.T., Farquhar, R.M., and Russell, R.D.
1955: Some dates and subdivisions of the Canadian Shield; *Proc. Geol. Assoc. Can.*, v. 7, Pt. 2, p. 27-79.

Fahrig, W.F., and Wanless, R.K.
1963: Age and significance of diabase dyke swarms of the Canadian Shield, *Nature*, v. 200, no. 4910, p. 934-937.

District of Mackenzie

Fahrig, W. F., and Jones, D. L.
1969: Paleomagnetic evidence for the extent of Mackenzie igneous events; Can. J. Earth Sci., v. 6, no. 4, p. 679-688.

Jory, L. T.
1964: Mineralogical and isotopic relations in the Port Radium pitchblende deposit, Great Bear Lake, Canada; Ph.D. thesis, Calif. Inst. Technol., 275 p.

Leech, A.P.
1966: Potassium-argon dates of basic intrusive rocks of the District of Mackenzie, N. W. T.; Can. J. Earth Sci., v. 5, p. 389-412.

Thorpe, R. I.
1971a: Geological study of silver deposits in Canada, in Report of Activities, Part A: April to October, 1970; Geol. Surv. Can., Paper 71-1, Pt. A, p. 94-96.

1971b: Lead isotopic evidence on age of mineralization, Great Bear Lake, District of Mackenzie (including a new model for certain anomalous leads); in Report of Activities, Part B: November 1970 to March, 1971; Geol. Surv. Can., Paper 71-1, Pt. B, p. 72-75.

GSC 72-40 Whole-rock, K-Ar age 1222 ± 38 m.y.

K = 1.40%, $^{40}Ar/^{40}K$ = 0.1006, radiogenic Ar = 99.2%.
Concentrate: Crushed whole-rock.

From chilled diabase.
(86 L) Mouth of No. 3 adit, Echo Bay Mine, Port Radium, District of Mackenzie, N. W. T., 66°05'20N, 118°01'00"W. For general geological mapping of the area see Robinson and Morton (1972). Sample TQ70-243 collected and interpreted by R. I. Thorpe.

The sample is fine-grained diabase taken from the chilled margin of a diabase sill about 150 feet thick that lies in a sequence of tuffaceous and porphyritic flow (?) rocks of the Echo Bay Group. A zircon U-Pb age of 1820 ± 30 m.y. by Jory (1964) for the granite intrusion off LaBine Point would suggest a minimum age of about 1800 m.y. for the host rocks.

The diabase sill has recently been dated at the Geological Survey of Canada by a Rb-Sr 5-point isochron at 1425 ± 48 m.y. ($\lambda\ Rb^{87} = 1.39 \times 10^{-11}$ yr^{-1}). The sample yielding a K-Ar age of 1222 ± 38 m.y. was, unfortunately, a sixth sample which does not fall on the Rb-Sr isochron. The sample is from or very near surface and may have been affected by weathering although it appears to be fresh. It is possible that the 1222 ± 38 m.y. date could represent a hydrothermal or other geological event. In any case the date is about 200 m.y. too young for consolidation of this diabase sill.

District of Mackenzie

References

Jory, L.T.
1964: Mineralogical and isotopic relations in the Port Radium pitchblende deposit, Great Bear Lake, Canada; Ph.D. thesis, Calif. Inst. Technol., 275 p.

Robinson, B.W., and Morton, R.D.
1972: The geology and geochronology of the Echo Bay area, Northwest Territories, Canada; Can. J. Earth Sci., v. 9, no. 2, p.158-171.

GSC 72-41 Whole-rock, K-Ar age 1319 ± 44 m.y.

$K = 2.83\%$, $^{40}Ar/^{40}K = 0.1118$, radiogenic Ar = 99.9%.
Concentrate: Crushed whole-rock.

From chilled diabase.
(86 K) North shore of Glacier Bay, Port Radium area, District of Mackenzie, N.W.T., 66°05'12"N, 117°58'35"W. For geological mapping of the area see Robinson and Morton (1972). Sample TQ71-118 collected and interpreted by R.I. Thorpe.

The sample is fine-grained diabase taken from the chilled margin of an east-west dyke about 30 feet wide that cuts andesite of the Upper Echo Bay sub-group. According to Jory (1964) diabase dykes belonging to this east-west set are older than the diabase sill in the area (see GSC 72-40) and older than the vein mineralization, although the vein structures predate the dykes. Since a Rb-Sr isochron at 1425 ± 48 m.y. (λ $Rb^{87} = 1.39 \times 10^{-11}$ yr^{-1}) has recently been obtained for the diabase sill, it appears that the 1319 ± 44 m.y. age is more than 100 m.y. low. The age by Jory (1964) of 1820 ± 30 m.y. for a granite intrusion in the area is a maximum age for the diabase dykes.

References

Jory, L.T.
1964: Mineralogical and isotopic relations in the Port Radium pitchblende deposit, Great Bear Lake, Canada; Ph.D. thesis, Calif. Inst. Technol., 275 p.

Robinson, B.W., and Morton, R.D.
1972: The geology and geochronology of the Echo Bay area, Northwest Territories, Canada; Can. J. Earth Sci., v. 9, no. 2, p. 158-171.

District of Mackenzie

GSC 72-42 Whole-rock, K-Ar age 604 ± 92 m.y.

K = 0.31%, $^{40}Ar/^{40}K$ = 0.0416, radiogenic Ar = 91%.
Concentrate: Crushed whole-rock.

From chilled dolerite.
(86 N) 23 miles north of Dismal Lakes, District of Mackenzie, 67°47'14.5"N, 117°41'06.5"W. Map-unit 18, GSC Map 18-1960. Sample BL9-692, collected and interpreted by W. R. A. Baragar.

The rock is a dark grey, fine-grained dolerite from the chilled lower contact of a sill. It is composed of a network of tiny plagioclase laths with interstitial pyroxene.

The sample on which the age determination was made is from one of the Coronation dolerite sills. It is a fairly fresh olivine-bearing rock. The age therefore, is believed to represent the original age of the intrusives. Other ages from the same group of intrusions range from 605 to 718 m.y. (Robertson and Baragar, 1972).

Reference

Robertson, W. A., and Baragar, W. R. A.
1972: The petrology and paleomagnetism of the Coronation Sills.

GSC 72-43 Biotite, K-Ar age 2400 ± 68 m.y.

K = 7.27%, $^{40}Ar/^{40}K$ = 0.2834, radiogenic Ar = 99.7%.
Concentrate: Light brownish orange biotite with approximately 10% chloritization.

From pegmatite dyke.
(85 H) Simpson Islands, East Arm, Great Slave Lake, District of Mackenzie, 61°42'34"N, 112°47'53"W. Map-unit 4, GSC Map 377A. Sample RM-207-524-68, collected and interpreted by E. W. Reinhardt.

The concentrate was derived from a specimen taken from a relatively large pegmatite dyke that cuts medium-grained meta-gabbro. The pegmatite is pink due to the dominance of pink plagioclase feldspar which interstitially encloses lesser quantities of white quartz and 'books' of black biotite (25%). The contact of the dyke with the meta-gabbro is irregular and a few smaller, northeastward-striking pegmatite dykes, about one foot in width, also cut the meta-gabbro in this vicinity. The meta-gabbro is part of an isolated occurrence and is thought to have been introduced into a layered sequence which is now part of a highly migmatized plutonic complex. Previous K-Ar mica ages from rocks of this complex yield 2555 m.y. (GSC 61-77) and 2480 m.y. (Burwash and Baadsgaard, 1962, p. 28). These dates reflect the time of plutonic migmatization and associated metamorphism; the present determination of 2400 m.y. roughly corresponds to this event. In addition, the contention that the meta-gabbro was introduced prior to migmatization is upheld.

Reference

Burwash, R.A., and Baadsgaard, H.
1962: Yellowknife-Nonacho age and structural relations; in the Tectonics of the Canadian Shield; Roy. Soc. Can., Special Publication no. 4, p. 22-29.

GSC 72-44 Hornblende, K-Ar age 1705 ± 58 m.y.

K = 0.69%, $^{40}Ar/^{40}K$ = 0.1624, radiogenic Ar = 96%.
Concentrate: Dark green, non-pleochroic hornblende with about 5% chlorite alteration.

From hornblende syenodiorite.
(85 H) Southwest tip of Blanchet Island, East Arm, Great Slave Lake, District of Mackenzie, 61°55'N, 112°44'30"W. Map-unit 13, GSC Map 377A. Sample RMG-363-68 collected by C.A. Giovanella and E.W. Reinhardt, interpreted by E.W. Reinhardt.

The concentrate was derived from a medium-grained, massive, pink syenodiorite that has intruded a thinly layered sequence of sediments consisting dominantly of interlaminated argillite and carbonate with lesser amounts of siltstone and sandstone. The clastic sediments are characteristically maroon or dark red whereas the carbonate varies from grey to pink in colour. These sediments show evidence of contact metamorphism and are strongly folded. From the writer's brief examination at the collecting site, the sediments appear to belong to Hoffman's (1968) Blanchet Formation of the Pethei Group (GSC Paper 68-42) rather than to the Kahochella Formation as proposed earlier by Stockwell (1936, GSC Map 377A).

The syenodiorite shows considerable variation in both hornblende content and grain size in the vicinity of the contact. The grain size generally increases away from the contact so that at a distance of about 10 feet it is essentially constant. The sample collected is part of an elongate 'dioritic' mass that extends for about 16 miles to the northeast within the west central part of Blanchet Island. Other similar bodies occur at scattered localities from the Caribou Islands in the southwest almost to Reliance in the northeast. Hoffman (1968, GSC Paper 68-42, p. 44) mentioned that these bodies commonly intrude the contact between the Pethei Group and Stark Formation.

Petrographically, the syenodiorite displays a well-developed igneous texture (average grain size 1 mm) defined by subhedral laths of zoned plagioclase (65%) and elongate subhedral hornblende (25%) which also appears to be zoned. Other primary minerals present are: K-feldspar, sphene, and opaque phases. Interstitial carbonate was noted in a few places. Alteration of plagioclase is confined mainly to the central zones (An_{30}) and consists of fine-grained epidote and muscovite. Outer zones of hornblende are green and weakly pleochroic, whereas the central zones are brown and highly pleochroic. The bulk of the hornblende zoning is probably a primary igneous feature but the presence of very small needle-like amphibole crystals elsewhere in the rock may be due to secondary crystallization. This coupled with the plagioclase alteration and very minor chloritization of hornblende can best be explained through deuteric action.

Analysis of the hornblende concentrate, consisting of a mixture of inner and outer zones of original amphibole crystals, should give the approximate time of igneous crystallization. The time required for zonal growth would be negligible compared with the absolute age. The value of 1705 ± 58 m.y. is therefore interpreted as an age of intrusion for the syenodiorite which in turn would establish a minimum for the Pethei Group. Biotite ages from similar 'dioritic rocks' are 1630 ± 50 m.y. (GSC 67-76) and 1795 ± 55 m.y. (GSC 67-77).

GSC 72-45 Hornblende, K-Ar age 1811 ± 62 m.y.

K = 0.816%, $^{40}Ar/^{40}K$ = 0.1779, radiogenic Ar = 95%.
Concentrate: Clean, pleochroic, light brown to dark green hornblende with no visible impurities.

From amphibolite.
(85 H) Petitot Islands, Great Slave Lake, District of Mackenzie, 61°37'30"N, 112°41'40"W. Map-unit 3 on GSC Map 377A. Sample RMG-182-684-68, collected by C. A. Giovanella and interpreted by E. W. Reinhardt.

The concentrate was extracted from a dark grey, well foliated, biotite-bearing amphibolite. The foliation is defined by alternating laminations of light and dark minerals with sub-parallel planar arrangement of hornblende and biotite grains. The mineralogical composition of the rock is approximately as follows: 15% quartz, 25% plagioclase (An_{30}), 50% hornblende, and 5% biotite. Accessory phases include: sphene (mainly in leucoxene), opaque minerals, apatite, and epidote. Greenish brown hornblende (0.1 mm) is irregular in shape and shows no clearly obvious alteration except for possible conversion to minor biotite and development of needle-like crystals in terminations perpendicular to the c-axis direction. This partially developed, rather fibrous habit appears to be more common in the vicinity of microfractures filled mainly by quartz. It was not possible to ascertain whether the bulk of the amphibole grains have experienced recrystallization following cataclasis. The suggestion of cataclastic deformation is shown by slight crushing of amphibole and plagioclase in addition to the network of microfractures that traverse the section. Alteration of plagioclase is variable, the products being mainly white mica and to a lesser extent, epidote. Biotite may be slightly chloritized. The specimen was selected partly because it was the least altered and deformed material of its kind from the Petitot Islands migmatitic zone.

The interpretation of the K-Ar date is included with GSC 72-46 (directly following).

District of Mackenzie

GSC 72-46 Hornblende, K-Ar age 1815 ± 65 m.y.

$K = 0.99\%$, $^{40}Ar/^{40}K = 0.1782$, radiogenic Ar = 92%.
Concentrate: Pleochroic, light brown to dark green hornblende with no visible impurities.

From amphibolite cataclasite.
(85 H) Petitot Islands, Great Slave Lake, District of Mackenzie, 61°38'N, 112°40'W. Map-unit 3 on GSC Map 377A. Sample RM-10A-10-68, collected and interpreted by E. W. Reinhardt.

The concentrate was separated from a specimen of weakly foliated, dark green, medium-grained amphibolite. A thin section of this rock revealed cataclastic grains of brownish green hornblende (40%) and andesine (35%), both in the range of 1 to 3 mm in size, set in a finer grained, partly cataclastic matrix composed of: biotite, chlorite, plagioclase, epidote, recrystallized quartz and microcline. Sphene is a plentiful accessory spatially associated with hornblende and trace amounts of apatite were observed here and there. The hornblende has a crushed appearance and about 5% appears to have been converted to biotite which in turn is partially chloritized. Open cleavages and fractures in the amphibole are often infilled with quartz and microcline. Most of the plagioclase shows alteration consisting mostly of fine-grained white mica and epidote and in places textures suggest partial replacement by K-feldspar.

Both the present specimen and RMG-182-68 (GSC 72-45) are representative of amphibolitic interbands occurring in migmatitic gneiss both on Petitot Islands and inland south of Hornby Channel. These migmatites consist of interbanded granitic and mafic-rich fractions. Although granitic bands are dominantly concordant with intervening metamorphosed strata, crosscutting relations and inclusions are commonplace. Undoubtedly, the migmatization progressed under plutonic conditions. At some later date these rocks experienced a strong penetrative deformation which produced mylonite and cataclasite and gave rise to a northeastward-striking, steeply dipping foliation which in most places roughly parallels the earlier stratiform foliation. Petrography of deformed rocks from the Thubun Lakes map-area (GSC Paper 69-21) further demonstrates that a retrograde metamorphism of lower thermal intensity either directly followed or was contemporaneous with penetrative deformation. In the case of GSC 72-46 such minerals as chlorite and epidote are recognized products of such retrogression. The granulated aspect and significantly large size of most hornblende and plagioclase would suggest that these minerals are higher grade crystallates that survived the effects of the retrograde event. Textural evidence of cataclasis is certainly weaker in GSC 72-45 as is also evidence of recrystallization. At one time the interpreter would have predicted Kenoran K-Ar dates for minerals that appear crushed without being recrystallized but experience from the Thubun Lakes area has shown that Hudsonian K-Ar dates are invariably obtained from rocks in zones of regional cataclasis even though these rocks are otherwise similar to radiogenically documented Archean lithologies in certain parts of the East Arm of Great Slave Lake (cf. GSC 66-78, GSC 66-79, GSC 67-72, GSC 67-78). One is therefore led to the conclusion that some reconstitution of hornblende components (recrystallization?) must have occurred during the retrograde metamorphism in spite of the virtual lack of supporting textural evidence. The numerical values 1811 ± 62 m.y. (GSC 72-45) and 1815 ± 65 m.y. (GSC 72-46) are in close agreement indicating some systematic control.

GSC 72-47 Muscovite, K-Ar age 1855 ± 55 m.y.

$K = 7.72\%$, $^{40}Ar/^{40}K = 0.1847$, radiogenic Ar = 99%.
Concentrate: Slightly stained muscovite with about 5% contamination by rock cementing material (mainly iron oxide).

From feldspathic sandstone.
(85 H) Wilson Island, Great Slave Lake, District of Mackenzie, 61°48'40"N, 112°49'00"W. Map-unit 6 on GSC Map 377A. Sample RMG-329-1518-68, collected by C. A. Giovanella and interpreted by E. W. Reinhardt.

The concentrate was separated from a specimen of maroon, fine-grained, feldspathic sandstone that locally alternates with buff sandstone along the south shore of Wilson Island. These rocks belong to Stockwell's (1936; GSC Map 377A) Sosan Formation and are probably part of Hoffman's (1968; GSC Paper 68-42) Hornby Channel Formation. Recent mapping by the writer in 1968 (GSC Paper 69-1, Part A) indicates that these sediments have a greater westward extension than shown on GSC Map 377A (Stockwell, 1936).

The sample is estimated to contain 20% quartz, 20% plagioclase, 27% microcline, and 8% muscovite. Quartz and feldspar are subangular and have an average grain size in the order of 0.1 mm. Muscovite occurs as thin plates that average 0.2 mm in length and define a foliation. The edges of these plates are ragged and the plates themselves are bent by compaction where in contact with clasts of quartz and feldspar. Sericitization of some feldspar clasts was noted but the majority show little alteration.

The mica plates are tentatively regarded as clastic and this would mean that the K-Ar age would predate sedimentation of the Great Slave Supergroup. A K-Ar muscovite age of 1785 ± 55 m.y. (GSC 67-74) and a K-Ar biotite age of 1825 ± 50 m.y. (GSC 67-75) were previously obtained from metamorphosed Wilson Island Group sediments. Similar K-Ar hornblende ages were found in penetratively deformed migmatitic gneisses to the south (see GSC 72-45, and GSC 72-46 of this report). The present K-Ar muscovite age of 1855 ± 55 m.y. would then suggest that this mica was derived either from the Wilson Island Group metasediments or some variation of mylonitized migmatite that occurs along the McDonald Fault system. The Wilson Island Group is the preferred source.

District of Mackenzie

GSC 72-48 Muscovite, K-Ar age 2495 ± 70 m.y.

$K = 7.52\%$, $^{40}Ar/^{40}K = 0.3038$, radiogenic Ar = 99%.
Concentrate: Relatively clean muscovite with about 5% chlorite contamination. Some of the mica flakes carry a slight yellowish stain.

From granite.
(76 E) 25 miles north of Yamba Lake, District of Mackenzie, 65°27'N, 111°36'W. Massive granitic rocks within map-unit C, GSC Paper 66-24. Sample BK-65-258, collected and interpreted by H.H. Bostock.

The rock is a medium-grained, buff coloured muscovite granite consisting of microcline (40%), quartz (30%), albite (20%), muscovite (10%), chlorite (2%) and accessory zircon.

The age, 2495 ± 70 m.y., provides a minimum age of intrusion of the minor granite body concerned, and is potentially of wider significance insofar as this body may be related to other late muscovite-bearing granites in the Contwoyto Lake area.

GSC 72-49 Whole-rock, K-Ar age 1765 ± 184 m.y.

$K = 0.56\%$, $^{40}Ar/^{40}K = 0.1712$, radiogenic Ar = 97%.
Concentrate: Crushed whole-rock.

From diabase.
(75 O) North end of Musclow Lake, District of Mackenzie, 63°48'N, 106°56'W. Map-unit 7c, GSC Map 4-1971, Artillery Lake. Sample FD69-1108B, collected and interpreted by J.A. Fraser.

The sample, a dark grey, greenish weathering, massive, fine-grained gabbro, composed of approximately equal amounts of andesine and fibrous amphibole altered in part to chlorite and epidote, with minor pyrite, was taken from the marginal zone of a coarse-grained dyke that intrudes massive biotite-muscovite granite of Archean age. The dyke, which is almost 100 feet thick, strikes 080 degrees and dips vertically, belongs to one of three dyke swarms exposed in the Artillery Lake map-area. The easterly trending dykes are massive to strongly foliated and, like the dyke sampled, are commonly rich in hornblende. The alteration of these dykes suggests that they may have been updated through argon loss and the K-Ar age is therefore considered to represent a minimum estimate of the age of intrusion.

District of Mackenzie

GSC 72-50 Whole-rock, K-Ar age 1635 ± 126 m.y.

$K = 1.57\%$, $^{40}Ar/^{40}K = 0.1520$, radiogenic Ar = 99%.
Concentrate: Crushed whole-rock.

From diabase.
(75 O) 5 miles south of Campbell Lake, District of Mackenzie, 63°09'N, 106°51 1/2'W. Map-unit 7b, Artillery Lake, map in preparation. Sample FD69-0313 collected by P. L. Broughton, interpreted by J. A. Fraser.

The sample was taken from the chilled margin of a diabase dyke that cuts massive granite of the Churchill Province south of McDonald Fault. The dyke, which is about 40 feet wide, dips almost vertically and strikes 008 degrees, belongs to one of three dyke sets exposed in the Artillery Lake map-area.

Dark grey, weathering light grey, the diabase is fine-grained, massive and fresh. It is composed of labradorite (70%), clinopyroxene (25%), carbonate (2%), opaque mineral (3%) and traces of biotite. About 3 per cent of the plagioclase is present as phenocrysts up to 2 mm long.

The age is considered to be that of intrusion of the dyke and is similar to the whole-rock age (1, 560 m.y.) obtained from one (GSC 70-74) of a set of northerly trending dykes exposed in the Slave Province east of Bathurst Inlet.

District of Keewatin

(GSC No. 72-51 to 72-67)

GSC 72-51 Hornblende, K-Ar age 2583 ± 74 m.y.

$K = 0.453\%$, $^{40}Ar/^{40}K = 0.3236$, radiogenic Ar = 98%.
Concentrate: Relatively clean, pleochroic, olive-brown to light bluish green hornblende with less than 2% biotite impurity and slight traces of quartz and chlorite.

From tonalite.
(55 L) South shore of the middle part of Kaminak Lake, District of Keewatin, 62°10'14"N, 94°58'40"W. Map-unit 2, GSC Map 1285A. Sample DM-520-1969, collected and interpreted by A. Davidson.

See GSC 72-52 for description and interpretation.

GSC 72-52 Biotite, K-Ar age 2095 ± 60 m.y.

$K = 7.43\%$, $^{40}Ar/^{40}K = 0.2246$, radiogenic Ar = 99%.
Concentrate: Impure, light greenish coloured biotite with about 15% chlorite alteration.

From tonalite.
(55 L) Details as for GSC 72-51.

The hornblende and biotite dated above are from the same sample of massive, medium-grained, equigranular, grey tonalite from the central part of the batholithic complex at Kaminak Lake. The hornblende age is almost identical to the age (2585 ± 70 m.y.) reported for hornblende extracted from a gabbroic phase in the northern part of the same complex. (GSC 67-87, Geol. Surv. Can., Paper 69-2A.) Together with a concordant U-Pb age determined for sphene from a tonalite pluton of the same complex of 2690 m.y., these ages are taken to confirm that at least some of the plutonic rocks, and all of the pre-Hurwitz metavolcanic rocks and related metasediments in this part of the Ennadai - Rankin Inlet greenstone terrane are Archean.

The biotite age reported above is the oldest biotite age so far obtained from the plutonic rocks of this region. Biotite ages range from this value down to 1795 m.y. (see GSC 67-88 and 67-89, Geol. Surv. Can., Paper 69-2A; GSC 60-61, Geol. Surv. Can., Paper 61-17, GSC 61-105, Geol. Surv. Can., Paper 62-17). Although other dating methods have not been applied to most of the plutonic rocks for which biotite ages have been obtained, all these plutonic rocks are likely Archean because they are cut by diabase dykes for which whole-rock K-Ar age determinations suggest an early Aphebian age (this report). These dykes are truncated and unconformably overlain by the Aphebian Hurwitz Group, which has itself been folded and mildly metamorphosed during Hudsonian Orogeny. This Hudsonian metamorphism was presumably responsible for updating the biotite ages, and took place prior to 1690 m.y., the age obtained from biotite in a fresh lamprophyre that cuts the Hurwitz Group (GSC 66-94, Geol. Surv. Can., Paper 67-2, Pt. A).

District of Keewatin

GSC 72-53 Whole-rock, K-Ar age 1810 ± 144 m.y.

