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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 63-17

AGE DETERMINATIONS AND GEOLOGICAL STUDIES
(Including Isotopic Ages— Report 4)

(Report and 5 figures)

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C. H. Stockwell, R. K. Wanless

Price 75 cents

1963

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AGE DETERMINATIONS AND GEOLOGICAL STUDIES

PART I - AGE DETERMINATIONS BY THE GEOLOGICAL SURVEY OF CANADA

Isotopic Ages. Report 4
- compiled by J. A. Lowdon

K-Ar Measurements on Mineral Pairs
- by R. K. Wanless and J. A. Lowdon

PART II - GEOLOGICAL STUDIES

Third Report on Structural Provinces, Orogenies, and Time-Classification of the Canadian Precambrian Shield
- by C. H. Stockwell

Ages of Regional Metamorphism of the Aldridge Formation near Kimberley, B. C. (Preliminary Report)
- by G. B. Leech

DEPARTMENT OF

MINES AND TECHNICAL SURVEYS

CANADA

The age determination program is a coordinated effort involving various field geologists, and the following geologists, mineralogists, and physicists of the Geological Survey of Canada.

R.K. Wanless J.A. Lowdon R.D. Stevens	Argon extraction, mass spectrometry, and age calculation.
R.J. Traill J.Y.H. Rimsaite G.R. Lachance	Mineralogy, mineral separation, X-ray analysis, and potassium determination.

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Illustrations

ABSTRACTS

K-Ar Measurements on Mineral Pairs—R.K. Wanless and J.A. Lowdon

The ages of twenty-six biotite-muscovite pairs were compared. Of these, sixteen pairs agree; the remaining ten show differences ranging from 11.5 to 38 per cent.

Third Report on Structural Provinces, Orogenies, and Time-Classification of Rocks of the Canadian Precambrian Shield—C. H. Stockwell

The reconnaissance study of the Canadian Shield was continued during 1962 and the additional potassium-argon dates obtained substantiate the divisions proposed in two previous reports (Stockwell, 1961, 1963—see "References"). The Grenville front has been extended eastward to the Atlantic Ocean. A new structural province, called the "Nain province", has been added. It lies mainly in Labrador north of the Grenville province. The Sickle Group has been placed in the Archaean, the Nonacho in the Lower Proterozoic, and the Athabasca in the Middle Proterozoic. Additional evidence indicates that certain parts of the Churchill province consist of Archaean rocks that were first involved in the Kenoran orogeny and were then moderately affected during the Hudsonian. As found along the Grenville front and elsewhere, new evidence is presented in support of the hypothesis that argon lost from an older biotite may be added to a younger biotite.

Ages of Regional Metamorphism of the Aldridge Formation near Kimberley, B. C. (Preliminary Report)—G. B. Leech

Potassium-argon ages of muscovite and biotite from interbedded quartzite and argillite, showing typical regional metamorphism (greenschist facies), of the Aldridge Formation of the Purcell (Precambrian) sedimentary sequence were determined. These were found to span the Palaeozoic era. The ages are regarded as hybrids reflecting chiefly polymetamorphism, with relatively minor contributions by detrital mica. They are interpreted to mean that Precambrian regional metamorphism was relatively more important and Mesozoic regional metamorphism correspondingly less important than has commonly been supposed.

PART I

AGE DETERMINATIONS BY THE GEOLOGICAL SURVEY OF CANADA

INTRODUCTION

This publication is the fourth in a series of annual releases of potassium-argon age measurements carried out in the laboratories of the Geological Survey of Canada. The first report (GSC Paper 60-17) contained 98 determinations; the second report (GSC Paper 61-17) presented 152 determinations; the third report (GSC Paper 62-17) contained 204 determinations; and this publication presents an additional 190 age measurements completed in 1962.

As age determinations recorded in earlier reports of this series are referred to in this report, to avoid confusion it should be noted that: "GSC 59-.." numbers refer to determinations reported in GSC Paper 60-17; "GSC 60-.." numbers to Paper 61-17; "GSC 61.." numbers to Paper 62-17; and "GSC 62-.." numbers to Part I of this report.

Procedure

All samples were examined mineralogically and all mineral concentrates were analyzed by X-ray diffraction to determine the degree of chloritization. X-ray fluorescence techniques were used to determine the potassium content. A high-frequency generator was used to fuse the sample material in vacuo and standard isotope dilution techniques were used to determine the radiogenic argon content.

Accuracy of Determinations

The analytical error has not been quoted for each determination but is approximately ±8% at 100 m.y., decreasing to approximately ±5% at 2,500 m.y. This estimate was made by comparing ages measured by the potassium-argon and lead-uranium methods on coeval mica, and uraninite and thorianite (see Wanless and Lowdon *in* Lowdon, 1961, p. 119)[1], by comparing the results of replicate K-Ar analyses on the same mineral concentrates, and by comparing the results from biotite-muscovite pairs from the same rock.

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[1]Names and/or dates in parentheses refer to references listed at the end of this report.

The limits to be applied to the calculated values are:

Age Range		Limits
100 m.y.	....	$\pm$8 m.y.
500 m.y.	....	$\pm$35 m.y.
1,000 m.y.	....	$\pm$60 m.y.
2,500 m.y.	....	$\pm$125 m.y.

Constants Employed in Age Calculations

Age calculations are based on the following potassium-40 decay constants:

$$\lambda_e = 0.585 \times 10^{-10}\ \text{yr}^{-1}$$

$$\lambda_{total} = 5.30 \times 10^{-10}\ \text{yr}^{-1}$$

Geological Time-scale

The post-Precambrian time-scales of Kulp (1961) and Holmes (1959) are shown in Figure I. Details regarding the ages on which the various divisions were established may be found in the original papers.