$K = 1.35\%$, $^{40}Ar/^{40}K = 0.1781$, radiogenic Ar = 99%.
Concentrate: Crushed whole-rock.

From basalt.
(55 L) Kaminak Lake area, District of Keewatin, 62°05'27"N, 94°55'57"W. Map-unit Adb, GSC Map 1285A. Sample DM411i-1969, collected and interpreted by A. Davidson.

Aphanitic, greenish grey basalt collected from the chilled west margin of a 125 foot wide, north trending partly altered diabase dyke cutting gneiss, about 300 feet west of and parallel to a dyke from which sample GSC 72-55 was obtained. The thin section shows a very fine aggregate of alteration minerals including amphibole, biotite, chlorite, epidote, and sphene containing laths and scattered microphenocrysts of plagioclase.

See GSC 72-64 for interpretation.

GSC 72-54 Whole-rock, K-Ar age 1815 ± 156 m.y.

$K = 1.06\%$, $^{40}Ar/^{40}K = 0.1787$, radiogenic Ar = 95%.
Concentrate: Crushed whole-rock.

From basalt.
(55 L) Kaminak Lake area, District of Keewatin, 62°05'29"N, 94°55'55"W. Map-unit Adb, GSC Map 1285A. Sample DM411k-1969, collected and interpreted by A. Davidson.

Sample of very fine-grained greenish grey basalt collected three feet from the east contact of the same diabase dyke from which sample GSC 72-53 was obtained. In thin section this rock is seen to be slightly coarser grained, and diabasic texture is preserved, but is otherwise identical to GSC 72-53.

See GSC 72-64 for interpretation.

GSC 72-55 Whole-rock, K-Ar age 1660 ± 166 m.y.

$K = 0.72\%$, $^{40}Ar/^{40}K = 0.1560$, radiogenic Ar = 97%.
Concentrate: Crushed whole-rock.

From basalt.
(55 L) Kaminak Lake area, District of Keewatin, 62°05'30"N, 94°55'47"W. Map-unit Adb, GSC Map 1285A. Sample DM411g-1969, collected and interpreted by A. Davidson.

District of Keewatin

Sample of very fine grained, greenish grey basalt taken two feet from west contact of a 70 foot wide, north-trending altered diabase dyke cutting gneiss 200 feet west of and parallel to the dyke GSC 72-56. Very similar appearance in thin section, except that the original diabasic texture is better preserved by less alteration of plagioclase laths.

See GSC 72-64 for interpretation.

GSC 72-56 Whole-rock, K-Ar age 1700 ± 176 m.y.

K = 0.59%, $^{40}Ar/^{40}K$ = 0.1617, radiogenic Ar = 94%.
Concentrate: Crushed whole-rock.

From diabase (basalt).
(55 L) 2 1/2 miles southeast of Kaminak Lake, District of Keewatin, 62°05'20"N, 94°55'31"W. Map-unit Adb, GSC Map 1285A. Sample DM-411f-1969, collected and interpreted by A. Davidson.

See GSC 72-57 for description and GSC 72-64 for interpretation.

GSC 72-57 Whole-rock, K-Ar age 1615 ± 172 m.y.

K = 0.59%, $^{40}Ar/^{40}K$ = 0.1496, radiogenic Ar = 98%.
Concentrate: Crushed whole-rock.

From diabase (basalt).
(55 L) Details as for GSC 72-56. This is another sample from the same locality.

Both samples were collected from the west margin of a 100 foot wide, north-trending dyke of altered diabase cutting gneiss, that lies about 400 feet west of and is parallel to the dyke of fresh diabase, GSC 72-58, for which three age determinations have been made. Both samples were taken from within two feet of the contact, and are of very fine grained, dull grey-green altered basalt. A thin section reveals an aggregate of very fine biotite, brown amphibole, epidote, chlorite, albite, sphene, and possibly serpentine. An original diabasic texture is faintly discernible.

See GSC 72-64 for interpretation.

GSC 72-58 Whole-rock, K-Ar age 2330 ± 200 m.y.

K = 0.80%, $^{40}Ar/^{40}K$ = 0.2695, radiogenic Ar = 98%.
Concentrate: Crushed whole-rock.

From diabase.
(55 L) 2.5 miles southeast of Kaminak Lake, District of Keewatin, 62°05'20"N, 94°55'30"W. Map-unit Adb, GSC Map 1285A. Sample DMA-82F-1967, collected and interpreted by A. Davidson.

District of Keewatin

Fresh, fine-grained, brownish grey diabase; sample taken 30 feet from the east contact of a 120 foot wide, north-trending dyke that cuts tonalite gneiss. The rock contains scattered, clear plagioclase phenocrysts up to one half inch across. The thin section shows an ophitic intergrowth of fresh plagioclase and pyroxenes, both augite and pigeonite. Scattered olivine crystals are partly replaced by antigorite and magnetite. Opaque grains are of magnetite and ilmenite in lamellar intergrowth. Small amounts of brown hornblende and minor brown biotite rim some pyroxene grains.

See GSC 72-64 for interpretation.

GSC 72-59 Whole-rock, K-Ar age 2315 ± 192 m.y.

$K = 0.81\%$, $^{40}Ar/^{40}K = 0.2658$, radiogenic Ar = 98%.

From basalt.
(55 L) 2 1/2 miles southeast of Kaminak Lake, District of Keewatin, 62°05'20"N, 94°55'30"W. Map-unit Adb, GSC Map 1285A. Sample DM-411B-1969, collected and interpreted by A. Davidson.

Very fine grained, dark grey basalt sample taken three feet from the east contact of the same diabase dyke last described. Its thin section shows a fine ophitic intergrowth of clear plagioclase and partly altered pyroxene with overgrowths of amphibole that grades from brown to green outwards. Grains of magnetite-ilmenite are fresh; clots of antigorite and magnetite dust replace olivine.

See GSC 72-64 for interpretation.

GSC 72-60 Whole-rock, K-Ar age 2265 ± 196 m.y.

$K = 0.78\%$, $^{40}Ar/^{40}K = 0.2566$, radiogenic Ar = 95%.
Concentrate: Crushed whole-rock.

From basalt-gneiss contact rock.
(55 L) 2 1/2 miles southeast of Kaminak Lake, District of Keewatin, 62°05'20"N, 94°55'30"W. Map-unit Adb, GSC Map 1285A. Sample DM-411A-1969, collected and interpreted by A. Davidson.

This sample is from the east chilled margin of the same diabase dyke described for the last two reported age determinations. It is a dark, slightly greenish grey, aphanitic basalt. In thin section it is seen to contain microphenocrysts of fresh plagioclase and partly altered augite set in a dark brownish very fine grained matrix of tiny plagioclase laths and brownish amphibole, probably secondary, scattered throughout with opaque granules.

See GSC 72-64 for interpretation.

District of Keewatin

GSC 72-61 Whole-rock, K-Ar age 2395 ± 218 m.y.

K = 0.69%, $^{40}Ar/^{40}K$ = 0.2823, radiogenic Ar = 97%.
Concentrate: Crushed whole-rock.

From basalt.
(55 L) Near southeast side of Kaminak Lake, District of Keewatin, 62°08'15"N, 94°52'45"W. Map-unit Adb, GSC Map 1285A. Sample DM-467Δ5b-1969, collected and interpreted by A. Davidson.

This sample is from the chilled margin of an 80 foot wide, north-trending diabase dyke that cuts hornblende tonalite, and is a black, flinty basalt. A thin section shows small phenocrysts of fresh augite and plagioclase and of altered olivine set in an almost opaque aphanitic groundmass containing tiny plagioclase microlites.

See GSC 72-64 for interpretation.

GSC 72-62 Whole-rock, K-Ar age 1690 ± 185 m.y.

K = 0.51%, $^{40}Ar/^{40}K$ = 0.1597, radiogenic Ar = 94%.
Concentrate: Crushed whole-rock.

From diabase.
(55 L) Peninsula between Quartzite and Snug Lakes, District of Keewatin, 62°20'30"N, 94°24'30"W. Map-unit Adb, GSC Map 1285A. Sample DMA-399A-1967, collected and interpreted by A. Davidson.

Sample taken from the chilled east margin of a 75 foot wide, north-trending diabase dyke that cuts pillowed meta-basalts. It is aphanitic and greenish grey. Its thin section shows an indeterminate brownish grey groundmass containing faintly discernible altered plagioclase laths. Scattered small plagioclase phenocrysts are mostly replaced by epidote and chlorite.

See GSC 72-64 for interpretation.

GSC 72-63 Whole-rock, K-Ar age 2550 ± 204 m.y.

K = 0.96%, $^{40}Ar/^{40}K$ = 0.3163, radiogenic Ar = 99%.
Concentrate: Crushed whole-rock.

From diabasic basalt.
(55 L) 6 miles south-southwest of Southern Lake, District of Keewatin, 62°05'38"N, 94°22'48"W. Map-unit Adb, GSC Map 1285A. Sample DMW-214B-1969, collected by R. B. Waitt, interpreted by A. Davidson.

District of Keewatin

The sample was collected within three inches of the contact of a 40 foot wide, northeast-trending diabase dyke that cuts hornblende gabbro. It is very fine grained, dark greenish grey basalt containing scattered, small, clear plagioclase phenocrysts. In thin section it is seen to be composed of small, zoned plagioclase laths and augite in ophitic intergrowth; much of the augite is altered fine brownish amphibole. Small aggregates of antigorite dusted with fine magnetite are presumably pseudomorphous after olivine.

See GSC 72-64 for interpretation.

GSC 72-64 Whole-rock, K-Ar age 1892 ± 66 m.y.

K = 0.900%, $^{40}Ar/^{40}K$ = 0.1905, radiogenic Ar = 98%.
Concentrate: Crushed whole-rock.

From diabase.
(55 L) Kaminak Lake area, District of Keewatin, 62°16'45"N, 94°37'00"W. Map-unit Adb, GSC Map 1285A. Sample DMR-40b-1967, collected by R. Newson and interpreted by A. Davidson.

Very fine grained, greenish grey basalt collected within two feet of the east contact of a 110 foot wide, north-trending dyke of porphyritic diabase that cuts massive hornblende tonalite. A groundmass of brownish amphibole and partly epidotized zoned plagioclase laths are seen in thin section to contain scattered plagioclase phenocrysts, small aggregates of antigorite, and small opaque grains partly surrounded by secondary sphene.

Diabase dykes are known to cut all types of plutonic rocks in the northeast part of the Ennadai - Rankin Inlet greenstone region. They range from a few feet to more than 120 feet wide, and are essentially vertical. Nearly all trend northerly, and are characterized by large, scattered to abundant plagioclase phenocrysts, in places concentrated in zones parallel to the dyke contacts. This northerly swarm is cut in a very few places by nonporphyritic westerly-trending diabase dykes. None of these dykes is known to cut the Aphebian strata of the Hurwitz Group.

Both to the north and to the south of the Ennadai - Rankin Inlet greenstone region, metamorphic grade increases, and the north-trending dykes show progressive metamorphism in these directions, eventually becoming boudinaged amphibolites. This metamorphism is attributed to Hudsonian Orogeny because the post-diabase Aphebian sediments are also affected. In the core of the Ennadai - Rankin Inlet greenstone region, where the effects of Hudsonian metamorphism have been minimal the diabase varies from extremely fresh to considerably altered, apparently without pattern. Of two dykes separated by only a few hundred feet of country rock, one may be fresh, the other altered. In a few places within individual dykes, diabase has been noted to change from fresh to altered along strike. Fresh dykes have intense black to dark grey chilled margins and sealed contacts, their plagioclase phenocrysts are clear or partly milky, and thin sections of their coarser parts reveal them to be composed essentially of fresh, zoned calcic plagioclase and pyroxene (both augite and pigeonite) in ophitic intergrowth, with minor olivine and lamellar ilmenite-magnetite or skeletal ilmenite. In most the olivine is partly or wholly altered to aggregates of fine antigorite and magnetite dust; minor brownish amphibole and biotite occur at the edges of some pyroxene grains. Altered dykes have medium grey to greenish grey chilled margins, commonly with fracturing or slight shearing parallel to their contacts, their phenocrysts are partly or wholly clouded white, grey, or yellow with fine epidote and sericite, and thin sections of their coarser parts reveal them to be composed of partly sericitized plagioclase, uralitized pyroxene with fine marginal biotite and chlorite. Ophitic texture is generally preserved, as are unreplaced cores of pyroxene in some dykes. Aggregates of chlorite and antigorite have replaced olivine grains, and sphene has partly or wholly replaced ilmenite. This alteration is similar to that found in some diabases that are not known to have been metamorphosed subsequent to emplacement, and is generally referred to as deuteric.

North and south of the core area where fresh dykes occur, all the dykes are altered. Alteration close to the core area does not appear very different to that in altered dykes within the core area, but as the higher grade terrains are approached, a more obvious metamorphic character is developed. One of the first new minerals attributable to metamorphism rather than to deuteric alteration is stilpnomelane, and one of the first metamorphic textures recognized is the beginning of reduction of the altered plagioclase phenocrysts to augen.

The five ages in excess to 2265 m.y. reported above were obtained from three dykes of fresh diabase between 6 and 25 miles south of the 'isograd' of northerly increasing metamorphism defined by the first occurrence of stilpnomelane in the dykes. The dyke whose reported age is 1892 m.y. is about 4 miles south of this isograd, and has a fresh core. The dyke dated 1690 m.y. is situated close to the stilpnomelane isograd and is considerably altered throughout, yet retains pyroxene cores. The six ages ranging from 1615 to 1815 m.y. were obtained from three dykes of altered diabase all within a few hundred feet of a fresh dyke whose apparent age is at least 400 m.y. older.

Field evidence does not support the idea that there were two periods of diabase dyke intrusion, and it is hard to explain the juxtaposition of fresh and altered dykes in the same outcrop, cutting the same country rock, by selective Hudsonian metamorphism of some of the dykes. It is considered more likely that the alteration was deuteric and took place shortly after the time of intrusion. On this basis, it is considered that the ages in excess of 2250 m.y., all obtained from fresh diabase, are close to the real age of the diabase dyke swarm. These ages are in accord with the geologic relations and the Archean ages of the plutonic country rocks determined by methods other than biotite K-Ar, and give a maximum age for the Aphebian Hurwitz Group. The ages of 1892 and 1690 m.y. probably represent progressive updating with increasing Hudsonian metamorphism. The relatively young ages obtained from the altered dykes associated spatially with fresh dykes are explained as follows: just as the biotite K-Ar ages determined for the Archean plutonic rocks in the same area show updating with respect to ages determined by other methods, the chilled margins of deuterically altered diabase dykes have been unable to retain radiogenic argon during the mild Hudsonian thermal increase, whereas the chilled margins of fresh diabase dykes have retained their radiogenic argon.

GSC 72-65 Biotite, K-Ar age 1820 ± 60 m.y.

$K = 8.06\%$, $^{40}Ar/^{40}K = 0.1796$, radiogenic Ar = 97%.
Concentrate: Clean, greenish brown biotite with no detectable chlorite.

From nepheline syenite.
(55 L) Northeast side of Kaminak Lake, District of Keewatin, 62°16.5'N, 94°46'W. Map-unit 4, GSC Map 1285A. Sample DMA-132f-67, collected and interpreted by A. Davidson.

Medium- to coarse-grained, grey, fresh nepheline syenite contains about 60% microcline, 30% nepheline, 5% biotite, and minor calcite, cancrinite, melanite, aegirine-augite, and apatite. The sample was collected from a wide dyke that cuts coarse-grained ijolite. Biotite is black and lustrous in hand specimen, and in thin section shows pleochroism from orange-brown to very deep olive, straight cleavage, and no sign of secondary green biotite or other alteration minerals.

See GSC 72-66 for interpretation.

GSC 72-66 Biotite, K-Ar age 1830 ± 56 m.y.

$K = 8.35\%$, $^{40}Ar/^{40}K = 0.1807$, radiogenic Ar = 99%.
Concentrate: Clean, light greenish coloured biotite with no visible alteration or impurities.

From calcite-bearing syenite.
(55 L) Kaminak Lake area, District of Keewatin, 62°17'30"N, 94°41'30"W. Map-unit 4, GSC Map 1285A. Sample DM579c-1969, collected and interpreted by A. Davidson.

Coarse-grained, grey calcite-bearing syenite composed of about 80% euhedral microcline crystals in a groundmass of calcite, with 5% interstitial biotite and minor sphene, zircon, apatite, and pyrite. The rock forms a dyke-like mass in coarse-grained ijolite, and varies in composition from syenite to feldspathic sövite. Biotite is black and lustrous in hand specimen, and in thin section is seen to form clusters of zoned euhedral crystals between feldspar crystals; pleochroism varies from straw-yellow to deep brown or olive-green, depending on zoning. Some of the larger biotite grains are bent or show kink planes, and fine-grained green biotite is present at the margins of some of the clusters of zoned crystals.

The two syenite samples whose biotite is dated above are from a late intrusive phase within an alkalic complex at Kaminak Lake. This complex is known to cut and metasomatize a tonalite pluton of the Kaminak Lake batholithic complex for which sphene was yielded a concordant age of 2690 ± 40 m.y. The two biotite ages are revealed to be updated, in the same manner as biotite ages from nearby plutonic rocks, by a whole-rock Rb-Sr isochron age of 2686 ± 58 m.y. obtained for the alkalic complex, and by a $^{207}Pb/^{206}Pb$ age of 2540 m.y. obtained from zircon from the same syenite whose K-Ar biotite age, above, is 1830 ± 56 m.y. The biotite dated 1820 ± 60 m.y. shows radiogenic argon to have been lost from primary igneous biotite that shows no signs of subsequent internal deformation, alteration, or recrystallization. Updating occurred during mild thermal overprinting related to Hudsonian Orogeny.

GSC 72-67 Muscovite, K-Ar age 1635 ± 52 m.y.

$K = 8.90\%$, $^{40}Ar/^{40}K = 0.1524$, radiogenic Ar = 99%.
Concentrate: Relatively clean, clear muscovite with approximately 3% free chlorite contamination. Some of the mica flakes have a slight yellow staining of split edges.

From pegmatite.
(55 E) North shore of a small narrow lake in the Eskimo Point map-area, District of Keewatin, 61°32'50"N, 94°21'00"W. Sample DM-327-1969, collected and interpreted by A. Davidson.

The muscovite dated above is from a coarse, white pegmatite composed of quartz, microcline, and muscovite that forms an irregular mass within fine-grained, grey quartz-feldspar-biotite schists that locally contain garnet and cordierite. These metasediments are part of the Archean supracrustal rocks of the Ennadai - Rankin Inlet greenstone terrane. The pegmatite is related to intrusive masses of pegmatitic granite to the south and east which are known to be younger than sediments of the Hurwitz Group 20 miles east of the sample location. The age reported above is 'Hudsonian', and is a minimum age for the intrusion of pegmatitic granite along the southern border of the Ennadai - Rankin Inlet greenstone terrane.

Saskatchewan

(GSC No. 72-68)

GSC 72-68 Whole-rock, K-Ar age 1110 ± 120 m.y.

$K = 0.78\%$, $^{40}Ar/^{40}K = 0.0884$, radiogenic Ar = 92%.
Concentrate: Crushed whole-rock.

From diabase.
(74 N) 4 miles east of Turner Point, Lake Athabasca, Saskatchewan, 59°07'N, 108°28 1/2'W. See GSC Paper 55-33. Sample FA-10-69, collected and interpreted by W. F. Fahrig.

The determination was carried out on chilled material from a narrow dyke that cuts the Athabasca Fm. It therefore provides a minimum age for Athabasca sedimentation.

Manitoba

(GSC No. 72-69 to 72-80)

GSC 72-69 Hornblende, K-Ar age 2557 ± 62 m.y.

$K = 0.789\%$, $^{40}Ar/^{40}K = 0.3178$, radiogenic Ar = 98%.
Concentrate: Clean, pleochroic, brownish green to bluish green hornblende with only a slight trace of free biotite impurity.

From quartz diorite.
(62 P) 3 miles northwest of English Lake, Manitoba, 51°22'30"N, 96°17'00"W. Map-unit 10, Hecla-Carroll Lake area, GSC Paper 49-42. Sample EE69-1104, collected and interpreted by I. F. Ermanovics.

See biotite GSC 72-70 for description and interpretation.

GSC 72-70 Biotite, K-Ar age 2375 ± 66 m.y.

$K = 7.04\%$, $^{40}Ar/^{40}K = 0.2784$, radiogenic Ar = 98%.
Concentrate: Light greenish coloured biotite with about 6% chlorite alteration and a trace of hornblende impurity.

From quartz diorite.
(62 P) Details as for GSC 72-69.

These specimens have a similar geological setting to GSC 72-71. Again, GSC 72-69 gives the age of metamorphic hornblende (M_1- metamorphism) of the diorite-quartz diorite, whereas biotite GSC 72-70 represents M_2- metamorphism.

See GSC 72-73 for further discussion.

GSC 72-71 Hornblende, K-Ar age 2614 ± 70 m.y.

$K = 0.973\%$, $^{40}Ar/^{40}K = 0.3309$, radiogenic Ar = 99%.
Concentrate: Clean, pleochroic, olive-green to bluish green hornblende with less than 2% biotite contamination.

From amphibolite.
(52 M) 4 miles northeast of Wallace Lake, Manitoba, 51°03'40"N, 95°21'40"W. Map-unit 7b, GSC Paper 69-42 (Hecla-Carroll Lake). Sample EE165, collected and interpreted by I. F. Ermanovics.

The specimen comes from an amphibolite inclusion or dyke in metamorphosed diorite-quartz diorite which represent diapiric intrusions adjacent to the volcanic belt rocks (Ermanovics, 1971). The age for the specimen is that of metamorphic hornblende. It was collected 2 miles north of the locality at which recrystallized biotite from quartz diorite gave 2515 ± 72 m.y. (GSC 72-74). This biotite is thought to be M_2- metamorphism, whereas hornblende is thought to be M_1- metamorphism in the area.

See GSC 72-73 for further discussion.

GSC 72-72 Hornblende, K-Ar age 2586 ± 62 m.y.

K = 1.02%, $^{40}Ar/^{40}K$ = 0.3245, radiogenic Ar = 99%.
Concentrate: Non-pleochroic, fresh hornblende with about 5% free biotite contamination.

From quartz diorite.
(53 D) Horseshoe Lake, Manitoba, 52°11'10"N, 95°52'20"W. Map-unit 8, Berens River - Deer Lake area, GSC Paper 70-29. Sample EE69-1174, collected and interpreted by I. F. Ermanovics.

See GSC 72-73 for description and interpretation.

GSC 72-73 Biotite, K-Ar age 2518 ± 68 m.y.

K = 7.32%, $^{40}Ar/^{40}K$ = 0.3091, radiogenic Ar = 99%.
Concentrate: Clean, light brownish green biotite with less than 2% hornblende contamination.

From quartz diorite.
(53 D) Details as for GSC 72-72.

The geological setting for these specimens is similar to that of GSC 72-69, 70 and 71, but the retrogressive metamorphic M_2-fabric shear-foliation is absent at the locality sampled. Both biotite and hornblende give M_1-metamorphic ages but because M_2-metamorphism was absent, the age spread between the minerals is smaller and may actually reflect relative argon retentivity (in cooling from upper amphibolite facies metamorphism) in this geological environment.

The dioritic rocks from which the above specimens were collected are the earliest major intrusions known in Manitoba, between latitudes 51 to 54 degrees (Ermanovics, 1971). Although they intrude the volcanic rocks, the magmas represented by these plutons are probably coeval with the last lavas comprising the volcanic rocks. The plutons are generally full of amphibolitic and gabbroic inclusions, and are commonly intruded by later, acid plutonic rocks. Metamorphism to upper amphibolite facies has recrystallized the mineralogy of these plutons and some portions (probably old) of greenstone belts; a common second metamorphism, related to shearing, effects 'greenschisting' and stabilized epidote, albite, biotite and chlorite. A total-rock and mineral Rb-Sr isochron of a diorite in this area gives a metamorphic age of 2555 ± 70 m.y. with an initial $^{87}Sr/^{86}Sr$ of 0.7016 ± 0.0012 (Turek and Peterman, 1971); this age is comparable to the metamorphic hornblende K/Ar ages. The same authors find that cataclastic zone rocks give a whole-rock isochron of 2345 ± 100 m.y.; this age is comparable to the younger biotite K/Ar age obtained in one of the present samples GSC 72-70. An earlier major Rb-Sr metamorphic event at 2730 ± 50 m.y. defined by these authors appears to be beyond the limit of the K/Ar method. (Note - all Rb-Sr isochron ages herein referred to have been based on a rubidium 87 decay constant of 1.39×10^{-11} yr^{-1}.)

Although there appears to be little doubt as to the greater capacity of hornblende, as compared to biotite, to retain argon it is also true that every biotite-hornblende pair cannot be interpretated in this way. The present array of K/Ar determinations seems to suggest that the biotite-hornblende pair in GSC 72-69, 70 reflects two metamorphisms (substantiated by Rb-Sr isochrons) whereas the Horseshoe Lake pair (GSC 72-72, 73), where the M_2-metamorphism is absent, show relative Ar retentivity.

References

Ermanovics, I. F.
1971: 'Granites', 'granite gneiss' and tectonic variation of the Superior Province in southeastern Manitoba; Geol. Assoc. Can., Spec. Paper No. 9, p. 77.

Turek, A., and Peterman, Z. E.
1971: Advances in the geochronology of the Rice Lake-Beresford Lake area, southeastern Manitoba; Can. J. Earth Sci., v. 8, p. 572.

GSC 72-74 Biotite, K-Ar age 2515 ± 72 m.y.

$K = 8.00\%$, $^{40}Ar/^{40}K = 0.3086$, radiogenic Ar = 99.4%.
Concentrate: Clean, light greenish biotite with no visible impurities.

From hornblende-biotite granodiorite.
(52 M) East shore of lake 4 miles north of Wallace Lake, Manitoba, 51°05'40"N, 95°22'35"W. Map-unit 4, Manitoba Dept. of Mines Map 47-1. Sample SH-22-59, collected by C.H. Stockwell and interpreted by I. F. Ermanovics.

The granodiorite is a medium-grained, dark grey, gneissic rock composed chiefly of quartz, oligoclase, orthoclase, biotite, and hornblende. The biotite is unchloritized, epidote is plentiful, and titanite, magnetite, and apatite are accessory. The body from which the sample was taken has been named the Wallace Lake granite which is mapped as the older of two granites; the younger is the Aikens Lake granite (GSC 60-87; 2,440 m.y.).

See GSC 72-76 for general discussion.

Manitoba

GSC 72-75 Biotite, K-Ar age 2510 ± 72 m.y.

$K = 7.62\%$, $^{40}Ar/^{40}K = 0.3067$, radiogenic Ar = 99.4%.
Concentrate: Light greenish brown biotite with about 15% chloritization.

From quartz monzonite.
(53 D) Apisko Lake, Manitoba, 52°32'20"N, 95°22'30"W. Map-unit 7, Berens River - Deer Lake area, GSC Paper 70-29. Sample EE69-1084, collected and interpreted by I.F. Ermanovics.

The rock is a pink, medium grained, leucocratic sample of the Apisko Lake quartz monzonite.

See GSC 72-76 for interpretation.

GSC 72-76 Biotite, K-Ar age 2555 ± 70 m.y.

$K = 7.64\%$, $^{40}Ar/^{40}K = 0.3176$, radiogenic Ar = 99%.
Concentrate: Relatively clean, brownish green biotite with less than 2% free chlorite contamination.

From syenodiorite.
(63 A) 16 miles north-northeast of Weaver Lake, Manitoba, 52°58'35"N, 96°40'W. Map-unit 6a, Berens River - Deer Lake area, GSC Paper 70-29. Sample EE69-1316, collected and interpreted by I.F. Ermanovics.

The rock is a coarse-grained, weakly foliated syenodiorite consisting of plagioclase, biotite, quartz and alkali feldspar. Plagioclase and quartz form ovoid pods or layers.

In the Berens plutonic belt of southeastern Manitoba leucocratic quartz monzonite forms the youngest (post orogenic) plutons. On the other hand, areas adjacent to volcanic belts, comprise older synorogenic plutons of mafic diorite and quartz diorite. Both quartz monzonite and mafic dioritic plutons are metamorphosed. In the diorites this is expressed as rock foliation, epidotized plagioclase, recrystallized quartz and biotite and porphyroblastic hornblende in various states of digestion and recrystallization. In leucocratic quartz monzonite only quartz can be demonstrated to have been recrystallized; the lack of a reference state for biotite in these rocks makes it difficult for that mineral to be interpreted as metamorphic. However, if the recrystallization of quartz is accompanied by sufficient heat then it is likely that the ages for both the Apisko Lake (2510 ± 72 m.y., GSC 72-75), and Weaver Lake (2555 ± 70 m.y., GSC 72-76) quartz monzonite plutons is a metamorphic event which is in keeping with the 2450 m.y. ages (GSC 61-128, 129) obtained on metamorphic biotite and muscovite from sediments of the Rice Lake greenstone belt. The age obtained for the mafic dioritic body (2515 ± 72 m.y., GSC 72-74) north of Wallace Lake is also a metamorphic age and within the sample and analytical errors fits the general scheme of metamorphic K-Ar thermal events in the area.

Manitoba

The tenet that the quartz monzonites might be post diorite metamorphism was based on an earlier analysis (GSC 60-88, 2670 m.y.) and does not hold in view of a redetermination of the same sample now shown to be 2515 ± 72 m.y. (GSC 72-75).

GSC 72-77 Biotite, K-Ar age 1900 ± 55 m.y.

$K = 7.28\%$, $^{40}Ar/^{40}K = 0.1917$, radiogenic Ar = 99%.
Concentrate: Impure greenish biotite with about 28% chlorite detected by X-ray diffraction. Optically the chlorite is not very evident except for the free flakes of that mineral.

From quartz monzonite.
(53 M) South shore of Bigstone River at point where the easterly flowing stream turns sharply northeasterly, Manitoba, 55°37'25"N, 95°04'15"W. Map-unit 7, GSC Map 55-8. Sample BA-U60, collected and interpreted by C.K. Bell.

A very fine grained (aplitic), massive to faintly gneissic, pink, quartz monzonite. Plagioclase (42%); quartz (minor myrmekite) 33%; microcline (20%); biotite (4%); chlorite (1%); apatite and magnetite (tr.).

This quartz monzonite occurs in the Superior Province (Cross Lake subprovince) approximately 4 miles south of the southern boundary of what has been interpreted as the Pikwitonei province (Bell, 1971) and 2 miles north of an Archean greenstone belt. The date 1900 ± 55 m.y. is anomalous and typical of those obtained from rocks lying in the same geotectonic position in the Cross Lake area to the west. In the Cross Lake subprovince, any dates on Archean rocks that fall between Kenoran and Hudsonian ages have been interpreted as the product of Hudsonian rejuvenation.

References

Bell, C.K.
1971: Boundary geology, Upper Nelson River area, Manitoba and Northwestern Ontario; Geol. Assoc. Can., Spec. Paper No. 9, p. 11-39.

GSC 72-78 Biotite, K-Ar age 1630 ± 50 m.y.

$K = 7.02\%$, $^{40}Ar/^{40}K = 0.1516$, radiogenic Ar = 99%.
Concentrate: Impure light green biotite with about 23% chlorite detected by X-ray diffraction. Optically the chlorite is not very evident.

From quartz monzonite.
(53 M) On island in eastward flowing river draining into head of Stupart Lake, Manitoba, 55°32'08"N, 94°40'25"W. Map-unit 7, GSC Map 55-8. Sample BA-U73, collected and interpreted by C.K. Bell.

Manitoba

Medium-grained, hypidiomorphic granular, orange-grey, quartz monzonite. Locally gneissic. Oligoclase (32%); microcline (perthite) (32%); quartz (32%); biotite (3%); pyroxene, hornblende, chlorite, muscovite and zircon (Tr.).

This quartz monzonite lies 17 miles ESE of BA-U60 (GSC 72-77) and is from northern boundary area of the Cross Lake subprovince. The quartz monzonite is in the same geotectonic position as BA-U60 relative to the Pikwitonei province and to what appears on the aeromagnetic map (GSC 7134G) to be the ESE extension of the Archean greenstone belt mentioned in the description of BA-U60. The quartz monzonite is considered to be Archean that has been rejuvenated during the Hudsonian event. The date is in accord with the other anomalous dates found along the north edge of the Superior Province.

GSC 72-79 Biotite, K-Ar age 2610 ± 70 m.y.

$K = 7.54\%$, $^{40}Ar/^{40}K = 0.3298$, radiogenic Ar = 99.5%.
Concentrate: Clean, unaltered, dark green biotite with 3% hornblende contamination.

From gneiss.
(53 N) Northernmost point of peninsula at northeast end of Stupart Lake, Manitoba, 55°39'00"N, 93°59'30"W. Map-unit 7, GSC Map 17-1962, Paper 62-8. Sample BA-U72, collected and interpreted by C.K. Bell.

See GSC 72-80 for description and interpretation.

GSC 72-80 Hornblende, K-Ar age $\frac{2355 \pm 72 \text{ m.y.}}{2300 \pm 72 \text{ m.y.}}$

$K = 1.31\%$, $^{40}Ar/^{40}K = \frac{0.2742}{0.2630}$, radiogenic Ar = $\frac{99\%}{99\%}$.
Concentrate: Clean, unaltered, dark green hornblende with about 3% mica contamination.

From gneiss.
(53 N) Details as for GSC 72-79.

Medium-grained, dark grey, oligoclase - quartz - hornblende - biotite (granodioritic) gneiss. Locally porphyroblastic and slightly cataclastic. Oligoclase (50%); quartz (25%); hornblende (12%); biotite (12%); apatite (tr.).

The aeromagnetic pattern (GSC 7133G) suggests that this granodioritic gneiss occurs along the north side of the Pikwitonei province. In this area, the granodiorite is flanked on the north by Aphebian (?) supracrustal rocks of the Fox River complex. Hence the granodioritic gneiss is from close (±4 miles) to the Pikwitonei - Churchill provinces boundary and would lie in the same geotectonic position as the amphibolite facies gneisses that flank the northeast edge of the Pikwitonei province in the Upper Nelson River area (Bell, 1971, Fig. 1). These gneisses are interpreted to be the polymetamorphic equivalents of the Pikwitonei province granulites. They may have been retrogressively metamorphosed during the Kenoran and/or Hudsonian events.

The biotite date of 2610 ± 70 m.y. could reflect either Kenoran or Hudsonian thermal rejuvenation of basement rocks that are probably older than 3000 m.y. Because of the high T-P conditions under which the Pikwitonei province granulite facies members formed, they were not as susceptible to thermal updating as were the water-rich Archean rocks of the Cross Lake sub-province. Hence their K-Ar ages have shown less fluctuations than those in the Cross Lake sub-province rocks and they have remained at 2400 m.y. or older. (See GSC 66-108, and discussion therein.)

Two runs on hornblende from this same rock gave 2355 ± 72 m.y. and 2300 ± 72 m.y. (GSC 72-80). The hornblende contains about 3% mica contamination. The younger date suggests averaging-down by a younger generation (possibly Hudsonian) mica than the mica that was dated at 2610 ± 70 m.y. (GSC 72-79).

Reference

Bell, C.K.
1971: Boundary geology, Upper Nelson River area, Manitoba and Northwestern Ontario; Geol. Assoc. Can., Spec. Paper No. 9, p. 11-39.

Ontario

(GSC No. 72-81 to 72-87)

GSC 72-81 Whole-rock, K-Ar age 993 ± 40 m.y.

$K = 0.533\%$, $^{40}Ar/^{40}K = 0.0765$, radiogenic Ar = 96%.
Concentrate: Crushed whole-rock.

From diabase.
(52 A) South of Thunder Bay, Ontario, 48°03'N, 89°33'W. Map-unit 4, GSC Map 355A. Sample FA-11-69, collected and interpreted by W. F. Fahrig.

The sample was obtained from the northeasterly trending Thunderbay Dykes which are also known as the Logan dykes (Robertson and Fahrig, 1971). This whole-rock age is in good agreement with other work (Robertson and Fahrig, 1971) suggesting that these intrusions are 1000 to 1100 m.y. old.

Reference

Robertson, W. A., and Fahrig, W. F.
1971: The great Logan paleomagnetic loop- the polar wandering path from the Canadian Shield rocks during the Neohelikian era; Can. J. Earth Sci., v. 8, p. 1355-1372.

GSC 72-82 Biotite, K-Ar age 1015 ± 36 m.y.

$K = 6.87\%$, $^{40}Ar/^{40}K = 0.0789$, radiogenic Ar = 97%.
Concentrate: Relatively clean, light brownish orange biotite with approximately 3% free chlorite impurity.

From gabbro.
(42 D) Little Pic River at bridge on Killala Lake road, Ontario, 48°43'N, 86°23'W. Ont. Dept. Mines Map P114. Sample 70035, collected and interpreted by K. L. Currie.

The sample is a fine-grained, banded rock consisting of labradorite, augite, and biotite. The presence of biotite is the sole indication of alkaline affinity of the rock. This rock was mapped by Puskas (1967) as part of a shell of gabbro surrounding the eastern part of the Port Coldwell complex. It also is possible that it could be a part of the Archean greenstone belt to the east. The date obtained, 1015 m.y., is essentially the same as that of the Port Coldwell complex (GSC 72-83). This is compatible with Puskas' hypothesis, but not with the idea that the rock is much older, unless it has been severely metasomatized, which seems unlikely from the petrography.

Ontario

GSC 72-83 Biotite, K-Ar age 1005 ± 36 m.y.

$K = 7.00\%$, $^{40}Ar/^{40}K = 0.0775$, radiogenic Ar = 98%.
Concentrate: Clean, light brown biotite with no visible impurities.

From granodiorite.
(42 D) Highway 17, 1/2 mile west of Big Pic River, Ontario, 48°54'N, 86°39'W. Map-unit 15, Ont. Dept. Mines Map P114. Sample 70190 collected and interpreted by K. L. Currie.

The sample is a pale pink, coarse-grained, homogeneous, granitoid rock composed mainly of oligoclase tablets, orthoclase and biotite. Original hornblende has been pseudomorphously replaced by pyroxene plus biotite. This rock, on the northwest side of the Port Coldwell complex, was considered to intrude the complex by Puskas (1967). The author considers it more probable that it is a fenitized wall-rock of the complex. The measured date, 1005 ± 36 m.y. is essentially the same as that deduced by Bullwinkel et al. (1958) for the complex itself. This is compatible with specimen GSC 72-82 being a strongly metasomatized wall-rock of the Port Coldwell complex, but not with its being an unaltered wall-rock. GSC 72-82 could be part of a later intrusive only if it is related to the Port Coldwell complex, which seems petrographically and petrologically unlikely.

GSC 72-84 Phlogopite, K-Ar age 1115 ±45 m.y.

$K = 5.74\%$, $^{40}Ar/^{40}K = 0.0931$, radiogenic Ar = 99%.
Concentrate: Brownish orange phlogopite with less than 5% attached feldspar impurity. Many of the mica flakes have good crystal form and some have darker brown biotite rims.

From carbonatite.
(42 B) Kapuskasing River in Teetzel Twp., about 10 miles north of Kapuskasing, Ontario, 48°35'00"N, 82°11'10"W. Sample BEN-1, collected by G. Bennett (Ont. Dept. Mines) and interpreted by K. L. Currie.

The occurrence is described by Bennett et al., 1967 as being a more or less concordant carbonate-rich zone surrounded by a halo of mafic silicate rocks, the whole lying within a migmatite complex. The age, 1155 m.y., is reasonably concordant with that of nearby circular nephelinitic-carbonatite complexes on the Kapuskasing high, such as Lackner Lake, but the form is more suggestive of the tabular ultramafic carbonatite complex as such as Cargill which commonly have ages of 1650 to 1750 m.y. In any case the age is much younger than K-Ar ages obtained from the surrounding granitoid rocks of the Superior Province, suggesting that the occurrence is an intrusive complex, not a carbonate layer within the migmatites of the Superior Province.

Ontario

Reference

Bennett, G., Brown, D.D., George, P.T., and Leahy, E.J., Operation
1967: Kapuskasing, Ont. Dept. Mines, Misc. Paper 10, p. 68-70.

GSC 72-85 Whole-rock, K-Ar age 128 ± 18 m.y.

K = 0.90%, $^{40}Ar/^{40}K$ = 0.0078, radiogenic Ar = 56%.
Concentrate: Crushed whole-rock.

From lamprophyre.
(42 I) West bank of Abitibi River, 4.5 kilometres north of Coral Rapids Post Office, Ontario, 50°14'15"N, 81°40'00"W. See Ont. Dept. Mines Map P370. Sample 29BK/67-2, collected by H.H. Bostock, interpreted by A.W. Norris.

The rock is a fine-grained, dark blue-grey lamprophyre with dark grey phenocrysts.

Dykes and sills of lamprophyric and kimberlitic composition have intruded the Devonian sedimentary rocks in the vicinity of Sextant and Coral Rapids on Abitibi River at the southern edge of the Moose River Basin. The Devonian formations intruded comprise the Sextant, Stooping River and Kwataboahegan. The outcrops of ultramafic rocks are highly conspicuous, easily accessible along the river, and located near the railway line, and for this reason they have been examined and described by numerous geologists. Some of the more recent descriptions of these rocks are by Martison (1953, p. 43), Bennett et al. (1967, p. 31-35), Brown et al. (1967), and George et al. (1967, p. 10-11) who incorporated data from diamond drill cores provided by the Hydro-Electric Power Commission of Ontario. The ultramafic rocks outcrop at three main localities along Abitibi River, at Sextant Rapids and at the head and foot of Coral Rapids, about 2 and 2.7 miles downstream respectively.

At Sextant Rapids the main ultramafic body is a lamprophyre sill, about 60 feet thick in the Sextant Formation, which extends across the river as a sheet. Numerous small irregular ultramafic apophyses cutting the Sextant Formation are present in this area along the west bank of Abitibi River. A description of the lamprophyre has been given by O.E. LeRoy in Wilson (1903, p. 237) as follows: "The hand specimens represent a very dark, almost black augite lamprophyre of a type closely allied to the monchiquites. The section consists of aggregates of calcite and serpentine as pseudomorphs after olivine, and pale-brown and pink idiomorphic augites in a groundmass of augite, shreds of biotite, calcite, chlorite, magnetite, and a fibrous zeolite". The zeolite was later identified as thomsonite by Walker (1932).

At the head of Coral Rapids, 2 miles downstream from Sextant Rapids, a lamprophyre sill about 60 feet thick, is partly exposed on the west bank of Abitibi River, and extends along the contact between the Sextant and Stooping River Formations.

At the foot of Coral Rapids on the west bank of Abitibi River a composite dyke is exposed consisting of lamprophyre and kimberlitic rock. The latter rock is described by Bennett et al. (1967, p. 34) as pale green, moderately soft, and exhibits a fragmental texture. The composite dyke is 80 to 100 feet wide, is at least 1,400 feet long, strikes southeast, and has a vertical dip.

Drilling by the Hydro-Electric Power Commission of Ontario in the vicinity of Coral Rapids has demonstrated that the ultramafic rocks occur in the Precambrian basement and also intrude more than 50 feet of the Sextant Formation, 35 feet of the Stooping River Formation, and 20 feet of the Kwataboahegan Formation.

The relationship of the ultramafic rocks to the sedimentary rocks of the area clearly indicates post early Middle Devonian (Eifelian) age for their intrusion. Potassium-argon age determination on lamprophyric rock collected from the west bank of Abitibi River at the south end of the dyke exposed at the foot of Coral Rapids indicates 128 ± 18 m.y. This dating suggests that the intrusion occurred during the late Jurassic to early Cretaceous time, about the same age as the Monteregion Intrusions in Quebec that are also dated late Jurassic to early Cretaceous (Sanford and Norris, 1970, p. 145).

References

Bennett, G., Brown, D.D., George, P.T., and Leahy, E.J.
1967: Operation Kapuskasing; Ont. Dept. Mines, Misc. Paper MP-10.

Brown, D.D., Bennett, G., and George, P.T.
1967: The source of alluvial Kimberlite indicator minerals in the James Bay Lowland; Ont. Dept. Mines, Misc. Pub. MP-7, 1967.

George, P.T., Brown, D.D., and Bennett, G.
1967: Operation Kapuskasing; Ont. Dept. Mines reprint of paper presented at 35th Ann. Meeting, Prospectors and Developers Assoc., Toronto, March 8, 1967, 44 p.

Martison, N.W.
1953: Petroleum possibilities of the James Bay Lowland area; Ont. Dept. Mines, v. 61, 1952, Pt. 6, p. 1-58, plus appendices (p. 59-95).

Ontario Department of Mines
1966: Otter Rapids Sheet, District of Cochrane; Ont. Dept. Mines, Prelim. Geol. Map No. P. 370, scale: 1 inch to 2 miles.

Sanford, B.V., and Norris, A.W.
1970: Hudson Platform; in Douglas, R.J.W., ed., Geology and Economic Minerals of Canada; Geol. Surv. Can., Econ. Geol. Rept. No. 1, 5th edition, ch. IV, p. 137-145.

Sanford, B.V., Norris, A.W., and Bostock, H.H.
1968: Geology of the Hudson Bay Lowlands (Operation Winisk); Geol. Surv. Can., Paper 67-60, p. 1-45.

Ontario

Walker, T. L.
1932: Thomsonite from Sextant Rapids, Timiskaming District, Ontario; Univ. Toronto Studies, Geol. Ser. No. 32, p. 5.

Wilson, W. J.
1903: Reconnaissance surveys of four rivers southwest of James Bay; Geol. Surv. Can., Ann. Rept. 1902-03, v. 15, Rept. A, p. 222-243.

GSC 72-86 Hornblende, K-Ar age 925 ± 40 m.y.

K = 0.797%, $^{40}Ar/^{40}K$ = 0.0698, radiogenic Ar = 93%.
Concentrate: Clean, unaltered, non-pleochroic, light green hornblende with no visible impurities.

From mafic band in marble.
(31 F) 0.5 mile south of Lavant Long Lake and 2.5 miles west of Clyde Forks village, Ontario, 45°08'N, 76°41'W. See ODM Map 1956-4. Sample JH-01, collected and interpreted by I. R. Jonasson.

See GSC 72-87 for description and interpretation.

GSC 72-87 Biotite, K-Ar age 839 ± 30 m.y.

K = 7.87%, $^{40}Ar/^{40}K$ = 0.0618, radiogenic Ar = 96%.
Concentrate: Very clean, unaltered, pale brown biotite with no visible impurities.

From mafic band in marble.
(31 F) Details as for GSC 72-86.

These determinations (GSC 72-86 and GSC 72-87) are on minerals from a mafic band in marble at the site of the Lanark Silver prospect. These diagnostic age determinations are of particular interest as this is the only recorded occurrence of cinnabar in the Canadian Shield and is therefore quite unusual.

The mafic band has a colour index of approximately 60 and the hornblende is dark green. Texture is predominantly idiomorphic and no megascopic crenulations are apparent. Calcite, biotite and hornblende are all in the size range of 1-2 mm. Minor pyrite is disseminated throughout the rock but tends to be concentrated near the biotite-hornblende and calcite contacts. Some chlorite has developed at the expense of hornblende but otherwise the rock is fresh.

The prospect has been considered to be either Proterozoic or Cretaceous. A Proterozoic age has been considered because the ore minerals are believed to be the same age as the host rock which lies entirely in the Grenville province and a Cretaceous age has been considered because the mineralization may somehow be related to the Ottawa Valley graben system.

Ontario

Although both determinations suggest a Precambrian age, the question is not satisfactorily resolved because of uncertainties associated with specimen selection. Further sampling of this unusual occurrence has been undertaken in the hope of settling the problem.

Quebec

(GSC No. 72-88 to 72-105)

GSC 72-88 Phlogopite, K-Ar age 862 ± 31 m.y.

$K = 8.63\%$, $^{40}Ar/^{40}K = 0.0639$, radiogenic Ar = 97%.
Concentrate: Clean, very light brown phlogopite with no visible impurities.

From mica-microcline rock.
(31 G) Adit of Haycock Mine, Quebec, 45°33'12"N, 75°43'15"W. Map-unit 7b, GSC Paper 70-20. Sample GHC-7, collected by D.D. Hogarth (Ottawa Univ.), interpreted by K.L. Currie and D.D. Hogarth.

The age dates fenite surrounding magnetite veins at the long-abandoned Haycock Iron mine near Cantley, Quebec. The fenite is composed of acmite, phlogopite and minor eckermannite and is thought to be contemporaneous with phlogopite-eckermannite fenites surrounding carbonatites near Meach Lake, Quebec which give an average date of 920 m.y.

GSC 72-89 Hornblende, K-Ar age 944 ± 40 m.y.

$K = 1.17\%$, $^{40}Ar/^{40}K = 0.0717$, radiogenic Ar = 98%.
Concentrate: Clean, pleochroic, light brown to dark green hornblende with a trace of biotite contamination.

From gneiss.
(32 B) Near Lac aux Cèdres, Bernier Twp., Quebec, 48°29'N, 75°35'W. Sample CZ-410-68, collected and interpreted by B.W. Charbonneau.

The rock is from a narrow band of hornblende gneiss in a mixed unit which is dominantly granitoid in composition. The age of 944 ± 40 m.y. is interpreted as Grenville.

See GSC 72-90 for further discussion.

GSC 72-90 Hornblende, K-Ar age 1223 ± 48 m.y.

$K = 0.928\%$, $^{40}Ar/^{40}K = 0.1007$, radiogenic Ar = 97%.
Concentrate: Clean, pleochroic, light brown to dark green hornblende with a trace of biotite contamination.

From gneiss.
(32 C) Near Lac Serpent, Valmy Twp., Quebec, 48°18'N, 76°05'W. Sample CZ-413-68, collected and interpreted by B.W. Charbonneau.

Quebec

The rock is from a minor band of hornblende gneiss in a mixed gneiss unit which is dominantly granitoid in composition. The hornblende gneiss is composed of green clinopyroxene, plagioclase (oligoclase-andesine), biotite, some clinopyroxene, quartz, minor garnet, magnetite, sphene, carbonate. The hornblende gneiss is the major lithology underlying a large magnetic anomaly in the area which was the reason for the study (Charbonneau, 1969). The age of 1223 ± 48 m.y. is Kenoran updated considerably by proximity to the Grenville boundary.

In summary a total of six age determinations (locations shown on diagram 1) were obtained in support of this project. Four of these ages were reported last year (Wanless et al., 1972). Two determinations, GSC 70-94 hornblende (978 ± 40 m.y.) and GSC 70-95 biotite (973 ± 36 m.y.) date the age of intrusion of a mafic carbonatite body. The following four age determinations are on gneissic metamorphic rocks:-

GSC 70-92	Hornblende	- 2195 ± 68 m.y.
GSC 70-93	"	- 1950 ± 53 m.y.
GSC 72-89	"	- 944 ± 40 m.y.
GSC 72-90	"	- 1223 ± 48 m.y.

These constitute a section across the Grenville-Superior boundary in the area. The determinations are listed below in order of distance from the front. The front is gradational in this area and the distances of samples GSC 70-92, 93 from the front have been revised slightly from the initial estimate reported last year (Wanless et al., 1972).

Sample No.		distance from front	age
GSC 72-89	Hornblende	0 mile	944 ± 40 m.y.
GSC 72-90	"	2 miles	1223 ± 48 m.y.
GSC 70-93	"	8 miles	1950 ± 53 m.y.
GSC 70-92	"	10 miles	2195 ± 68 m.y.

Diagram No. 2 shows the ages transferred into a single section. Accepting the Grenville mean age as 955 m.y. and the Kenoran mean age as 2480 m.y. (Wanless, 1969), the full Kenoran age would be reached about two miles farther to the northwest (based on extrapolation of the age vs distance relationship shown on diagram No. 2). Thus the full age transition from the Kenoran age of 2480 m.y. in the Superior Province to the Grenvillian age of 955 m.y. in the Grenville province is accomplished in a transition zone about 12 miles wide in this area.

Quebec

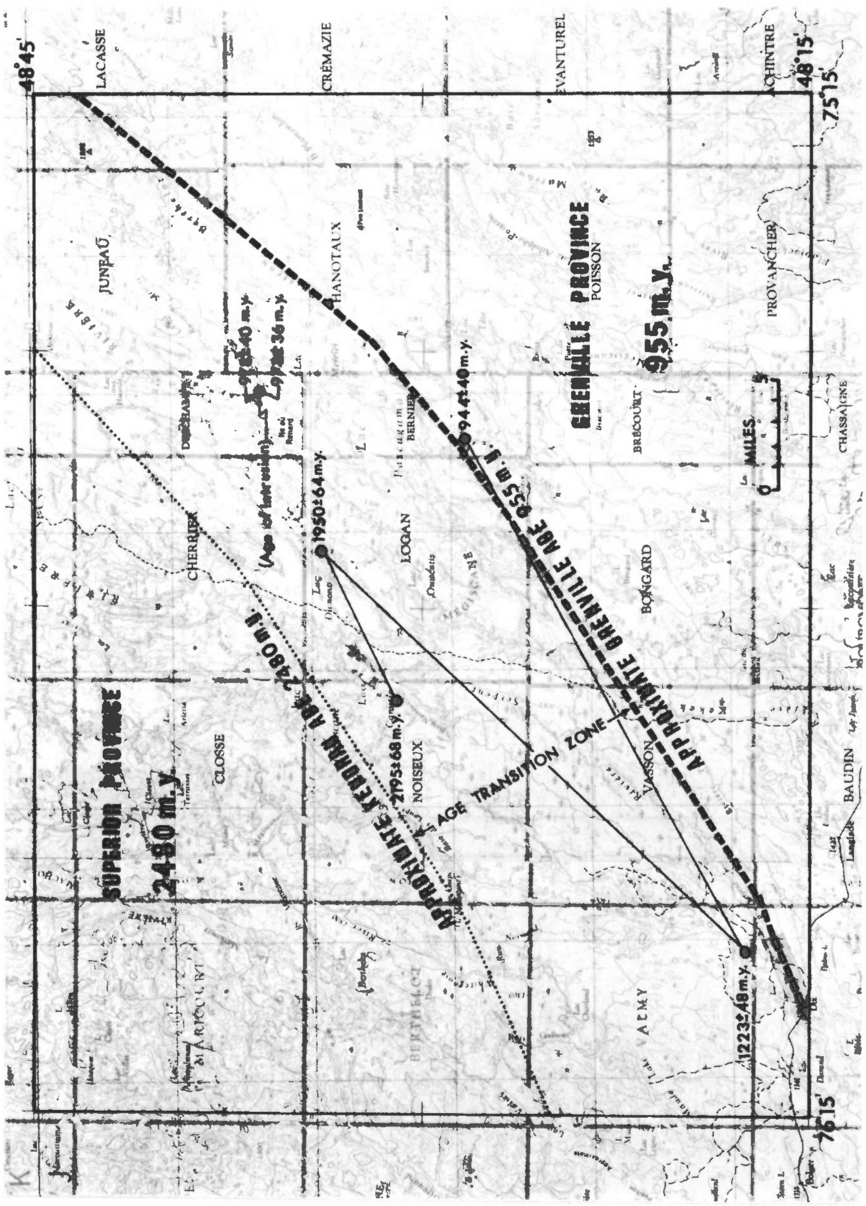

Figure 3. Position of K-Ar age determinations across Grenville - Superior boundary, Mégiscane Lake area, Quebec.

Quebec

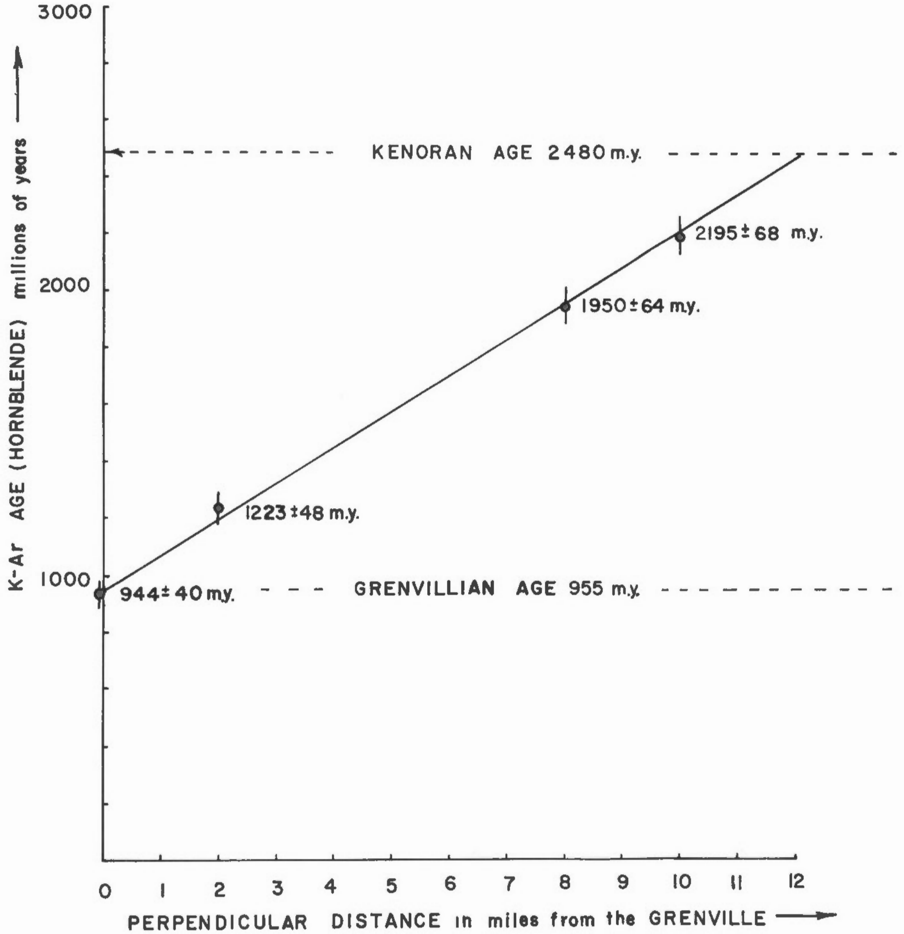

Figure 4. K-Ar age determinations for hornblendes from the Grenville - Superior boundary region, Mégiscane Lake area, Quebec.

References

Charbonneau, B. W.
1969: "A Grenville Front Magnetic Anomaly" Megiscane Lake area, Quebec, part of 32 B W 1/2, 32 C E 1/2, GSC Paper 69-1, Part A, p. 70-72.

Wanless, R. K.
1969: "Isotopic Age Map of Canada"; Geol. Surv. Can., Map 1256A. Scale 1:5,000,000.

Wanless, R. K., Stevens, R. D., Lachance, G. R., and Delabio, R. N.
1972: Age determinations and geological studies. K-Ar Isotopic ages Report 10, p. 58-60; Geol. Surv. Can., Paper 71-2.

Quebec

GSC 72-91 Hornblende, K-Ar age 2706 ± 144 m.y.

$K = 0.059\%$, $^{40}Ar/^{40}K = 0.3530$, radiogenic Ar = 80%.
Concentrate: Clean, pleochroic, bluish green to brownish green hornblende with a trace of chlorite impurity. (Note low potassium concentration.)

From mineralized anorthosite.
(32 G) 8-2 Drift, Cedar Bay Mine, Chibougamau area, Quebec, 49°54'N, 74°18'10"W. Quebec Dept. Mines Map No. 1293. Sample KQ-70 Cedar Bay, collected by mine geologist and interpreted by R.V. Kirkham.

The sample consisted of about 97 per cent massive, medium to dark green, vitreous, coarse-grained amphibole cut by two 1/32-inch wide carbonate veinlets with minor pyrite.

The amphibole occurs as an alteration product of anorthosite along the copper-bearing transgressive structures of the Doré Lake complex. This date, although it remains to be substantiated, supports the theory that the Doré Lake complex and the transgressive copper ores of the Chibougamau camp are Archean. The fact that the Doré Lake complex and the copper-bearing zones, here suggested to be 2706 ± 144 m.y., have both been extensively deformed and lie within the boundaries of the Superior Province is also suggestive of an Archean age.

GSC 72-92 Biotite, K-Ar age 1240 ± 45 m.y.

$K = 7.06\%$, $^{40}Ar/^{40}K = 0.1024$, radiogenic Ar = 98%.
Concentrate: Light orange coloured biotite with about 5% free chlorite contamination.

From coarse diabase.
(24 J) Southern Ungava Bay, Quebec, 58°13'N, 67°58'W. Sample TA67-T146, collected and interpreted by F.C. Taylor.

This sample is from a swarm of sheet-like diabase dykes that extend across the south of Ungava Bay. This sample is from the same swarm as whole-rock sample GSC 67-115 (1270 ± 115) which is from the chill zone of a dyke. The K-Ar age is considered to be the approximate age of the intrusion.

GSC 72-93 Biotite, K-Ar age 1585 ± 52 m.y.

$K = 7.82\%$, $^{40}Ar/^{40}K = 0.1452$, radiogenic Ar = 99%.
Concentrate: Relatively clean, light greenish coloured biotite with a few brownish flakes.

From granite.
(24 A) About 22 miles west of Wedge Point, George River, Quebec, 56°24'15"N, 65°19'15"W. Sample TA69-T037, collected and interpreted by F.C. Taylor.

Quebec

This sample is from a light grey massive to moderately foliated, porphyritic, biotite granodiorite. The K-Ar age is considered to be the age of intrusion of this synorogenic granodiorite - a product of the Hudsonian orogeny.

GSC 72-94 Hornblende, K-Ar age 1605 ± 60 m.y.

$K = 1.32\%$, $^{40}Ar/^{40}K = 0.1483$, radiogenic Ar = 96%.
Concentrate: Clean, non-pleochroic, light brownish coloured hornblende with no visible contamination.

From granulite.
(24 I) Ungava area, Quebec, 58°06'N, 64°02'W. Sample BA-233, collected by C.K. Bell, interpreted by F.C. Taylor.

This sample is from a mafic and relatively massive phase of granulite. The K-Ar age is considered to be the age of the metamorphism.

GSC 72-95 Biotite, K-Ar age 817 ± 30 m.y.

$K = 7.53\%$, $^{40}Ar/^{40}K = 0.0598$, radiogenic Ar = 98%.
Concentrate: Clean, light brown biotite with less than 1% chlorite alteration.

From gneissic granodiorite.
(12 E) Atlantic Richfield (ARCO) Anticosti No. 1 drillhole, basement Core No. 3, 12611.2 - 12611.8 feet, 1 mile northeast of The Jumpers, south shore of Anticosti Island, Quebec, 49°23'30"N, 63°31'30"W. Sample PB70-169. Collected by E.G. Petrie (Atlantic Richfield), interpreted by W.H. Poole.

The sample consisted of a 4-inch core, seven inches long, of a dark red to reddish grey, medium- to coarse-grained, vaguely banded granitic rock. Dark green-grey carbonate-chlorite-feldspar-quartz crush-veinlets cut the rock. The bulk of the rock consists of about 25% slightly strained quartz, 20% slightly clouded potash feldspar, 45% plagioclase altered to white mica and carbonate, and the remainder of biotite, chlorite after hornblende, and accessories. Biotite is undeformed and pleochroic yellow to red-brown, and contains dark alteration products along the cleavages.

The 817 m.y. date is somewhat low for typical Grenvillian ages. Most dates near and north of Gulf of St. Lawrence range from the mid-800's to high 900's. Perhaps the alteration associated with the veinlets in the sample contributed to a slight loss of ^{40}Ar.

Quebec

GSC 72-96 Hornblende, K-Ar age 443 ± 18 m.y.

$K = 0.287\%$, $^{40}Ar/^{40}K = 0.0292$, radiogenic Ar = 78%.
Concentrate: Clean, pleochroic dark olive-green to brownish yellow hornblende with no visible alteration or impurity.

From amphibolite.
(22 B) Road outcrop 1/4 mile north of mouth of Ruisseau Isabelle, Trans Gaspesian Highway, Shickshock Mountains, Quebec, 48°52'50"N, 66°06'45"W. Map-unit 1, Quebec Dept. Nat. Res., Map 1584. Sample PB70-136. Collected and interpreted by W.H. Poole.

The amphibolite is dark grey-green, fine to medium grained, dense and well foliated, and consists dominantly of hornblende. Hornblende is unaltered, well crystallized, and pleochroic light yellow to bright green to dark olive-green, and is linearly oriented within the foliation. Feldspar is untwinned, altered to fine white mica, and planar oriented parallel with the foliation. Accessory well-crystallized sphene is abundant and apatite minor. Epidote, feldspar and calcite microveinlets are rare.

The amphibolite is a major component in regionally metamorphosed basic volcanic and sedimentary rocks of the Shickshock Group of uncertain age, probably Cambrian-Early Ordovician. The age of regional metamorphism is also uncertain but probably pre-Middle Ordovician from regional stratigraphic and structural reconstructions.

The date of 443 ± 18 m.y. agrees well with the replicate dates of 437 ± 20 and 437 ± 21 m.y. on hornblende from amphibolite in the inlier surrounded by unconformably overlying Silurian and Devonian strata 60 miles on trend to the east (GSC 70-106)*, and it agrees reasonably well with three replicate dates ranging from 414 ± 18 to 434 ± 18 m.y. (GSC 70-107)* on a muscovite concentrate from the same inlier. Thus the best K-Ar hornblende date on these metamorphic minerals lies near 440 m.y., that is, near the Ordovician-Silurian boundary according to the Geological Society Phanerozoic time-scale 1964.

From the geological reconstructions, it appears that the dates do not record the initial regional metamorphic event of presumed pre-Middle Ordovician age. They may reflect uplift during Middle Ordovician allochthony or perhaps uplift in late Ordovician or earliest Silurian following emplacement of the allochthons.

The present dates are in fair agreement with the redetermined age of 413 ± 16 m.y. (GSC 61-184)** on a Shickshock metamorphic muscovite farther west and serve to emphasize the probability that the 495 m.y. dates (GSC 61-185 and 186)** on biotite and muscovite from the aureole developed on Shickshock schist near the Mt. Albert peridotite contact are too high. Unfortunately reserve stocks of concentrates and rock samples are exhausted and re-analyses cannot be undertaken until the rocks are resampled.

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* See Geol. Surv. Can., Paper 71-2, p. 65-67.

** See Geol. Surv. Can., Paper 62-17, p. 106-108.

Quebec

GSC 72-97 Biotite, K-Ar age 358 ± 16 m.y.

K = 7.24%, $^{40}Ar/^{40}K$ = 0.0231, radiogenic Ar = 96%.
Concentrate: Reasonably clean concentrate consisting of dark brown to opaque biotite flakes. About 5% of the biotite flakes are chloritized. A few zoned prisms of apatite, and zircon haloes are present. A few flakes of green hornblende and minor chlorite are also present. Chlorite/biotite 0.05.

From granite.
(22 A) Parc de la Gaspésie, 3.0 miles southwest of Mont Jacques-Cartier, Quebec, 48°57'24"N, 65°59'36"W. Map-unit G, Geological Map of Gaspé Peninsula, Map 1642, Quebec Dept. Natural Resources (1967). Sample SDM 61-2742, collected by I. D. MacGregor and interpreted by W. H. Poole.

This date has resulted from a new argon extraction and analysis of reserve biotite concentrate held over from the analysis reported in 1963 (GSC 62-122, Geol. Surv. Can., Paper 63-17, p. 81). Potassium analysis was not repeated.

See GSC 72-98 for interpretation.

GSC 72-98 Hornblende, K-Ar age 342 ± 14 m.y.

K = 0.449%, $^{40}Ar/^{40}K$ = 0.0219, radiogenic Ar = 89%.
Concentrate: Clean, pleochroic, light green to dark olive-green hornblende with no visible alteration or contamination.

From quartz diorite.
(22 H) Parc de la Gaspésie, 2.5 miles west-northwest of Mont Jacques-Cartier, Quebec, 49°00'13"N, 65°59'50"W. Map-unit G, Geological Map of Gaspé Peninsula, Map 1642, Quebec Dept. Natural Resources (1967). Sample PB 70-148. Collected by H. S. de Römer, Quebec Dept. Nat. Resources, and interpreted by W. H. Poole.

The quartz diorite is grey, hornblendic, fine grained, equigranular and massive. Quartz is only slightly strained, and plagioclase well zoned and twinned, subhedral, and clouded with alteration products. Hornblende is anhedral to subhedral, pleochroic light yellow-green to dark olive-green, and unaltered. Accessories are sphene, black iron ore and apatite. The quartz diorite represents a phase of the McGerrigle Batholith and a hornblende date serves to check the biotite date reported above (GSC 72-97) and the whole-rock dates referred to below.

The McGerrigle Batholith (Jacques-Cartier or Table Tops granite) cuts Lower Ordovician rocks to the north of Silurian and Devonian sedimentary and volcanic rocks which are themselves cut by stocks and dykes of granitic and/or volcanic affinity. It is geologically reasoned that these intrusions are of the same age and probably mid-Devonian.

Quebec

The 420 m.y. date reported in 1963 suggested a Silurian age. (No atmospheric argon contaminant was detected in the extracted argon.) More recently two K-Ar whole-rock dates from the McGerrigle Batholith, each of which is an average of two determinations were reported as 356.4 ± 4 and 346.2 ± 7 m.y., that is, Late Devonian (de Römer, 1970, addendum).

The two new dates reported here of 358 ± 16 m.y. on biotite from the pink phase of the batholith and of 342 ± 14 m.y. on hornblende from the grey phase are in complete agreement with de Römer's dates. All indicate a Late Devonian age of the batholith (or of uplift of the batholith). The earlier reported date of 420 m.y. (GSC 62-122, in Geol. Surv. Can., Paper 63-17, p. 81) should be extirpated from the records and the new date of 358 ± 16 m.y. substituted.

Reference

de Romer, H.S.
1970: Geology of the Madeleine Nord River area; Quebec Dept. Nat. Res., P.R. 594.

GSC 72-99 Whole-rock, K-Ar age 294 ± 45 m.y.

K = 0.54%, $^{40}Ar/^{40}K$ = 0.0186, radiogenic Ar = 80%.
Concentrate: Crushed whole-rock.

From diabase.
(22 A) On shore, 1.7 miles northwest of Cap Bon Ami, Gaspé Peninsula, Quebec, 48°48'45"N, 64°13'30"W. Map-unit 13, Quebec Dept. Mines Map 663. Sample LA67-0202, collected by A. Larochelle and interpreted by W.H. Poole.

See GSC 72-100 for description and interpretation.

GSC 72-100 Whole-rock, K-Ar age 277 ± 40 m.y.

K = 0.67%, $^{40}Ar/^{40}K$ = 0.0174, radiogenic Ar = 91%.
Concentrate: Crushed whole-rock.

From basalt.
(22 A) On shore, 1.7 miles northwest of Cap Bon Ami, Gaspé Peninsula, Quebec, 48°48'45"N, 64°13'30"W. Map-unit 13, Quebec Dept. Mines Map 663. Sample LA67-0205, collected by A. Larochelle and interpreted by W.H. Poole.

The two dates (GSC 72-99 and -100), were determined from two samples from the same diabase dyke. The dyke is 8 feet wide, is vertical and cuts Lower Devonian shaly limestone of the Cap Bon Ami Formation. The dyke-rock is a dark green-grey, dense, aphanitic rock consisting of a diabasic intergrowth of 40% unaltered plagioclase laths, 30% augite plus a brown mineral resembling biotite, black iron ore and amygdules filled with chlorite.

McGerrigle (1950) mapped several diabase dykes scattered throughout eastern Gaspé Peninsula and reported others from oil well chips which are not exposed at the surface. The dated dyke here reported is representative of the nine around and near Baie de Gaspé. Most cut the Battery Point Formation of late Early Devonian-early Middle Devonian age. McGerrigle (1950, p. 102) presumed them to be of Devonian or Carboniferous age.

The two dates differ by 6% but with the analytical error of 40 to 45 m.y. must be considered in agreement. The average of the two dates, 285 ± 45 m.y., spans the interval Late Carboniferous to Early Permian. The dates agree well with whole-rock K-Ar dates of 295 ± 22 and 309 ± 22 m.y. reported on diabase well chips some 22 miles on trend to the west (GSC 65-126, 127 in GSC Paper 66-17, p. 98-100).

The dykes are thus late Carboniferous or early Permian.

Reference

McGerrigle, H.W.
1950: The geology of eastern Gaspé; Quebec Dept. Mines, Geol. Rept. 35, 168 p.

GSC 72-101 Whole-rock, K-Ar age 282 ± 15 m.y. / 292 ± 17 m.y.

K = 0.842%, $^{40}Ar/^{40}K$ = 0.01784 / 0.01849, radiogenic Ar = 88.0% / 84.7%.
Concentrate: Crushed whole-rock.

From basalt.

(22 A) On shore at Marine Biological Station in Grande-Rivère, Gaspé Peninsula, Quebec, 48°23'30"N, 64°29'30"W. Map-unit 3b, Quebec Dept. Nat. Res. P.R. 487 (Map 1459). Sample PB 68-161, collected by W.H. Poole and interpreted by R.K. Wanless and W.H. Poole.

See GSC 72-102 for description and interpretation.

GSC 72-102 Whole-rock, K-Ar age (See note below)

K = 0.783%, $^{40}Ar/^{40}K$ = 0.01840, radiogenic argon = 90%.
Concentrate: Crushed whole-rock.

From basalt.

(22 A) On shore at Marine Biological Station in Grande-Rivière, Gaspé Peninsula, Quebec, 48°23'30"N, 64°29'30"W. Map-unit 3b, Quebec Dept. Nat. Res. P.R. 487 (Map 1459). Sample PB 69-53, collected by W.H. Poole, interpreted by R.K. Wanless and W.H. Poole.

Quebec

The basalt is dark green-grey to dark grey, dense, fine grained, equigranular, massive, and undeformed but for coarse jointing. In thin section, microphenocrysts of augite, labradorite laths and olivine (partly altered to iddingsite, chlorite and possibly serpentine) are set in a flow-aligned groundmass of the same minerals. Olivine in sample GSC 72-102 rimmed with limonite alteration.

The basalt forms a flat-lying sheet within early Upper Carboniferous(?) red limestone-conglomerate of the Bonaventure Formation. At the sample locality only the basalt is exposed, but two miles along the shore to the east, Sanschagrin (1963) reported that the sheet is 25-30 feet thick, lies 25 to 30 feet above the base of the Bonaventure, and near the top contains amygdules of quartz, carbonate and a zeolite, thomsonite. The rock could be a flow or a sill; a sill interpretation is favoured. The analyzed samples were collected from the interior of the sheet, within a few feet stratigraphically of one another, and no more than 200 feet apart.

In determining the ages for the two samples, it was found that the conventional correction employed to account for the presence of atmospheric argon was satisfactory for one sample GSC 72-101 but not for the second sample GSC 72-102. Specifically we found that GSC 72-101 yielded replicate ages of 282 and 292 m.y. whereas analyses of sample GSC 72-102 indicated much higher ages ranging from 317 to 367 m.y. Since the two samples are the same age, some other explanation was sought to account for the apparent difference of some 70 m.y. By plotting the total $^{40}Ar/^{36}Ar$ against $^{40}K/^{36}Ar$ values determined for the three analyses of sample GSC 72-102, it was possible to show that the initial $^{40}Ar/^{36}Ar$ ratio in this sample is 760 - much higher than the accepted atmospheric argon value of 295. Employing this higher, graphically determined ratio to correct the data obtained for sample GSC (1822) yields an age of 291 m.y., in excellent agreement with the conventionally determined result for sample GSC 72-101. From this analysis of the available data, we conclude that excess ^{40}Ar is present in the rocks comprising the sill(?) and that this excess argon is not homogeneously distributed throughout the rock. The agreement obtained for the two samples encourages acceptance of the age of 292 m.y. (near the Carboniferous-Permian boundary) for the rock but we recommend that this assignment be considered tentative.

Of possible significance is the fact that sample GSC 72-102 bearing the excess argon appears to be slightly more altered than sample GSC 72-101 - it contains 7% less potassium and limonite rims the olivine crystals. Perhaps the excess argon is related to an alteration process.

The apparent date of 290 m.y. agrees well with the whole-rock dates of 277 ± 40 and 294 ± 45 m.y. from dykes farther north on Gaspé Peninsula (See GSC 72-100 and 72-99, this publication).

Reference

Sanschagrin, R.
1963: Preliminary report on Grande-Rivière area; Quebec Dept. Nat. Res., P.R. 487.

Quebec

GSC 72-103 Whole-rock, K-Ar age (See GSC 72-105).

K = 0.427%.
Concentrate: Crushed whole-rock.

From lamprophyre.
(21 E) Suffield Mine, 7 miles southwest of Sherbrooke, Quebec, 45°19'15"N, 71°57'30"W. See map-unit 6, Quebec Dept. Nat. Res. Map No. 1566. Sample PB 69-123, collected by R.Y. Lamarche, Quebec Dept. Nat. Res., interpreted by R.K. Wanless and W.H. Poole.

See GSC 72-105 for description and interpretation.

GSC 72-104 Whole-rock, K-Ar age (See GSC 72-105).

K = 0.475%.
Concentrate: Crushed whole-rock.

From lamprophyre.
(21 E) Suffield Mine, 7 miles southwest of Sherbrooke, Quebec, 45°19'15"N, 71°57'30"W. Map-unit 6, Quebec Dept. Nat. Res. Map 1566. Sample PB69-121, collected by R.Y. Lamarche and interpreted by R.K. Wanless and W.H. Poole.

See GSC 72-105 for description and interpretation.

GSC 72-105 Whole-rock, K-Ar age (See note below).

K = 0.45%.
Concentrate: Crushed whole-rock.

From lamprophyre.
(21 E) Diamond drill core 642 feet below surface, Suffield Mine, 7 miles southwest of Sherbrooke, Quebec, 45°19'15"N, 71°57'30"W. Map-unit 6, Quebec Dept. Nat. Res. Map 1566. Sample PB69-122, collected by R.Y. Lamarche and interpreted by R.K. Wanless and W.H. Poole.

Three samples were collected from a dyke intersected at low angles by a diamond drill. The dyke is probably a few feet wide, and has a dark brownish grey, aphanitic interior with about 15% phenocrysts of feldspar and augite. The dyke has chilled margins an inch or two wide against schistose rhyolitic tuffs of the Cambro-Ordovician Ascot Formation, the host in this area of several sulphide bodies containing copper, zinc and other metals (St-Julien and Lamarche, 1965). Sample GSC 72-103, from the interior of the dyke, in thin section consists of 15% phenocrysts of which 10% are fresh, clear labradorite-bytownite laths and 5% subhedral to euhedral fresh augite. The groundmass consists of intergranular labradorite-bytownite laths, equant augite and dispersed fine calcite with black iron ore and apatite accessories and some chlorite. The other two samples are from the chilled margins on each side of the dyke. GSC 72-104 consists of 15% plagioclase and augite phenocrysts in a semi-opaque brownish groundmass with flow-aligned microphenocrysts of plagioclase. Microveinlets of calcite cut the rock. The other sample of chilled margin GSC 72-105 is similar except that the augite phenocrysts and microphenocrysts in the groundmass are pseudomorphously replaced by calcite.

The dyke is believed to be of the Monteregian series, and thus to be Jurassic or Cretaceous in age (Lamarche, pers. comm., 1969).

A total of seven analyses were carried out on the three samples. The potassium values obtained are consistent but the isotopic composition of the argon varied considerably. When the conventional $^{40}Ar/^{36}Ar$ ratio of 295 for the atmospheric argon correction was applied, the resulting dates ranged from 124 to 208 m.y. But when the total $^{40}Ar/^{36}Ar$ values are plotted against the $^{40}K/^{36}Ar$ ratios, straight lines drawn through some replicate analyses intersect the total $^{40}Ar/^{36}Ar$ ordinate at points higher than 295. Specifically, sample GSC 72-104 and two analyses of 72-105 define a line which intersects the ordinate at 310, whereas two analyses of sample 72-103 yielded an intersection of 342. When these new values are used to correct for the initial argon content in lieu of the 295 value, then the following results are obtained:

		Correction value used	Corrected %radiogenic Ar	Age m.y.
GSC 72-103	first determination	342	23.6	126.0
	second determination	342	20.9	126.0
GSC 72-104	first determination	310	6.1	123.3
	second determination	295	8.0	128.1
	third determination	295	13.0	123.7
GSC 72-105	first determination	310	18.8	127.5
	second determination	310	45.4	127.7
			Average	126.1 ±1.2 m.y.

The average value of 126.1 ±1.2 m.y., Early Cretaceous, agrees very well with Rb-Sr whole-rock date of 124 m.y. on Brome and Shefford intrusions, 30 miles to the west (Fairbairn et al., 1963), and is generally higher than K-Ar and Rb-Sr dates on minerals (see Wanless, 1969).

The graphical treatment provides a means of identifying samples with excess initial ^{40}Ar, and provides a method of correcting for this excess in order to determine the age of the rock. Noteworthy is that samples collected within only a few feet of one another differ in initial radiogenic argon. Whether the excess argon accompanied the magma on emplacement or was absorbed after emplacement from a radiogenic argon flux pervading the country rock, is not known.

References

Fairbairn, H.W., Faure, G., Pinson, W.H., Hurley, P.M., and Powell, J.L.
1963: Initial ratio of strontium 87 to strontium 86, whole-rock age, and discordant biotite in the Monteregian igneous province, Quebec; J. Geophys. Res., v. 68, p. 6515-6522.

St-Julien, P., and Lamarche, R.Y.
1965: Geology of Sherbrooke area; Quebec Dept. Nat. Res., P.R. 530.

Wanless, R.K.
1969: Isotopic age map of Canada; Geol. Surv. Can., Map 1256A.

New Brunswick

(GSC 72-106 to 72-123)

GSC 72-106 Muscovite, K-Ar age 424 ± 17 m.y.

$K = 8.62\%$, $^{40}Ar/^{40}K = 0.0278$, radiogenic Ar = 97%.
Concentrate: Impure, light greenish-stained muscovite with about 5% chlorite contamination.

From gneissic granite.
(21 O) Barracks Brook, 2,000 feet southwest of its mouth on South Sevogle River, New Brunswick, 47°04'11"N, 66°17'50"W. Map-unit 2 "Paragneiss", GSC Map 1220A (1970). Sample HHA-1-191, collected and interpreted by H. Helmstaedt.

The rock is light grey-brown to dark grey, medium- to fine-grained quartzofeldspathic gneiss. Modal analysis yielded 27% quartz, 32% potash feldspar, 15% albite, 13% biotite, 12% muscovite, 0.04% opaque minerals, and traces of chlorite and zircon. Recorded albite content includes alkali feldspar with a diffuse chessboard twinning; this variety may contain a potash feldspar phase in addition to albite. The texture of the rock indicates that it is not a paragneiss as designated on Map 1220A (Anderson, 1970) but a deformed granite similar to unit 9a on the same map.

The granite has intruded quartzites which form the basal part of the Middle Ordovician Tetagouche Group in the area. Both granite and its country rocks were deformed together. The gneissosity is defined by streaks of biotite and is shallow dipping to horizontal. It corresponds in orientation to the second tectonic fabric (S_2) of the country rock (Helmstaedt, 1971; in press). S_2 was crenulated in places during the third deformation (D_3), the axes of crenulation corresponding to L_3 in more schistose country rocks within a mile to the north. Muscovite and biotite were probably stable during the late deformation as both have been largely recrystallized and only traces of chloritization can be observed. The date on the muscovite of 424 ± 17 m.y. (Silurian) is thought to represent a post-D_3 age which indicates that D_3 in the area was a pre-Devonian event.

References

Anderson, F.D.
1970: Geology, Big Bald Mountain; Geol. Surv. Can., Map 1220A.

Helmstaedt, H.
1971: Structural geology of Portage Lakes area, Bathurst-Newcastle district, New Brunswick; Geol. Surv. Can., Paper 70-28, 52 p.

in press: Structural sequence and fabric in the Clearwater area, Bathurst-Newcastle district, New Brunswick; Geol. Surv. Can., Paper.

New Brunswick

GSC 72-107 Biotite, K-Ar age 359 ± 14 m.y.

$K = 5.96\%$, $^{40}Ar/^{40}K = 0.0232$, radiogenic Ar = 96%. Concentrate: 40% nearly opaque biotite, 40% brown biotite, and 20% greenish grey flakes of biotite slightly bleached and chloritized. Some of the brown flakes contain zircon inclusions surrounded by prominent pleochroic haloes. Chlorite/biotite 0.10. (Re-examination of the concentrate indicates that the colour differences noted probably result from differing flake thicknesses rather than from any fundamental variations in mica composition.)

From biotite quartz monzonite.
(21 J) Southwest Miramichi River, west shore, 2,400 feet upstream from mouth of McKiel Brook, New Brunswick, 46°30'35"N, 66°57'05"W. Map-unit 3a, GSC Map 6-1963. Sample 5-35-2/PB, collected and interpreted by W.H. Poole.

See GSC 72-110 for description and interpretation.
See also GSC 61-189 in Geol. Surv. Can., Paper 62-17, p. 110-112.

GSC 72-108 Biotite, K-Ar age 386 ± 18 m.y.

$K = 6.58\%$, $^{40}Ar/^{40}K = 0.0251$, radiogenic Ar = 96%. Concentrate: Mostly clean biotite. About 10% of the flakes have acicular inclusions along slightly chloritized edges. A small amount of green chlorite is present. Chlorite/biotite 0.04.

From cataclastic muscovite-biotite granite.
(21 J) Road, 1.3 miles west-southwest of South Burnthill Brook bridge, New Brunswick, 46°40'25"N, 66°59'37"W. Map-unit 3b, GSC Map 6-1963. Sample 5-30-5/PB, collected and interpreted by W.H. Poole.

See GSC 72-110 for description and interpretation.
See also GSC 61-190 in Geol. Surv. Can., Paper 62-17, p. 110-112.

GSC 72-109 Muscovite, K-Ar age 356 ± 16 m.y.

$K = 8.77\%$, $^{40}Ar/^{40}K = 0.0230$, radiogenic Ar = 96%. Concentrate: Mostly clean flakes of muscovite. Some are fractured and some contain air trapped between (001) sheets. A few flakes are intergrown with quartz along the edges and are stained ginger-brown by iron oxides. Chlorite not detected.

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From cataclastic muscovite-biotite granite.
(21 J) Road, 8,000 feet southwest of South Burnthill Brook bridge, New Brunswick, 46°40'02"N, 66°59'18"W. Map-unit 3b, GSC Map 6-1963. Sample 5-30-6/PB, collected and interpreted by W.H. Poole.

See GSC 72-110 for description and interpretation.
See also GSC 61-191 in Geol. Surv. Can., Paper 62-17, p. 110-112.

GSC 72-110 Muscovite, K-Ar age 364 ± 18 m.y.

K = 9.01%, $^{40}Ar/^{40}K$ = 0.0235, radiogenic Ar = 93%.
Concentrate: Clean concentrate of muscovite. Some flakes contain quartz inclusions and yellow-stained patches. Chlorite not detected.

From pegmatite.
(21 J) Napadogan - Juniper highway, 1.05 miles east of the mouth of Biggar Brook, near the picnic site, New Brunswick, 46°30'39"N, 67°05'49"W. Map-unit 1, of Figure 1 on page 12 of Geol. Surv. Can., Paper 72-1A. Sample 5-60-23B/PB, collected by R.R. Potter and interpreted by W.H. Poole.

See also GSC 63-156 in Geol. Surv. Can., Paper 64-17, part 1, p. 107-110.

About ten years ago, fourteen K-Ar age determinations were made on biotite and muscovite concentrates from gneiss, schist, cataclastic granite and pegmatite, all reasoned to have been metamorphosed or intruded during late Ordovician or early Silurian, and from undeformed granite and greisen considered to have formed during the Devonian (Poole, 1963). One of the first analysis on an "old" granite yielded 497 m.y., about the Cambrian-Ordovician boundary, while later samples from the "old" terrane yielded dates ranging from 385 to 463 m.y. with most in the 410-435 m.y. interval. During the same period, four samples of probable Devonian granites yielded mineral ages ranging from 339 to 423 m.y., Silurian to early Carboniferous. At that time, the writer viewed the dates as generally supporting his contention that regional greenschist metamorphism and intrusion occurred in the core of the Miramichi anticlinorium during the late Ordovician and that later, the massive granites were emplaced during the Devonian.

The dates obtained yielded a disturbing range of numbers when intergrated via the geologic time-scale into the geological evolution of the region. The "old" granites intruded metamorphosed strata, the oldest in the sequence, which have yielded early Ordovician-early Middle Ordovician fossils, i.e. at about 480 m.y.; the 497 m.y. date was too old. A 423 m.y. date (Silurian) on a "Devonian" granite was too old; this analysis was subsequently repeated and yielded a satisfactory date of 378 ± 16 m.y. (See GSC 70-111 in Geol. Surv. Can., Paper 71-2, p. 71.) More recently, R. Skinner working in the Tuadook Lake map-area, adjacent to the north, obtained only

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Devonian dates ranging from 376 to 386 m.y. from regionally metamorphosed rocks and granites of both "old" and "young" types (GSC 70-115 to 70-119 in Geol. Surv. Can., Paper 71-2, p. 73-76). Some doubt remains as to whether the regional metamorphism and "old" granites are late Ordovician or are Devonian but early in the Acadian Orogeny; the latter interpretation was favoured by Potter et al. (1968). However, recent structural investigations in the Bathurst-Newcastle district has convinced Helmstaedt (1971; in press) that the "old" granites and the regional metamorphism are indeed late Ordovician.

Because of these uncertainties, the K-Ar dates in the anticlinorium in central New Brunswick were re-examined and most marked for re-analysis. Unfortunately, reserve concentrates of biotite and muscovite sufficient for a re-analysis were available only for a few, but nevertheless these are adequate to markedly revise some of the earlier analyses and cast doubt on the others.

Two biotite and two muscovite concentrates from "old" granites were re-analyzed. The new results are in good agreement and all yield Devonian dates.

	Old Analysis				New Analysis			
Mineral	Lab. No.	%K*	%radiogenic argon	Age m.y.	Lab. No.	%K (I.D.)**	%radiogenic argon	Age m.y.
Biotite	GSC 61-189	7.16	83	497	GSC 72-107	5.96	96	359 ± 14
Biotite	" 61-190	6.98	100	410	" 72-108	6.58	96	386 ± 18
Muscovite	" 61-191	8.63	91	435	" 72-109	8.77	96	356 ± 16
Muscovite	" 63-156	8.73	100	463	" 72-110	9.01	93	364 ± 18

*By flame photometric and/or X-ray fluorescence
**I. D. = Isotope dilution.

The larger-than-expected error in the older analyses has several origins. Potassium analyses by isotope dilution methods altered the values by 2 to 17% among the four samples. Two potassium values were increased and two were decreased. The percentage of radiogenic argon in the argon extracted from the samples varied considerably, in part owing to the relative insensitivity to ^{36}Ar of the mass spectrometer in use at that time; an accurate determination is necessary for correcting for atmospheric argon contamination. The resulting new dates are all lower (younger) than the old dates by percentages ranging from 6% to 28%. Sample GSC 61-189 was the greatest offender with 17% decrease in potassium and a 28% decrease in the age.

The new dates agree well with the five dates on samples collected by R. Skinner nearby to the north (GSC 70-115 to 70-119 in Geol. Surv. Can., Paper 71-2, p. 73-76). Concentrates of muscovites, biotite and hornblende yielded dates of 376, 379, 382, and 386 ± 16 to 18 m.y. Skinner concluded from his field studies that four represent samples from the "old" terrane and one (382 m.y.) represented a Devonian granite. It appears that K-Ar dates cannot differentiate between the "old" (Ordovician ?) and "young" rocks. The dates either reflect crustal uplift or argon degassing during the Devonian if the premise that the "old" rocks were first metamorphosed and intruded during late Ordovician is correct. Alternatively, the dates alone can be regarded as support of the premise that the "old" metamorphism and intrusion were actually Devonian events, early in the Acadian Orogeny. The structural work of Helmstaedt referred to above supports the premise of late Ordovician events, and is further substantiated by the K-Ar muscovite date of 424 ± 17 m.y. (See GSC 72-106, this publication) from a gneissic granite equivalent to the cataclastic granites of the central New Brunswick area under discussion (assuming the 424 m.y. date is analytically correct).

Of the six remaining earlier K-Ar mineral dates on the "old" terrane within this central New Brunswick area, for which insufficient reserve mineral concentrates are available for re-analysis, the earlier reported analyses must be viewed with suspicion. The writer recommends that they all be set aside and not used until they can be checked. These dates are:

Analysis No.	Mineral	Rock	%radiogenic argon	Age m.y.
a) From GSC Paper 62-17, p. 109				
GSC 61-188	Biotite	Gneiss	90	411
b) From GSC Paper 63-17, p. 99-100				
GSC 62-155	Muscovite	Gneiss	100	417
GSC 62-156	Muscovite	Schist	100	432
c) From GSC Paper 64-17 (Part 1), p. 108-110				
GSC 63-157	Biotite	Gneiss	100	399
GSC 63-158	Biotite	Gneiss	96	385
GSC 63-159	Muscovite	Gneiss	97	400

References

Helmstaedt, H.

1971: Structural geology of Portage Lakes area, Bathurst-Newcastle district, New Brunswick; Geol. Surv. Can., Paper 70-28, 52 p.

in press: Structural sequence and fabric in the Clearwater area, Bathurst-Newcastle district, New Brunswick; Geol. Surv. Can., Paper.

Poole, W.H.

1963: Geology, Hayesville, New Brunswick; Geol. Surv. Can., Map 6-1963.

Potter, R.R., Jackson, E.V., and Davies, J.L. (Compil.)

1968: Geological Map, New Brunswick; N.B. Dept. Nat. Resources, Map N.R. - 1.

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GSC 72-111 Biotite, K-Ar age 486 ± 20 m.y.

$K = 6.53\%$, $^{40}Ar/^{40}K = 0.0324$, radiogenic Ar = 97%.
Concentrate: Slightly altered olive-green biotite with about 1% hornblende impurity. Most flakes show slight chlorite alteration at their edges and the total chlorite content is about 10%. A few of the mica flakes contain opaque inclusions.

From granite.
(21 G) Road-cut near top of hill in Milford, suburb of Saint John, New Brunswick, 45°16'05"N, 66°06'30"W. Map-unit 14, GSC Map 1113A. Sample PB-65-277, collected and interpreted by W.H. Poole.

This determination was made by re-extraction and analysis of argon from reserve biotite concentrate made from sample PB-65-277 in order to confirm the significant date of 479 ± 20* m.y. determined three years ago. Potassium was not re-analyzed.

See GSC 72-113 for description and interpretation.

GSC 72-112 Biotite, K-Ar age 482 ± 20 m.y.

$K = 7.19\%$, $^{40}Ar/^{40}K = 0.0321$, radiogenic Ar = 96%.
Concentrate: Clean, brown biotite with no visible impurities. A few of the mica flakes have split edges.

(21 G) From granite.

See GSC 72-113 for location, description, and interpretation.

GSC 72-113 Hornblende, K-Ar age 508 ± 20 m.y.

$K = 1.13\%$, $^{40}Ar/^{40}K = 0.0341$, radiogenic Ar = 96%.
Concentrate: Relatively clean concentrate of pleochroic, light brown to dark green hornblende with approximately 2% biotite contamination.

From granite.
(21 G) Kingsville Street, Milford, suburb of Saint John, New Brunswick, 45°16'02"N, 66°06'12"W. Map-unit 14, GSC Map 1113A. Sample PB-70-65, collected and interpreted by W.H. Poole.

The three above ages plus the earlier reported age (GSC 67-128) were determined on two samples of the same Fairville granite collected less than 1/2 mile apart. The first sample yielded replicate biotite ages of 479 ± 20 m.y. (GSC 67-128) and 482 ± 20 m.y. (GSC 72-111). The sample is

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*See GSC 67-128 in Geol. Surv. Can., Paper 69-2A, p. 69-70.

a purplish grey, massive, homogeneous, undeformed and coarse-grained granite. Oligoclase is well twinned, weakly zoned and irregularly clouded. Potash feldspar forms large anhedra which are clouded mainly along incipient fractures. Quartz, about 15% of the rock, is slightly strained. About 10% of the rock consists of biotite and chlorite, and traces of hornblende. Biotite is pleochroic light yellow to dark brown. Dark opaque alteration products rim biotite crystals and lie along cleavage planes. Biotite has an internal 'blistered' appearance. Some aggregates of chlorite have developed from biotite and hornblende.

The second sample yielded a biotite age of 482 ± 20 m.y. (GSC 72-112) and a hornblende age of 508 ± 20 m.y. (GSC 72-113). The sample is similar to the first: pink-grey, very coarse grained, massive, undeformed granite. Quartz, potash feldspar and twinned, slightly clouded oligoclase make up subequal proportions. About 5% of the rock is biotite, pleochroic light yellow to dark brown, undeformed and with some opaque minerals along the cleavage planes. Another 5% of the rock is hornblende, pleochroic yellow to yellow-green and green, slightly altered to chlorite.

The Fairville granite is less than one mile in diameter, and forms one member of an assemblage of gneisses, granites, gabbros, and diorites collectively called the Golden Grove intrusions (Hayes and Howell, 1937; Alcock, 1938). The age of the intrusions is much in doubt. They cut only the Precambrian Green Head Group of metamorphosed and unmetamorphosed sedimentary rocks, the oldest rocks in the region, which are faulted against upper Hadrynian volcanic rocks, the next younger. The assemblage may contain intrusions of different ages Alcock (1938) believed that plutonic rocks of three ages were present: 1) Precambrian, post-Green Head and pre-Coldbrook (Hadrynian), 2) Precambrian, post-Coldbrook and pre-Paleozoic, and 3) Devonian. Hayes favoured a Precambrian age for them all. Pebbles of granite occur in conglomerate intercalated in Coldbrook volcanics (Alcock, 1938) and in Cambrian conglomerate (Weeks, 1957, p. 142).

The four dates, three on biotite of 479, 486 and 482 m.y. and one on hornblende of 508 m.y., all agree very well within the limits of error, and indicate an early Ordovician age. The dates are similar to a 508 m.y. (GSC 62-159) age on biotite from a gneiss developed from Green Head Group rocks in the same belt some 6 miles to the northeast, and to a 500 m.y. date on biotite from a gabbro which cuts Coldbrook rocks 55 miles to the northeast (GSC 62-160; both samples described in Geol. Surv. Can., Paper 63-17, p. 102-103). Since Cambrian-early Ordovician sedimentation was continuous in this region, the writer interprets the K-Ar dates to indicate uplift in late Early Ordovician or early Middle Ordovician. No strata of Middle and Late Ordovician age are known to occur in southern New Brunswick. But the ages of actual intrusion and of regional metamorphism to gneiss are probably older, either post-Coldbrook, pre-Cambrian as reflected in the appearance of red immature sediments of the Hadrynian-Cambrian Ratcliffe Brook Formation, or post-Green Head, pre-Coldbrook. The writer is inclined to favour the former hypothesis because granitic plutons are commonly genetically and more or less temporally associated with thick piles of acidic and basic volcanics rather than limestone, shale and sandstone, and because Helmstaedt and Tella (1972) studying the structural evolution of equivalent rocks in eastern Cape Breton Island concluded that the plutonic rocks were emplaced near the Hadrynian-Cambrian boundary.

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References

Alcock, F.J.
1938: Geology of Saint John region, New Brunswick; Geol. Surv. Can., Mem. 216, 65 p.

Hayes, A.O., and Howell, B.H.
1937: Geology of Saint John, New Brunswick; Geol. Soc. Amer., Special Paper No. 5, 146 p.

Helmstaedt, H., and Tella, S.
1972: Structural history of pre-Carboniferous rocks in parts of eastern Cape Breton Island; in Report of Activities, Part A: April to October, 1971; Geol. Surv. Can., Paper 72-1, Part A, p. 7-10.

GSC 72-114 Hornblende, K-Ar age $\frac{407 \pm 20 \text{ m.y.}}{374 \pm 18 \text{ m.y.}}$

$K = 0.65\%$, $^{40}Ar/^{40}K = \frac{0.0266}{0.0242}$, radiogenic Ar = $\frac{92\%}{86\%}$.

Concentrate: Clean, pleochroic, brown to dark bluish green hornblende with a trace of biotite impurity.

From granodiorite.

(21 G) Road-cut, east side of Highway 1, 1.0 mile due south of Goldsmiths Brook, Oak Bay area, New Brunswick, 45°11'26"N, 67°08'24"W. Map-unit 6 or 7, GSC Map 1096A. Sample D142-PB, collected by L.R. Fyffe, interpreted by G.E. Pajari (University of New Brunswick).

See GSC 72-117 for description and interpretation.

GSC 72-115 Biotite, K-Ar age $\frac{384 \pm 18 \text{ m y.}}{378 \pm 16 \text{ m.y.}}$

$K = 7.03\%$, $^{40}Ar/^{40}K = \frac{0.0249}{0.0245}$, radiogenic Ar = $\frac{94\%}{97\%}$.

Concentrate: Brownish coloured biotite with approximately 5% chloritization and about 1% hornblende contamination.

From granodiorite.

(21 G) Details as for GSC 72-114.

See GSC 72-117 for description and interpretation.

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GSC 72-116 Hornblende, K-Ar age 393 ± 16 m.y.

$K = 0.698\%$, $^{40}Ar/^{40}K = 0.0256$, radiogenic Ar = 91%.
Concentrate: Relatively clean concentrate or pleochroic light brown to dark green hornblende with less than 1% biotite contamination.

From granodiorite.
(21 G) Road-cut, east side of Highway 1, 1.0 mile due south of Goldsmiths Brook, Oak Bay area, New Brunswick, 45°11'26"N, 67°08'24"W. Map-unit 6 or 7, GSC Map 1096A. Sample D142-2-PB, collected by L.R. Fyffe, interpreted by G.E. Pajari (University of New Brunswick).

See GSC 72-117 for description and interpretation.

GSC 72-117 Biotite, K-Ar age 397 ± 13 m.y.

$K = 6.54\%$, $^{40}Ar/^{40}K = 0.0259$, radiogenic Ar = 97%.
Concentrate: Light brownish biotite with approximately 10% chloritization and less than 1% hornblende contamination.

From granodiorite.
(21 G) Details as for GSC 72-116.

The sample (from the St. George pluton), a granodiorite, represents a hybridized magmatic phase in a reaction zone formed between a gabbro and a younger adamellite. Although the average K-Ar biotite age (385 ± 11 m.y.) differs slightly from the average K-Ar hornblende age (391 ± 22 m.y.), the differences are well within the analytical error.

The K-Ar average age for both minerals (389 ± 20) correlates favourably with the Rb-Sr whole-rock age of 401 ± 15 m.y.* in this part of the pluton (R.F. Cormier, written comm. 1972) and a K-Ar biotite age of 380 m.y. reported by Tupper and Hart (1961).

Reference

Tupper, W.M., and Hart, S.R.
1961: Minimum age of the Middle Silurian in New Brunswick based on K-Ar method; Geol. Soc. Amer. Bull., v. 72, p. 1285-8.

*Rubidium-87 decay constant 1.39; an age of 379 is obtained with a decay constant of 1.47.

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GSC 72-118 Hornblende, K-Ar age 415 ± 19 m.y.

$K = 0.567\%$, $^{40}Ar/^{40}K = 0.0272$, radiogenic Ar = 89%.
Concentrate: A mixture of orange-brown and pleochroic orange to green hornblende with a trace of biotite and quartz contamination.

From granodiorite.
(21 G) St. Stephen Nickel Mine dump, shaft at Rodger Farm, New Brunswick, 45°13'N, 67°18'W. Map-unit 6, GSC Map 1096A. Sample PB70-146, collected and interpreted by G. E. Pajari.

See GSC 72-119 for description and interpretation.

GSC 72-119 Biotite, K-Ar age 350 ± 15 m.y.

$K = 6.02\%$, $^{40}Ar/^{40}K = 0.0225$, radiogenic Ar = 94%.
Concentrate: Orange coloured biotite with approximately 15% chlorite alteration.

From granodiorite.
(21 G) Details as for GSC 72-118.

The sample was obtained from the mine dump of the St. Stephen Nickel property and represents a medium-grained granodiorite that occurs as small dykes and irregular small intrusions in the vicinity of and within the large roof pendant at this site. The dykes are not chilled against the gabbro or the roof pendant rocks and appear to have intruded the gabbro before complete solidification of the host had occurred.

Geological observations have shown that there is no evidence of deformation of the gabbroic and anorthositic rocks in the pluton, and therefore, on geological grounds, a Devonian age is acceptable. The difference in the biotite and hornblende ages are apparently real as evidenced by the similarity between the biotite-hornblende pairs from two different localities in the pluton and are difficult to explain.

The co-existing biotite (GSC 72-119) and hornblende (GSC 72-118) from the granodiorite dyke had a common origin and the difference in age is either a function of argon overpressure at the time of crystallization or a later thermal event. Argon overpressure must be considered unlikely in the potassium-poor environment (gabbroic) into which the granodiorite dyke was intruded. The St. George calc-alkali pluton, a few miles to the southeast of St. Stephen, has been dated at 390-400 m.y. (see St. George report GSC 72-114 to 117) and could not have provided the thermal event to lower the biotite age to 350-360 m.y. However, the stocks immediately north of the St. Stephen gabbro and the St. George pluton were emplaced 320-338 m.y. age (Ruitenberg et al., 1970).

On geological evidence the St. Stephen and St. George plutons are post-Orogenic (Acadian) in age. The similarity of the K-Ar hornblende age from St. Stephen and the K-Ar biotite, K-Ar hornblende, and Rb-Sr whole-rock ages from the St. George pluton (see GSC 72-114, 115, 116, 117), is also suggestive of approximate contemporaneity. Tentatively, the hornblende K-Ar age is accepted as being correct and the K-Ar biotite age is considered to have been partially degassed during a period of Mississippian intrusion.

Reference

Ruitenberg, A.A., Shafiquallah, M., and Tupper, W.M.
1970: Late tectonic mineralized structure in southwestern New Brunswick; Geol. Assoc. Can., Programme and Abstracts, Winnipeg Meeting.

Note-

The sample was collected from the same mine dump as GSC 63-155 (sample MB-STS-62) which yielded a biotite date of 462 m.y. A second sample (GSC 72-120) was subsequently obtained from an outcrop about one mile south of the dump to check this result (see discussion for GSC 72-120 and 121). The biotite from the outcrop sample contained a much lower potassium content than the original concentrate (5.29% vs. 7.22%) and has yielded a date of 364 ± 16 m.y. in reasonable agreement with the second dump sample detailed above. The large difference in potassium concentration and the discordant dates obtained suggests to us that the original concentrate was not from the gabbro. We suspect that two or more samples were inadvertently switched either in the field or the laboratory and therefore recommend that the original 462 m.y. date be extirpated from the records.

GSC 72-120 Hornblende, K-Ar age 401 ± 20 m.y.

K = 0.56%, $^{40}Ar/^{40}K$ = 0.0261, radiogenic Ar = 83%.
Concentrate: Clean, unaltered, dark brown hornblende. Contamination consists of only traces of chlorite, orthopyroxene, mica and quartz.

From gabbro.
(21 G) Details as for GSC 72-121.

See GSC 72-121 for description and interpretation.

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GSC 72-121 Biotite, K-Ar age 364 ± 16 m.y.

$K = 5.29\%$, $^{40}Ar/^{40}K = 0.0235$, radiogenic Ar = 97%.
Concentrate: Relatively clean, pale reddish brown biotite with about 5% free chlorite contamination.

From gabbro.

(21 G) Road-cut at junction 1 mile northwest of St. Stephen, New Brunswick, 45°12'50"N, 67°17'50"W. Map-unit 6, GSC Map 1096A. Sample PB-65-193, collected and interpreted by W.H. Poole.

The gabbro is dark grey, equigranular, medium grained and massive. Thin section shows a diabasic texture of 65% fresh, well-twinned labradorite laths, 25% augite and brown hornblende, and 10% red-brown biotite.

The gabbro is associated with peridotite, and together they have intruded the Lower Ordovician Cookson Formation (Charlotte Group, Dark Argillite Division). A K-Ar date of 462 ± 20 m.y. (see GSC 63-155, Paper 64-17, p. 107) was obtained on biotite from gabbro collected at the mine dump on the St. Stephen Nickel property, about one mile to the north. This date is clearly Middle Ordovician and coupled with the existence of an unconformity at the base of cobble-conglomerate of the mid-Silurian Oak Bay Formation five miles to the east, the gabbro-peridotite was assumed to be Taconian and of an age similar to the ultramafic rocks which extend from the Eastern Townships to western Newfoundland. The present biotite and hornblende dates were carried out to check the Ordovician date, and also because gabbro and diorite forms large bodies associated with the acknowledged Devonian St. George granite batholith a few miles to the east. Because of this relationship, peridotite has been argued to be likewise Devonian.

The biotite age of 364 ± 16 m.y. and hornblende date of 401 ± 20 m.y., both from the same sample, are significantly different. Both ages are characteristic of Devonian and Acadian ages in the Maritime Provinces. The difference is confirmed within the limits of error by the biotite date of 350 ± 15 m.y. and hornblende date of 415 ± 19 m.y., both again from the same sample but collected from the mine dump about one mile north in the same pluton (see GSC 72-118 and 119). Although the ages are essentially Devonian, a geological explanation for the difference is not obvious. G. E. Pajari ascribes the difference to probable partial degassing of the biotite, and not the hornblende, by apparently younger granites a few miles to the northeast. No reasonable alternative is apparent.

The original age of 462 ± 20 m.y. on biotite from the mine dump sample is probably in error; perhaps a sample was switched by accident in the laboratory or the field. In any case, the date was not confirmed by the GSC 72-118 and 119 dates and should be extirpated from the records. (See also note following report for GSC 72-119.)

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GSC 72-122 Whole-rock, K-Ar age 289 ± 13 m.y.

$K = 2.28\%$, $^{40}Ar/^{40}K = 0.01827$, radiogenic Ar = 99%.
Concentrate: Crushed whole-rock.

From mugearite.
(21 G) Currie Mtn., 5 miles west of Fredericton, New Brunswick, 45°59'02"N, 66°45'30"W. Map-unit 24, GSC Map 37-1959. Sample S31-2-PB collected by M. Cherry and interpreted by G. E. Pajari (University of New Brunswick).

See GSC 72-123 for description and interpretation.

GSC 72-123 Whole-rock, K-Ar age 276 ± 12 m.y.

$K = 1.48\%$, $^{40}Ar/^{40}K = 0.01740$, radiogenic Ar = 97%.
Concentrate: Crushed whole-rock.

From mugearite.
(21 G) Currie Mtn., 5 miles west of Fredericton, New Brunswick, 45°58'58"N, 66°45'20"W. Map-unit 24, GSC Map 37-1959. Sample S31-10-PB, collected by M. Cherry and interpreted by G. E. Pajari (University of New Brunswick).

The specimens GSC 72-122 and GSC 72-123 represent the chilled edge and core of the Currie Mountain intrusion. The intrusion is an elliptical pipe with surface dimensions of 1,500' x 600' which intrudes Pennsylvanian clastic rocks of uppermost Namurian C-lowermost Westphalian A age (H. W. van de Poll; pers. comm.).

The rock constituting the intrusion is aphanitic to fine-grained dark green to black containing a megascopically observable preferred orientation of feldspar laths. In thin section, the texture is pilotaxitic and the feldspar (65%) is normally zoned from An_{50} to anorthoclase. Zoned olivine (7%), commonly altered to chlorite, occurs in the groundmass and ranges in composition from Fo_{60} to Fo_{40}. Augite (15%), Fe-Ti oxides (8%) and apatite (3%) are the remaining constituents. The rock is mineralogically and chemically a mugearite of the alkali olivine basalt magma family.

The Currie Mountain intrusion is petrologically identical to two sills exposed in the Royal Road quarry about five miles from the mountains. These two occurrences are believed, therefore, to be contemporaneous.

The K-Ar age obtained is consistent with the available geological information.

Prince Edward Island

(GSC No. 72-124 to 72-126)

GSC 72-124 Biotite, K-Ar age 341 ± 15 m.y.

K = 7.14%, $^{40}Ar/^{40}K$ = 0.0218, radiogenic Ar = 93%.
Concentrate: Impure, dark brown biotite with about 12% chlorite alteration. Some of the mica flakes have a blistered texture.

From granite boulder.
(11 L) West 1/4 mile from Rocky Point, Prince Edward Island, 46°39'N, 63°54'W. Sample PC 44/70, collected and interpreted by V.K. Prest.

This sample was from an area NW of Malpeque Bay, Prince Edward Island.

Many granitic erratics were found NW of Malpeque Bay where the last active ice appears to have moved southward. It would therefore be logical to find boulders derived from the Precambrian Shield in this area. But once again a Devonian age is indicated and hence the source area is very probably New Brunswick to the west.

Thus, out of seven samples dated, five have been in the range of ca. 360 ± 25 m.y., one was 500 m.y., and one was 1125 ± 40 m.y. The latter was checked by Rb-Sr and gave 830 m.y. so that the Precambrian age is apparently confirmed. An anorthosite boulder, megascopically and microscopically similar to intrusive bodies north of the St. Lawrence River in Quebec, gave a K-Ar age of 668 ± 81 m.y. based on a whole-rock analyses, which date is considered to be minimal. Here again, a Precambrian source for the anorthosite seems logical. It is clear from the five dates on boulders from different parts of the island that most of the erratics may be derived from New Brunswick. This is in keeping with the ESE glacial lineations over eastern and north-central parts of Prince Edward Island. But a Devonian-age indicator northwest of Malpeque Bay, where the last ice flow is thought to have been southward, points to a western source for the late-ice which might otherwise have been assigned to a northern (Acadian Bay) ice lobe.

Clearly, more age determinations on carefully selected glacial erratics are needed to adequately round out the glacial picture but six out of seven dates is surely sound evidence of the importance of Appalachian-derived ice over Prince Edward Island during the last major glaciation.

GSC 72-125 Whole-rock, K-Ar age 210 ± 30 m.y.

K = 0.81%, $^{40}Ar/^{40}K$ = 0.0130, radiogenic Ar = 88%.
Concentrate: Crushed whole-rock.

From basalt.
(11 L) Northeast end of George Island, Malpeque Bay, Prince Edward Island, 46°35'55"N, 63°46'10"W. Sample BPD-7K-PB, collected by R.F. Black and interpreted by W.H. Poole.

See GSC 72-126 for description and interpretation.

Prince Edward Island

GSC 72-126 Whole-rock, K-Ar age 211 ± 29 m.y.

$K = 0.81\%$, ${}^{40}Ar/{}^{40}K = 0.0131$, radiogenic Ar = 84%.
Concentrate: Crushed whole-rock.

From basalt.
(11 L) Northeast end of George Island, Malpeque Bay, Prince Edward Island, 46°35'55"N, 63°46'10"W. Sample BPD-9K-PB, collected by R.F. Black and interpreted by W.H. Poole.

The rock is an aphanitic basalt sill (or maybe a dyke) which is dark grey, massive, dense, unaltered and undeformed. In thin section, microphenocrysts of olivine, about 5% of the rock, are partly altered to chlorite and serpentine. The groundmass consists of a mainly submicroscopic assemblage bearing what appear to be microlites of clinopyroxene.

The sill has intruded flat-lying or gently tilted Permo-Pennsylvanian fine-grained red sediments. Larochelle (in Geol. Surv. Can., Paper 67-39) concluded from paleomagnetic studies that the sill was intruded about late Permian.

The two dates, 210 and 211 m.y. are self-confirming and indicate that no heterogeneously distributed excess ${}^{40}Ar$ is present in the samples. Furthermore, a whole-rock sample from the sill was analyzed several years ago by N.J. Snelling of Oxford University and yielded 207 ± 8 m.y. (A. Larochelle, pers. comm., 1970), further confirming the reliability of the two dates.

These three dates place the age of the sills at about middle Triassic. The sills were emplaced at a relatively high level in the sediments so that post-emplacement thermal and uplift events are not a consideration. The dates obtained are slightly older than the Late Triassic basalt flows (200 ± 10 m.y. Carmichael and Palmer, 1968) and dyke (197 ± 32 m.y. Larochelle and Wanless, 1966) in Nova Scotia. Although it is impossible to be sure, it appears that the George Island sill is older than the Late Triassic volcanism. In any case, the K-Ar dates do indicate that the sill is slightly younger than the age indicated by the paleomagnetic studies.

References

Carmichael, C.M., and Palmer, H.C.
1968: Paleomagnetism of the Late Triassic, North Mountain Basalt of Nova Scotia; J. Geophys. Res. 73, no. 8, p. 2811-2822.

Larochelle, A., and Wanless, R.K.
1966: The Paleomagnetism of a Triassic Dyke in Nova Scotia; J. Geophys. Res. 71, no. 20, p. 4949-4953.

Nova Scotia

(GSC No. 72-127 to 72-130)

GSC 72-127 Biotite, K-Ar age 576 ± 23 m.y.

K = 6.59%, $^{40}Ar/^{40}K$ = 0.0394, radiogenic Ar = 97%.
Concentrate: Light brown biotite with about 10% chlorite mainly as flake-edge alteration, and about 2% hornblende impurity.

From granodiorite.
(21 H) On lumber road on north side of Jeffers Brook, Nova Scotia, 45°28'36"N, 64°17'56"W. See Southampton No. 82 map-sheet. Sample KA67-66, collected by D.G. Kelly and interpreted by W.H. Poole.

See GSC 72-130 for description and interpretation.

GSC 72-128 Biotite, K-Ar age 555 ± 22 m.y.

K = 6.81%, $^{40}Ar/^{40}K$ = 0.0377, radiogenic Ar = 94%.
Concentrate: Brownish biotite with about 15% chlorite as an alteration product of the mica. Hornblende contamination amounts to less than 2%.

From granodiorite.
(21 H) Details as for GSC 72-127.

See GSC 72-130 for description and interpretation.

GSC 72-129 Biotite, K-Ar age 535 ± 22 m.y.

K = 6.78%, $^{40}Ar/^{40}K$ = 0.0362, radiogenic Ar = 98%.
Concentrate: Brownish, altered biotite with about 18% chloritization.

From granodiorite.
(21 H) On lumber road, north side of Jeffers Brook, Cobequid Mountains, Nova Scotia, 45°28'36"N, 64°17'56"W. Map-unit 14, Geological Map of Nova Scotia, 1965. Sample PB 69-119, collected and interpreted by W.H. Poole.

See GSC 72-130 for description and interpretation.

Nova Scotia

GSC 72-130 Hornblende, K-Ar age $\frac{606 \pm 28 \text{ m.y.}}{618 \pm 28 \text{ m.y.}}$

$K = \frac{0.42}{0.431}\%$, $^{40}Ar/^{40}K = \frac{0.0418}{0.0428}$, radiogenic Ar = $\frac{90}{94}\%$.
Concentrate: Relatively clean, unaltered, pleochroic tan to bluish green hornblende with traces of chlorite and quartz impurity.

From granodiorite.
(21 H) Lumber road, north side of Jeffers Brook, Cobequid Mountains, Nova Scotia, 45°28'36"N, 64°17'56"W. See map-unit 14, Geological Map of Nova Scotia. Sample PB 69-118, collected and interpreted by W.H. Poole.

The rock from which all these biotite and hornblende concentrates were made is light green-grey, medium-grained, equigranular hornblende-biotite granodiorite or quartz diorite. It is massive and undeformed. Quartz, about 20%, is equant and only slightly strained. Plagioclase is highly clouded, weakly zoned and finely twinned. Biotite formed 10%, pleochroic light tan to dark brown and altered to chlorite along cleavage planes and along the edges of the crystals. Hornblende, about 5%, is fresh and pleochroic tan to bluish green.

The small pluton has intruded rocks of the Cobequid Mountains not known to be older than mid-Silurian. When the first biotite dates from sample KA 67-66 yielded 576 ± 23 m.y. and 555 ± 22 m.y., a then-acceptable interpretation seemed impossible to make. As a consequence, the samples PB 69-118 and PB 69-119 were collected at and within a few hundred yards of the first sample site in order to check the dates. It is now certain that the pluton is much older than Silurian, and a major revision in the age of the stratified rocks must be made.

The three biotite dates of 576, 555, and 535 m.y. seem to fall in the Early and Middle Cambrian, while the two hornblende dates of 606 and 618 are distinctly late Hadrynian. It seems probable that the hornblende dates are closer to the age of the pluton because known Silurian strata in the Cobequid Mountains are strongly folded and this event could have partly degassed the less resistant biotites. Still the Cambrian dates they retain clearly indicate that the Acadian deformational and (?)intrusive events were relatively weak, and the temperature of the pluton was not raised to the relatively low temperatures required to degas the biotites in the Acadian Orogeny.

Almost certainly then, the pluton is latest Hadrynian (or earlymost Cambrian) and the strata it cuts must be equivalent to the Hadrynian Fourchu and Coldbrook Groups which are dominantly volcanic. Similar late Hadrynian K-Ar dates have been obtained for hornblende from a granite in the Antigonish Highlands (582 m.y.) and from a quartz-diorite/syenodiorite in the Coxheath Hills (584 m.y.) (See GSC 66-156 and GSC 66-160, GSC Paper 67-2A, p. 124, 129) and recently a Rb-Sr whole-rock isochron on a dominantly acidic volcanic formation in the Highlands yielded a Cambrian date (R.F. Cormier, pers. comm., 1973).

Nova Scotia

The important contribution made by all these isotopic dates is to indicate the presence of a belt of Avalon Platform Hadrynian and Cambrian stratified and plutonic rocks lying on trend between southeast Cape Breton Island in the east and the Caledonian Mountains of southern New Brunswick in the west. This Cobequid-Antigonish belt has been an anomaly in geological reconstructions because rocks no older than Silurian in the Cobequid area and Ordovician in the Antigonish area were believed to be represented within the unfossiliferous, thick lower sequences. The stratigraphy must now be revised and the results will be much more consistent and intelligible within the regional context.

Newfoundland

(GSC No. 72-131 to 72-161)

GSC 72-131 Hornblende, K-Ar age 1418 ± 52 m.y.

$K = 1.33\%$, $^{40}Ar/^{40}K = 0.1238$, radiogenic Ar = 98%.
Concentrate: Pleochroic olive-brown to light green hornblende with less than 2% biotite contamination. Many of the hornblende crystals show some degree of alteration.

From basic dyke rock.
(24 P) Northern Labrador, Newfoundland, 59°27'55"N, 64°00'25"W. Sample TA67-T399A, collected and interpreted by F.C. Taylor.

The hornblende of this determination is from an undeformed, garnet-bearing, metamorphosed basic dyke that cuts granulite. The age is considered to be the approximate time of the metamorphism.

Reference

Morgan, W.C., and Taylor, F.C.
1972: Granulite facies metamorphosed basic dykes of the Torngat Mountains, Labrador; Min. Mag., v. 38, p. 666-669.

GSC 72-132 Hornblende, K-Ar age 1138 ± 44 m.y.

$K = 1.42\%$, $^{40}Ar/^{40}K = 0.0914$, radiogenic Ar = 98%.
Concentrate: Relatively clean, pleochroic, olive-brown to dark green hornblende with less than 2% attached biotite impurity.

From granodiorite.
(24 A) 2 miles southeast of Lac Brisson and east of Lac de la Hutte Sauvage, George River, on the Quebec-Newfoundland (Labrador) boundary, 56°18'15"N, 64°09'00"W. Sample TA69-T005, collected and interpreted by F.C. Taylor.

This sample is from a massive, equigranular, medium-grained, hornblende granodiorite. The K-Ar age is considered to be the age of intrusion. The pluton from which this sample was obtained forms part of the post-tectonic adamellitic suite of intrusives.

GSC 72-133 Whole-rock, K-Ar age $\frac{3195 \pm 86 \text{ m.y.}}{3205 \pm 84 \text{ m.y.}}$

$K = 0.66\%$, $^{40}Ar/^{40}K = \frac{0.4903}{0.4928}$, radiogenic Ar = $\frac{98}{95}$%.
Concentrate: Crushed whole-rock.

Newfoundland

From chilled diabase.
(14 M) North of Seven Islands Bay, Labrador, Newfoundland, 59°28'N, 63°40'W. Sample TA67-T394A, collected and interpreted by F.C. Taylor.

These two determinations are from the chill zone of a dark grey-green diabase dyke. As the host rocks of the dyke are Proterozoic age the 3 billion year determinations are probably the result of excess argon in the sample.

GSC 72-134 Biotite, K-Ar age $\frac{1505 \pm 37 \text{ m.y.}}{1516 \pm 58 \text{ m.y.}}$

$K = 6.02\%$, ${}^{40}Ar/{}^{40}K = \frac{0.1348}{0.1361}$, radiogenic $Ar = \frac{99\%}{99\%}$.
Concentrate: Clean, very thick, dark green biotite with less than 2% attached quartz contamination.

From granodiorite.
(14 E) About 3 miles east of Wheeler Mountain, Labrador, Newfoundland, 57°33'30"N, 62°15'45"W. Sample TA69-T257, collected and interpreted by F.C. Taylor.

This sample is from a pink, massive, equigranular, medium-grained granodiorite that forms part of the adamellite intrusive suite in northern Labrador. The pluton from which this sample was obtained lies wholly within Archean migmatite terrain. As the adamellitic suite invariably post-dates anorthosite in the region (which is considered to be about 1400 m.y. old) the K-Ar age of 1520 m.y. appears to be slightly too old. As no intrusive rocks immediately pre-dating the anorthosite are known in this region it is not considered likely that this sample is pre-anorthosite and hence the age is probably slightly anomalous.

GSC 72-135 Biotite, K-Ar age 1160 ± 40 m.y.

$K = 6.18\%$, ${}^{40}Ar/{}^{40}K = 0.0936$, radiogenic $Ar = 99\%$.
Concentrate: Relatively clean, light brown biotite with less than 2% chlorite alteration.

From granite.
(14 F) 12 miles southwest of Snyder Bay, Labrador, Newfoundland, 57°02'00"N, 61°57'00"W. Sample TA69-T336, collected and interpreted by F.C. Taylor.

This sample is from a massive, pink, equigranular, coarse-grained biotite granodiorite. The K-Ar age is considered to be the age of intrusion. As this granodiorite contains fluorite, as do many of the adamellite plutons, it probably is part of the same intrusive suite.

Newfoundland

GSC 72-136 Whole-rock, K-Ar age 1420 ± 110 m.y.

$K = 1.57\%$, $^{40}Ar/^{40}K = 0.1239$, radiogenic Ar = 96%.
Concentrate: Crushed whole-rock.

From chilled diabase.
(14 F) 3 1/4 miles southwest of Snyder Bay, Labrador, Newfoundland, 57°07'30"N, 61°46'30"W. Sample MZ69-T377, collected by W.C. Morgan, interpreted by F.C. Taylor.

This sample is from the chill zone of a prominent, north striking, massive, dark grey, diabase dyke. The K-Ar age is considered to be the approximate age of the intrusion.

GSC 72-137 Biotite, K-Ar age 1170 ± 40 m.y.

$K = 7.68\%$, $^{40}Ar/^{40}K = 0.0950$, radiogenic Ar = 98%.
Concentrate: Relatively clean, light brown biotite with about 2% chloritization of the mica.

From pegmatite.
(14 F) On coast, 1 1/2 miles south of Cape Kiglapait, Labrador, Newfoundland, 57°05'00"N, 61°23'00"W. Sample TA69-T329A, collected and interpreted by F.C. Taylor.

This sample is from a six foot thick pegmatite dyke cutting the Kiglapait layered intrusion. The K-Ar age is considered to be the age of intrusion of the dyke. It confirms an age of 1140 m.y. obtained for biotite from pegmatite by Beall et al. (1963) and suggests the pegmatite is related to the adamellite suite of intrusions.

Reference

Beall, G.H., Hurley, P.M., Fairbairn, H.W., and Pinson, W.H.
1963: Comparison of K-Ar and whole-rock Rb-Sr dating in New Quebec, Labrador; Am. J. Sci., v. 261, p. 571-580.

GSC 72-138 Biotite, K-Ar age 1175 ± 40 m.y.

$K = 7.65\%$, $^{40}Ar/^{40}K = 0.0956$, radiogenic Ar = 99%.
Concentrate: Clean, light brownish orange biotite with no visible contamination.

From adamellite.
(14 C) Southwest shore of Tasialuk Lake, Labrador, Newfoundland, 56°09'45"N, 61°36'15"W. Sample TA69-T436, collected and interpreted by F.C. Taylor.

Newfoundland

This sample is from massive, porphyritic adamellite. The K-Ar age is considered to be the age of intrusion and is in agreement with other K-Ar ages for adamellite in this region.

GSC 72-139 Hornblende, K-Ar age 1544 ± 56 m.y.

$K = 0.607\%$, $^{40}Ar/^{40}K = 0.1399$, radiogenic Ar = 98%. Concentrate: Pleochroic, light brown to bluish green hornblende with less than 2% biotite contamination. Trace impurities of chlorite and quartz are also present. Some of the hornblende grains show evidence of alteration.

From gabbro.
(13 J) Cape Harrison area, Coast of Labrador, Newfoundland, 54°55'N, 59°02'W. Sample J22-8 collected and interpreted by F.C. Taylor.

This sample is from a grey-green gabbro which forms a part of the Adlavik Gabbro intrusive suite. The K-Ar age is considered to be the approximate age of the intrusion.

GSC 72-140 Whole-rock, K-Ar age 2185 ± 68 m.y.

$K = 0.962\%$, $^{40}Ar/^{40}K = 0.2412$, radiogenic Ar = 99%. Concentrate: Crushed whole-rock.

From (?) gabbro.
(13 I) East of island, Hamilton Inlet, Coast of Labrador, Newfoundland, 54°27'N, 57°28'W. See GSC Map 69-48. Sample SG-192-8, collected by I.M. Stevenson and interpreted by F.C. Taylor.

This sample is from a massive, medium- to coarse-grained, dark green gabbro believed to be part of the Michael suite of intrusive rocks. The age, 2185 ± 68 m.y., is anomously old for this suite of rocks. A similar age (2080 ± 42 m.y.) was determined on another dyke 12 miles to the east by Grasty et al. (1969). Those authors considered the 2080 m.y. age to be anomalous due to possible argon addition "under rather peculiar conditions" at or close to the Grenville front. At present the 2185 m.y. age cannot be satisfactorily resolved.

References

Stevenson, I.M.
1970: Geol. Surv. Can., Paper 69-48.

Grasty, R.L., Ruckledge, J.C., and Elders, W.A.
1969: New K-Ar age determinations on rocks from the east coast of Labrador; Can. J. Earth Sci., v. 6, no. 2, p. 340-344.

Newfoundland

GSC 72-141 Whole-rock, K-Ar age 1030 ± 37 m.y.

$K = 0.467\%$, $^{40}Ar/^{40}K = 0.0802$, radiogenic Ar = 94%.
Concentrate: Crushed whole-rock.

From gabbro.
(13 K) 1 1/4 mile north of peninsula dividing Seal Lake, Labrador, Newfoundland, 54°21'08"N, 61°38'20"W. Map-unit 12, GSC Map 1079A. Sample BLS-100-68, collected and interpreted by W.R.A. Baragar.

The rock is a medium-grained ophitic gabbro with randomly oriented partly altered plagioclase laths and olivine grains contained in large (1-2 cm) augite ophites. The rock contains about 10-15% olivine, some magnetite surrounded by biotite fringes.

See GSC 72-143 for interpretation.

GSC 72-142 Whole-rock, K-Ar age 784 ± 32 m.y.

$K = 0.27\%$, $^{40}Ar/^{40}K = 0.0569$, radiogenic Ar = 93%.
Concentrate: Crushed whole-rock.

From basalt.
(13 K) 1 mile west-northwest from the southwest tip of Snegamook Lake, Labrador, Newfoundland, 54°32'17 1/2"N, 61°39'00"W. Map-unit 10, GSC Map 1079A. Sample BLS-143-68, collected and interpreted by W.R.A. Baragar.

The rock is a greenish grey, fine- to medium-grained basalt composed of randomly oriented plagioclase laths held, for the most part, in augite ophites. Interstitial chlorite forms about 25% of the section and is thought to be derived from devitrified glass. The plagioclase is from 10 to 20% altered.

See GSC 72-143 for interpretation.

GSC 72-143 Whole-rock, K-Ar age 915 ± 38 m.y.

$K = 0.83\%$, $^{40}Ar/^{40}K = 0.0689$, radiogenic Ar = 96%.
Concentrate: Crushed whole-rock.

From basalt.
(13 K) 3 miles northwest from east end of Wuchusk Lake, Labrador, Newfoundland, 54°25'23.6"N, 61°40'15"W. Map-unit 10, GSC Map 1079A. Sample BLS-117-68, collected and interpreted by W.R.A. Baragar.

Newfoundland

The rock is a dark grey, fine-grained basalt with ophitic texture. It is composed of randomly oriented plagioclase laths suspended in a mosaic of titanaugite grains. Chlorite blebs, at least in part pseudomorphic after olivine, compose about 20% of the rock. The magnetite content is 5-10%.

Age determinations on the three samples were made with a view to determining the original age of the Seal Lake Group, Labrador. Unfortunately the ages obtained can not be the original ages. The Seal Lake Group overlies the Harp Lake anorthosite body with evident unconformity and is folded from the south by Grenville deformation. The age, therefore, must be between the age of anorthosite, assumed to be 1400 m.y. the same as that obtained for the Michikamau anorthosite (Emslie, 1964), and the age of Grenville stabilization, about 900 m.y. The three ages obtained are probably all influenced by events attending the Grenville Orogeny.

Reference

Emslie, R. F.
1964: Potassium-argon age of the Michikamau Anorthositic Intrusion, Labrador; Nature, v. 202, p. 172.

GSC 72-144 Whole-rock, K-Ar age 984 ± 73 m.y.

K = 2.03%, $^{40}Ar/^{40}K$ = 0.0756, radiogenic Ar = 98%.
Concentrate: Crushed whole-rock.

From basalt.
(13 O) Aillik Bay, Labrador, Newfoundland, 55°12'N, 59°13'W. Map-unit 9, GSC Bulletin 26. Sample FA-9-69, collected and interpreted by W. F. Fahrig.

The analysis was carried out on material from gently dipping basic sheets in the Aillik Bay area of Labrador and provides a first approximation of the age of intrusion.

GSC 72-145 Whole-rock, K-Ar age 346 ± 42 m.y.

K = 1.00%, $^{40}Ar/^{40}K$ = 0.0222, radiogenic Ar = 85%.

From basalt.
(13 O) Aillik Bay, Labrador, Newfoundland, 55°12'N, 59°12'W. Map-unit 9, GSC Bulletin 26. Sample FA-6-69, collected and interpreted by W. F. Fahrig.

Material analyzed was from the chilled margin of a southeasterly-striking diabase dyke. The age seems anomalously low, and as these dykes are in the vicinity of young lamprophyre intrusions (see GSC 72-151 and 152) the age may reflect argon loss at the time of these intrusions.

Newfoundland

GSC 72-146 Whole-rock, K-Ar age 871 ± 64 m.y.

$K = 2.13\%$, $^{40}Ar/^{40}K = 0.0648$, radiogenic Ar = 97%.
Concentrate: Crushed whole-rock.

From basalt.
(13 O) Aillik Bay, Labrador, Newfoundland, 55°12'N, 59°12'W. Map-unit 9, GSC Bulletin 26. Sample FA-5-69, collected and interpreted by W.F. Fahrig.

From an easterly trending diabase dyke. Age is minimum age of intrusion.

GSC 72-147 Whole-rock, K-Ar age 951 ± 73 m.y.

$K = 0.194\%$, $^{40}Ar/^{40}K = 0.0723$, radiogenic Ar = 77%.
Concentrate: Crushed whole-rock.

From basalt.
(13 O) Aillik Bay, Labrador, Newfoundland, 55°12'N, 59°12'W. Map-unit 9, GSC Bulletin 26. Sample FA-4-69, collected and interpreted by W.F. Fahrig.

The K-Ar age was obtained from chilled diabase dyke margin and presumably provides a minimum age of intrusion.

GSC 72-148 Whole-rock, K-Ar age 935 ± 64 m.y.

$K = 2.42\%$, $^{40}Ar/^{40}K = 0.0708$, radiogenic Ar = 98%.
Concentrate: Crushed whole-rock.

From basalt.
(13 O) Aillik Bay, Labrador, Newfoundland, 55°12'N, 59°13'W. Map-unit 9, GSC Bulletin 26. Sample FA-3-69, collected and interpreted by W.F. Fahrig.

See GSC 72-149 for interpretation.

GSC 72-149 Whole-rock, K-Ar age 685 ± 32 m.y.

$K = 4.45\%$, $^{40}Ar/^{40}K = 0.0483$, radiogenic Ar = 98%.
Concentrate: Crushed whole-rock.

From basalt.
(13 O) Aillik Bay, Labrador, Newfoundland, 55°12'N, 59°13'W. Map-unit 9, GSC Bulletin 26. Sample FA-2-69, collected and interpreted by W.F. Fahrig.

Newfoundland

This whole-rock determination provides a minimum age for the intrusion of this dyke. Whole-rock ages on petrographically similar dykes e.g. GSC 72-148. have yielded ages approaching 1 billion years so presumably this sample has lost a significant amount of argon.

GSC 72-150 Whole-rock, K-Ar age $\frac{1315 \pm 50 \text{ m.y.}}{1315 \pm 52 \text{ m.y.}}$

$K = 1.11\%$, $^{40}Ar/^{40}K = \frac{0.1111}{0.1115}$, radiogenic Ar = $\frac{98\%}{98\%}$.
Concentrate: Crushed whole-rock.

From basalt.
(13 I) North of Hamilton Inlet, Labrador, Newfoundland, 54°27'N, 57°17'W. Map-unit 9, GSC Bulletin 26. Sample FA-1-69, collected and interpreted by W.F. Fahrig.

These whole-rock analyses provide a minimum age of intrusion of the Michael gabbros which form an extensive set of dykes extending west from Smokey Island archipelago on the coast of Labrador. The K-Ar data are reasonably concordant with a Rb-Sr isochron from these rocks (R.K. Wanless, pers. comm.) which yields an age of 1390 ± 81 m.y. (using $\lambda = 1.47 \times 10^{-11} \text{ yr}^{-1}$).

Reference

Fahrig, W.F., and Larochelle, A.
1972: Paleomagnetism of the Michael gabbro and possible evidence of the rotation of Makkovik sub-province; Can. J. Earth Sci., vol. 9, p. 1287-1296.

GSC 72-151 Phlogopite, K-Ar age 331 ± 14 m.y.

$K = 7.21\%$, $^{40}Ar/^{40}K = 0.0212$, radiogenic Ar = 96%.
Concentrate: Relatively clean, very light brown to light green phlogopite with some tiny opaque inclusions but no visible alteration.

From biotite lamprophyre.
(13 O) Aillik Bay, Labrador, Newfoundland, 55°12'N, 59°12'W. Map-unit 8, GSC Bulletin 26. Sample FA-7-69, collected and interpreted by W.F. Fahrig.

See GSC 72-152 for interpretation.

Newfoundland

GSC 72-152 Phlogopite, K-Ar age 397 ± 16 m.y.

$K = 7.47\%$, $^{40}Ar/^{40}K = 0.0258$, radiogenic Ar = 95%.
Concentrate: Clean, light pinkish brown phlogopite with no visible impurities. The colour of the mica varies from light brown through light green to colourless and approaches muscovite in appearance.

From biotite lamprophyre.
(13 O) Aillik Bay, Labrador, Newfoundland, 55°12'N, 59°12'W. Map-unit 8, GSC Bulletin 26. Sample FA-8-69, collected and interpreted by W.F. Fahrig.

The micas of these two samples were derived from two narrow S.E. striking lamprophyre dykes and provide a minimum age for these intrusions (see GSC 72-145).

GSC 72-153 Hornblende, K-Ar age 903 ± 38 m.y.

$K = 1.17\%$, $^{40}Ar/^{40}K = 0.0678$, radiogenic Ar = 96%.
Concentrate: Relatively clean, pleochroic, light brown to dark green hornblende with less than 1% free biotite impurity.

From gneiss.
(12 I) North shore, North East Arm, Fourche Harbour, Newfoundland, 50°31'20"N, 56°20'50"W. Sample BK-69-41a, collected and interpreted by H.H. Bostock.

See GSC 72-154 for description and GSC 72-157 for interpretation.

GSC 72-154 Biotite, K-Ar age 512 ± 20 m.y.

$K = 7.22\%$, $^{40}Ar/^{40}K = 0.0345$, radiogenic Ar = 98%.
Concentrate: Light greenish coloured biotite with about 8% chlorite alteration.

From gneiss.
(12 I) Details as for GSC 72-153.

The rock is a mesocratic, medium-grained, dark green gneiss consisting mainly of feldspar (30%), amphibole (30%) and biotite (40%).

See GSC 72-157 for interpretation.

Newfoundland

GSC 72-155 Biotite, K-Ar age 434 ± 18 m.y.

$K = 7.75\%$, $^{40}Ar/^{40}K = 0.0285$, radiogenic Ar = 97%.
Concentrate: Relatively clean, light greenish brown biotite with no visible alteration. Some of the mica flakes contain pleochroic haloes.

From gneiss.
(12 I) One mile north of Eastern Head, Fourche Harbour, Newfoundland, 50°32'10"N, 56°15'50"W. Sample BK-69-51a, collected and interpreted by H.H. Bostock.

The sample is from a fine-grained leucocratic gneiss consisting of quartz (28%), microcline (17%), plagioclase (48%), biotite (6%), and minor sphene, chlorite, muscovite, and epidote-allanite.

See GSC 72-157 for interpretation.

GSC 72-156 Muscovite, K-Ar age 843 ± 24 m.y.

$K = 8.45\%$, $^{40}Ar/^{40}K = 0.0622$, radiogenic Ar = 96%.
Concentrate: Clean, unaltered, clear muscovite with no visible contamination.

From pegmatite.
(12 I) Shoreline of Canada Bay, about 1 mile south of Torrent Cove, Newfoundland, 50°43'41"N, 56°10'50"W. Sample BK-70-482D, collected and interpreted by H.H. Bostock.

The pegmatite from which the muscovite was obtained is a salmon-pink and grey-green rock with about 30% grey smoky quartz, 50% feldspar and 20% pale, translucent, slightly crinkled, coarse-grained muscovite. The feldspar crystals show evidence of fracturing.

See GSC 72-157 for further discussion and interpretation.

GSC 72-157 Hornblende, K-Ar age 903 ± 37 m.y.

$K = 0.736\%$, $^{40}Ar/^{40}K = 0.0678$, radiogenic Ar = 95%.
Concentrate: Clean pleochroic, olive-brown to dark green hornblende with no visible alteration or contamination.

From metagabbro.
(12 I) 14 miles west of Canada Head, Canada Bay, Newfoundland, 50°41'35"N, 56°26'00"W. Sample BKJ-69-439a, collected and interpreted by H.H. Bostock.

This rock is a dark, greenish black, medium fine-grained ophitic metagabbro consisting mainly of plagioclase (60%), hornblende (30%), hypersthene (5%), biotite (3%), and magnetite (2%).

Newfoundland

The northern Long Range Grenville inlier consists in large part of gneisses in the upper amphibolite or lower granulite metamorphic facies, into which megacrystic and equigranular granitic plutons have been emplaced. The gneisses and plutons of the eastern part of the inlier have been intruded by dolerite dykes and are unconformably overlain by the Bradore Formation (=Cloud Mountains Formation) and by basalt (=Lighthouse Cove Formation), the latter being locally underlain by a few feet of Bradore arkose. The Bradore Formation is in turn conformably overlain by the Devils Cove Formation at Canada Bay. In the western part of the inlier pelitic rocks within the high grade gneisses locally contain andalusite as well as sillimanite where they approach the plutons, suggesting that the plutons have produced narrow retrograde aureoles. In the east however, a complex and extensive pattern of greenschist facies metamorphic overprints is evident that affects gneiss, plutons and dykes.

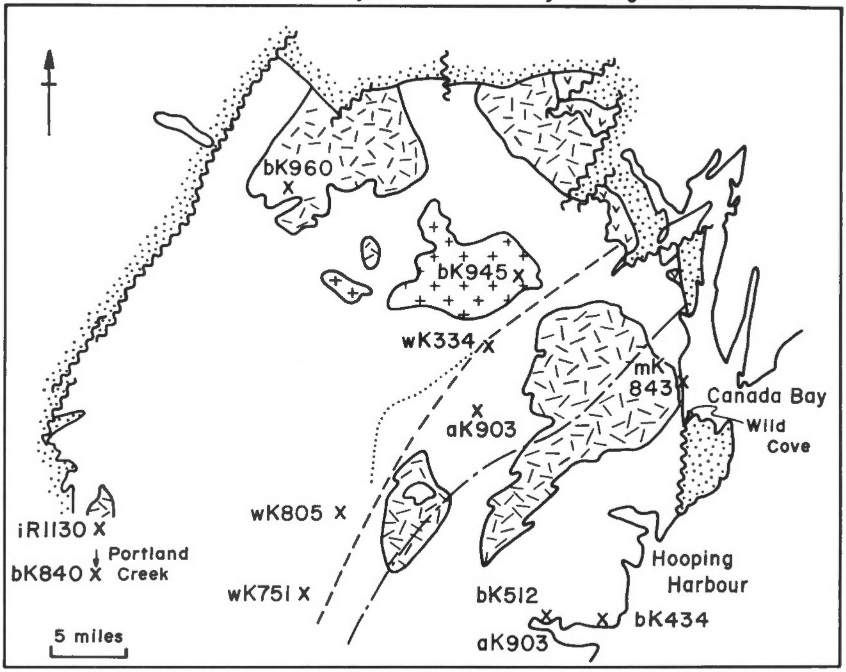
Pringle (1971) has determined a Rb-Sr isochron date of 1130 ± 90 m.y. ($\lambda_{Rb^{87}} = 1.39 \times 10^{-11}$ yr^{-1}) for megacrystic granitic rocks intruding gneisses of the western Long Range Grenville inlier. This age he interprets to represent the time of granite emplacement. Biotite K-Ar ages by Lowdon et al. (1963), 960 ± 65 (GSC 61-200) and 945 ± 65 m.y. (GSC 61-201), and by Pringle et al. (1971), 840 ± 20 m.y., from granites in the western part of the Grenville inlier were interpreted by Pringle et al. as reflecting uplift (of the western part of the inlier) after Grenville metamorphism. Dolerite dykes were collected by Clifford and dated by Wanless et al. (1966), K-Ar whole-rock age 334 ± 100 m.y. (GSC 64-158); by Fahrig and dated by Wanless et al. (1968), K-Ar whole-rock age 751 ± 100 m.y. (GSC 66-169); and by Pringle et al. (1971), average K-Ar age 805 ± 35 m.y. (Note that the co-ordinates of Fahrig's dyke as originally published were approximate only, the co-ordinates to the nearest minute being, 50°33'N, 56°39'W, placing the dyke at the west edge of the swarm.)

In the eastern part of the inlier, dykes, granites and gneisses have been overprinted by greenschist metamorphism as shown by crystallization of secondary biotite and epidote in the granite and gneiss, and by retrogression of plagioclase and pyroxene principally to sausurite, albite, and amphibole in the dykes. Retrogression of the dykes however does not extend as far west as does that in the gneisses, so that the westernmost unaltered and slightly altered dykes cut retrograded gneisses. The locations of the dykes sampled by Fahrig and by Pringle suggest that they lie within this unaltered western fringe. The dyke collected by Clifford (1965), perhaps just within the area of overprint, yielded an age of 334 m.y. (GSC 64-158) (Wanless et al., 1966). Consideration of the error limits assigned shows that this age overlaps the range of K-Ar biotite ages obtained from gneisses near the east coast and it seems likely that it may reflect the same post dyke events that are responsible for the biotite K-Ar ages.

Two K-Ar hornblende ages (903 ± 37 m.y. (GSC 72-157) and 903 ± 38 m.y. (GSC 72-153)) are from retrograded metagabbro bands, one from the west margin of the overprinted area and one from near the east coast. One K-Ar muscovite age (843 ± 24 m.y.) (GSC 72-156) represents a pegmatite intrusive into phyllitic rocks lying structurally beneath the megacrystic granite west of Canada Bay and believed to be of cataclastic origin related to emplacement of the granite pluton. Two K-Ar biotite ages from

Newfoundland

Dates derived from work by G.S.C. and by Pringle et al 1971.



LEGEND

Post Grenville sedimentary rocks

basalt

equigranular pluton

megacrystic pluton

Grenville metamorphic rocks

b - biotite
m - muscovite
a - amphibole
i - isochron
w - whole rock
K - potassium-argon
R - Rubidium-strontium

Fault

Approx. west limit of abundant epidote (early greenschist facies metamorphism)

Approx. west limit of slightly altered dolerite dykes

Approx. west limit of severely altered dolerite dykes

Figure 5. Summary of radiometric dates — Northern Long Range Grenville Inlier.

gneisses near the east coast and near Williamsport are 434 ± 18 m.y. (GSC 72-155) (late Upper Ordovician) and 512 ± 20 m.y. (GSC 72-154) (late Upper Cambrian) respectively.

The hornblende and muscovite dates are apparently of the same age or younger than the northwestern biotite dates and may therefore represent an extension of Grenville metamorphism related to the pre-dyke greenschist overprint in the eastern part of the inlier. This overprint is approximately coextensive with possible folding of the eastern megacrystic pluton and surrounding gneisses (Bostock, 1970), which did not widely affect the other northern plutons.

The alteration pattern of the dolerite dykes, which progresses in intensity eastward toward the coast (a pattern previously suggested by Foley, 1937, in the Great Harbour Deep area), shows that conditions favourable to greenschist facies metamorphism also occurred subsequent to dyke emplacement. These conditions may simply reflect deuteric alteration and progressive increase in depth of burial toward the east coast at the time of emplacement of the dykes; however other evidence of late greenschist facies metamorphism, restricted to the eastern part of the inlier, is at hand. A Precambrian regolith lying beneath the Bradore Formation at Canada Bay, and presumably beneath the basalts which are thought to be fed by the dolerite dykes, is thoroughly indurated and contains secondary as opposed to detrital muscovite, in contrast to the same regolith exposed west of the Precambrian inlier which is friable and contains fine-grained sericite or illite. Furthermore, sheared siliceous limestone of the Devils Cove Formation at Wild Cove contains late chlorite and biotite, and minor albite, suggesting that greenschist facies metamorphism may have occurred after the late Lower Cambrian, the age of the fossil assemblage in this formation (Palmer in North, 1971). The K-Ar biotite dates (late Cambrian and late Ordovician) probably reflect uplift, that may have followed a complex pattern progressing eastward toward the coast. They thus provide a minimum age of greenschist facies metamorphism that is consistent with alteration of the Devils Cove Formation.

Present data thus suggest that the Precambrian rocks of the Long Range Grenville inlier were intruded by megacrystic granites about 1130 m.y. ago (Pringle et al., 1971). West of Hooping Harbour the granitic rocks may have been redistributed by folding that caused an extensive eastern greenschist facies overprint. Uplift of the northern plutons occurred about 950 m.y. ago as suggested by biotite ages (Lowdon et al., 1963). The same uplift presumably affected the northeastern part of the inlier where an unconformity developed on the Grenville gneisses, but farther south the gneisses may have remained more deeply buried. Intrusion of dolerite dykes occurred about 800 m.y. or more ago (as suggested by K-Ar whole-rock ages by Pringle et al. and by Fahrig). Whether these dykes reached the surface and fed the basalt flows of the Lighthouse Cove Formation, or whether there was a parallel, later (but pre-late Lower Cambrian) period of dyke intrusion that contributed to these flows is not known. The supracrustal rocks at Canada Bay were buried in Cambrian-Ordovician time sufficiently deeply to permit a second period of greenschist facies metamorphism, which also presumably affected a belt of gneisses some miles across that extend to the southwest along the coast. This metamorphism occurred after the late Lower Cambrian but before final uplift in the Upper Ordovician-Lower Silurian.

Newfoundland

References

Bostock, H.H.
1970: Precambrian rocks, Long Range Mountains, Northwest Newfoundland (12 I); Geol. Surv. Can., Paper 70-1, pt. A, p. 125-129.

Clifford, P.M.
1965: Paleozoic flood basalts in Northern Newfoundland and Labrador; Can. J. Earth Sci., v. 2, p. 183-187.

Foley, F.C.
1937: Geology and mineral deposits of the Hawke Bay - Great Harbour Deep area, Northern Newfoundland; Nfld. Dept. Nat. Res., Bull. 10, p. 1-22.

Lowdon, J.A., Stockwell, C.H., Tipper, H.W., and Wanless, R.K.
1963: Age determinations and geological studies; Geol. Surv. Can., Paper 62-17, p. 118.

North, F.K.
1971: The Cambrian of Canada and Alaska; in Cambrian of the New World (ed., Holland, C.H.); Wiley Interscience, N.Y., p. 256.

Pringle, I.R., Miller, J.A., and Warrell, D.M.
1971: Radiometric age determinations from the Long Range Mountains, Newfoundland; Can. J. Earth Sci., v. 8, p. 1325-1330.

Wanless, R.K., Stevens, R.D., Lachance, G.R., and Rimsaite, J.Y.H.
1966: Age determinations and geological studies; Geol. Surv. Can., Paper 65-17, p. 96.

Wanless, R.K., Stevens, R.D., Lachance, G.R., and Edmonds, C.M.
1968: Age determinations and geological studies; Geol. Surv. Can., Paper 67-2, pt. A, p. 136.

GSC 72-158 Phlogopite, K-Ar age 353 ±16 m.y.

$K = 5.96\%$, $^{40}Ar/^{40}K = 0.0227$, radiogenic Ar = 97%.
Concentrate: Brownish orange phlogopite with about 8% chlorite occurring both as free flakes and as an alteration product of the mica.

From lamprophyre.
(2 L) Northwest end of Northern Grey Island (Groais Island), Newfoundland, 50°57'55"N, 55°38'10"W. Sample WF-305b-69, collected and interpreted by H. Williams (Memorial University).

This age determination was made on phlogopite from a brownish-weathering lamprophyre dyke. The dyke cuts metamorphic rocks, which constitute most of Grey Island and which are correlatives of the pre-Ordovician

Newfoundland

Fleur de Lys Group (Williams, 1967). Pebbles of the lamprophyre dyke occur in nearby Carboniferous conglomerates that unconformably overlie the metamorphic rocks. The isotopic age of the lamprophyre dyke at 353 ± 16 m.y. is consistent with these field relationships.

Reference

Williams, Harold
1967: Island of Newfoundland; Geol. Surv. Can., Map 1231A.

GSC 72-159 Muscovite, K-Ar age 368 ±16 m.y.

K = 7.98%, $^{40}Ar/^{40}K$ = 0.0238, radiogenic Ar = 94%.
Concentrate: Relatively clean, clear muscovite with about 4% chlorite impurity. Some of the mica flakes carry a slight brownish stain.

From granite pegmatite.
(2 L) Northeast end of South Grey Island (Bell Island), southwest of Northeast Rock, Newfoundland, 50°47'30"N, 55°28'30"W. See GSC Map 1231A. Sample WF-299c-69, collected and interpreted by H. Williams (Memorial University).

This age determination was made on muscovite from a pegmatitic phase of a granite body that constitutes the northeastern part of southern Grey Island. The granite cuts and post-dates polyphase deformation in metamorphic rocks that are correlated with the Fleur de Lys Group of the Burlington Peninsula, Newfoundland (Williams, 1967). Its isotopic age at 368 ± 16 m.y. is consistent with Devonian ages characterizing similar intrusions in northeastern Newfoundland.

Reference

Williams, Harold
1967: Island of Newfoundland; Geol. Surv. Can., Map 1231A.

GSC 72-160 Muscovite, K-Ar age 412 ±14 m.y.

K = 7.26%, $^{40}Ar/^{40}K$ = 0.0269, radiogenic Ar = 98%.
Concentrate: Mostly clear muscovite with approximately 3% chlorite contamination. The mica flakes with chlorite are very light brown in colour.

From schist.
(12 A) Old highway 1,200 yds. northeast of old bridge over Steady Brook, Newfoundland, 48°57'05"N, 57°49'20"W. Map-unit 2, GSC Map 8-157. Sample PB70-42, collected and interpreted by W.H. Poole.

See GSC 72-161 for description and interpretation.

Newfoundland

GSC 72-161 Muscovite, K-Ar age 429 ± 14 m.y.

$K = 7.06\%$, $^{40}Ar/^{40}K = 0.0282$, radiogenic Ar = 98%.
Concentrate: Impure muscovite with approximately 10% chlorite contamination. The contaminated mica flakes are yellow-stained, while the fresh mica is clear.

From schist.

(12 A) Old highway 1, at old bridge over Steady Brook, northeast of Corner Brook, Newfoundland, 48°57'00"N, 57°49'25"W. Map-unit 2, GSC Map 8-1957. Sample PB70-43, collected and interpreted by W.H. Poole.

The two samples were collected about 200 yards apart, PB70-43 at the old bridge over Steady Brook and PB70-42 to the northeast along the old road.

The sample at the bridge is an albite-muscovite schist, greenish grey, with about 20% tiny albite porphyroblasts and a fine cross-cutting crenulation. Muscovite, about 15% of the rock, is only locally bent on the crenulation. Quartz, chlorite, zircon and ilmenite partly altered to leucoxene are also present. The other sample is a muscovite-quartz schist, white to silvery grey, consisting mainly of laminae rich in muscovite interlayered with laminae rich in quartz. In thin section, muscovite, 10% of the rock, is planar and unaltered. Quartz grains are flattened in the plane of the schistosity and are strained. Albite porphyroblasts are rare. Chlorite, zircon and ilmenite altered partly to leucoxene are also present.

The schists form part of a belt of regionally metamorphosed rocks, the western crystalline belt, which extends through western Newfoundland from Burlington Peninsula to Stephenville where it is partly covered by Carboniferous strata and where exposed, merges with metamorphic rocks extending along the south coast of Newfoundland. The age of the metamorphism is uncertain. The metamorphosed strata at this locality are probably Cambrian in age and in the Burlington Peninsula are probably Hadrynian and maybe also Cambrian. M.J. Kennedy (e.g. in Poole and Rodgers, 1972, p. 70-71) has concluded that in the Burlington Peninsula the metamorphism and polydeformation are pre-Arenig, that is, pre-late Early Ordovician. Massive granites cut the metamorphic rocks, and they and the metamorphic rocks have yielded Devonian K-Ar mineral dates.

The two ages, 412 and 429 m.y., are similar and would seem to suggest a Silurian event, be it original metamorphism or uplift. The latter alternative is favoured and perhaps has affected the two samples slightly differently. Uplift may well be associated with the formation of polymictic conglomerate, red feldspathic sandstone and acidic and basic volcanics of the Silurian(?) Springdale Group which lies along the east side of the crystalline belt north of the present sample site.

Reference

Poole, W.H., and Rodgers, John
1972: Appalachian geotectonic elements of the Atlantic Provinces and Southern Quebec; excursion A63 and C63, 24th International Geological Congress, Montreal; 200 p.

Atlantic Shelf

(GSC No. 72-162 to 72-163)

GSC 72-162 Glauconite, K-Ar age 84 ± 4 m.y.

$K = 4.43\%$, $^{40}Ar/^{40}K = 0.0050$, radiogenic Ar = 47%.
Concentrate: Clean concentrate of green glauconite pellets with no visible contamination.

From silty glauconite horizon.
(20 I) Shell Canada Ltd; drill hole at 3,015 feet below sea level, offshore Nova Scotia, 42°42'10.716"N, 64°43'53.040"W. Sample Shell Mohawk B-93, collected and interpreted by P.F. Moore and K. Leskiw of Shell Canada Ltd.

The sample that the concentrate comes from is a sidewall core consisting of greyish olive, slightly calcareous silty glauconite, bounded above and below by light olive slightly calcareous mudstone.

The glauconite sample did not contain any diagnostic fauna but is bracketed by fossiliferous sediments. The planktonic foraminifera in a sidewall core 15 feet (5 m) stratigraphically above the glauconite sample suggest an age no younger than the *Globotruncana stuarti* zone of Trinidad, the *Globotruncana elevata* zone of Tunisia or the "forms of Globotruncana thalmanni/flexuosa group" zone of the central Swiss Alps, and the *Globotruncana stuartiformis* zone compiled from literature (Bolli, H.M., 1966, Table 1).

Globotruncana helvetica and *Praeglobotruncana stephani* found in samples 85 feet (26 m) stratigraphically below the glauconite, suggest an age no older than the *Globotruncana inornata* zone of Trinidad or the *Globotruncana helvetica* zone of Algeria, Morocco, Tunisia and the central Swiss Alps (Bolli, H.M., 1966, Table 1).

Bolli, H.M. (1966) concludes that the *G. elevata* zone is Campanian and the *G. helvetica* zone is Turonian. These assignments are supported by the unpublished work of Shell paleontologists. The age of the glauconite, based on biostratigraphy is therefore somewhere between Turonian and Campanian.

The radiometric age of 84 ± 4 m.y. almost exactly spans the Coniacian Stage on the 'Geological Society Phanerozoic time-scale 1964' (Quart. J. Geol. Soc. Lond. 120s, 260-2) and is thus in excellent accord with the biostratigraphy.

The following is a list of the foraminifera identified in samples from 15 feet (5 m) to 1,000 feet (305 m) above the glauconite sample.

Gyroidina nitida (Reuss) Morrow, *Globotruncana lapparenti* group, *Robulus navarroensis* (Plummer) Cushman, *Guembelina globulosa* (Ehrenberg) Egger, *Globorotalia umbilicata* Loetterle, *Arenobulimina americana* Cushman, *Dorothia bulletta* (Carsey) Plummer, *Tritaxia ellisorae* Cushman, *Globotruncana elevata* Brotzen, *Globotruncana cretacea* d'Orbigny, *Kyphopyxa christneri* (Carsey) Cushman, *Globorotalia micheliniana* (d'Orbigny) Cushman, *Guembelina pseudotessera* Cushman, *Marssonella oxycona* (Reuss) Cushman, *Gaudryina (Pseudogaudryina) pyramidata* Cushman, *Globotruncana angusticarinata* Gandolfi, *Gyroidina girardana* (Reuss) Cushman.

Atlantic Shelf

Reference

Bolli, H.M.
1966: Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera; Boletin Informativo of the Asociacion Venezolana de Geologia, Mineria y Petroleo, v. 9, no. 1, p. 3-32.

GSC 72-163 Glauconite, K-Ar age 16 ± 2 m.y.

$K = 5.51\%$, $^{40}Ar/^{40}K = 0.0009$, radiogenic Ar = 35%.
Concentrate: Clean, light green glauconite with no visible impurities.

From glauconitic mudstone.
(10 N) Shell Canada Ltd. drill hole at 1,620-1,650 feet below sea level, Atlantic Shelf, southwest of Sable Island, 43°43'16.142"N, 60°13'17.414"W. Sample Shell Onondaga E-84, collected and interpreted by P.F. Moore and K. Leskiw of Shell Canada Ltd.

The sample was obtained from drill cuttings of a slightly calcareous, glauconitic, medium-buff coloured mudstone.

The glauconite sample, though not itself fossiliferous, is bracketed by rocks containing a rich microfauna. The cuttings from the sediments 30 feet (9 m) above the sample yielded the following planktonic foraminifera: Globoquadrina dehiscens, Orbulina universa, Globigerina cf. praebulloides, Globigerinoides triloba and Globorotalia scitula. This assemblage best characterizes the early to mid-Miocene zones, e.g. from the Globorotalia fohsi barisanensis to the Globorotalia acostaensis zones of the Carribean and Java (Bolli, 1966) or from the Globorotalia fohsi barisanensis to the Globigerina bulloides zones of northwest Venezuela (Blow, 1959).

Eight hundred feet (244 m) below the glauconite the cuttings yielded Globorotalia mayeri. This form does not range higher than the mid-Miocene Globorotalia mayeri zone.

The benthonic foraminifera found in cuttings above and below the glauconite are characteristic of the Chesapeake group of Maryland, which is mid-Miocene in age.

The glauconite sample can therefore confidently be assigned to the mid-Miocene on the evidence of both planktonic and benthonic foraminifera.

The radiometric age of 16 ± 2 million years would fall within the 12 to 19 million year span allotted to the middle Miocene on the 'Geological Society Phanerozoic time-scale 1964' (Quart. J. Geol. Soc. Lond. 120s, 260-2). Thus the radiometric and biostratigraphic results are in excellent accord.

A more complete list follows of the foraminifera recovered in the sidewall cores and cuttings derived from strata 430 feet (131 m) above the glauconite to 800 feet (244 m) below.

Bulimina gracilis Cushman, Nonion pizarrensis (Berry), Buliminella elegantissima (d'Orbigny), Spiroplectammina exilis Dorsey, Bolivina paula

Atlantic Shelf

Cushman and Cahill, Globigerina bulloides d'Orbigny, Robulus americanus (Cushman) var. spinosus (Cushman), Bolivina floridana Cushman, Marginulina sp. C and D (Cushman Coll. Nos. 37728, 37729, 37730 from zone 13, Calvert formation) cf. indica LeRoy, Textularia eustisensis McLean n. sp., Uvigerina cf. tenuistriata Cushman, Lagena substriata (Williamson) var., Globigerinoides triloba Reuss, Globorotalia scitula (Brady), Robulus americanus (Cushman), Globigerina cf. praebulloides Blow, Orbulina universa d'Orbigny, Globoquadrina dehiscens (Chapman, Parr, and Collins), Martinottiella communis (d'Orbigny), Siphogenerina lamellata Cushman cf. S. transversa Cushman, Bolivina lafayettei McLean n. sp., Dentalina cf. intermedia Hantken.

References

Blow, W.H.
1959: Age, correlation and biostratigraphy of the upper Tucuyo (San Lorenzo) and Pozon formation, eastern Falcon, Venezuela; Bull. Amer. Pal., v. 39, no. 178, p. 59-251.

Bolli, H.M.
1966: Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera; Boletin Informativo of the Asociacion Venezolana de Geologia, Mineria y Petroleo, v. 9, no. 1, p. 3-32.

APPENDIX

GSC Age Determinations Listed by N.T.S. Co-ordinates

1-M

62-189, 190; 63-136, 137; 66-170, 171; 70-145, 146, 147, 152.

1-N

65-150; 70-156.

2-C

70-155.

2-D

59-94, 95, 96, 97, 98; 60-151, 152; 63-182; 65-142, 143; 66-172; 70-153, 154.

2-E

62-187, 188; 63-168, 169, 170, 171, 183, 184; 64-159; 65-144, 145, 146, 147, 148, 149; 67-144; 70-151.

2-F

70-148.

2-L

72-158, 159.

2-M

66-173.

3-D

63-161.

10-N

72-163.

11-D

70-122, 123.

11-E

66-156, 157, 158; 70-124, 125.

11-F

62-168, 169.

11-K

66-159, 160, 161.

11-L

65-133, 134, 135; 66-163; 70-128, 129, 130; 72-124, 125, 126.

<u>11-O</u>

61-202; 63-162; 65-138, 139, 140, 141; 66-168.

<u>11-P</u>

67-143.

<u>12-A</u>

64-158; 67-142; 70-120, 121; 72-160, 161.

<u>12-B</u>

60-147, 199; 62-186; 63-166, 167.

<u>12-E</u>

65-129; 66-153; 70-102, 103, 104, 105; 72-95.

<u>12-H</u>

60-148; 61-203, 204; 70-143, 144, 149.

<u>12-I</u>

60-149; 61-200, 201; 66-169; 70-150; 72-153, 154, 155, 156, 157.

<u>12-L</u>

60-133, 134, 143.

<u>12-O</u>

60-135.

<u>13-C</u>

66-167; 67-138.

<u>13-D</u>

60-132.

<u>13-E</u>

64-160; 70-133.

<u>13-F</u>

60-145; 67-136, 137.

<u>13-H</u>

60-146; 67-141.

<u>13-I</u>

70-138, 142; 72-140, 150.

<u>13-J</u>

70-134, 135, 136, 137; 72-139.

<u>13-K</u>

60-144; 61-196; 62-183, 184, 185; 63-178, 179; 72-141, 142, 143.

<u>13-L</u>

61-197; 62-177; 63-148, 163, 177; 64-157; 65-151.

13-M

63-174; 64-162; 70-131, 132.

13-N

62-178; 63-172.

13-O

62-179, 180, 181, 182; 67-133, 134, 135; 70-140, 141; 72-144, 145, 146, 147, 148, 149, 151, 152.

14-C

72-138.

14-D

60-143; 63-175; 65-122, 152.

14-E

61-195; 62-172; 63-181; 64-164; 65-153; 66-166; 72-134.

14-F

62-171; 63-180; 64-163; 72-135, 136, 137.

14-L

63-173, 176; 64-165; 67-130, 131, 132, 140.

14-M

67-129; 72-133.

20-I

72-162.

20-P

61-194; 62-167.

21-A

59-93; 62-163; 164, 165, 166; 65-132 66-155.

21-B

61-193; 62-161, 162.

21-E

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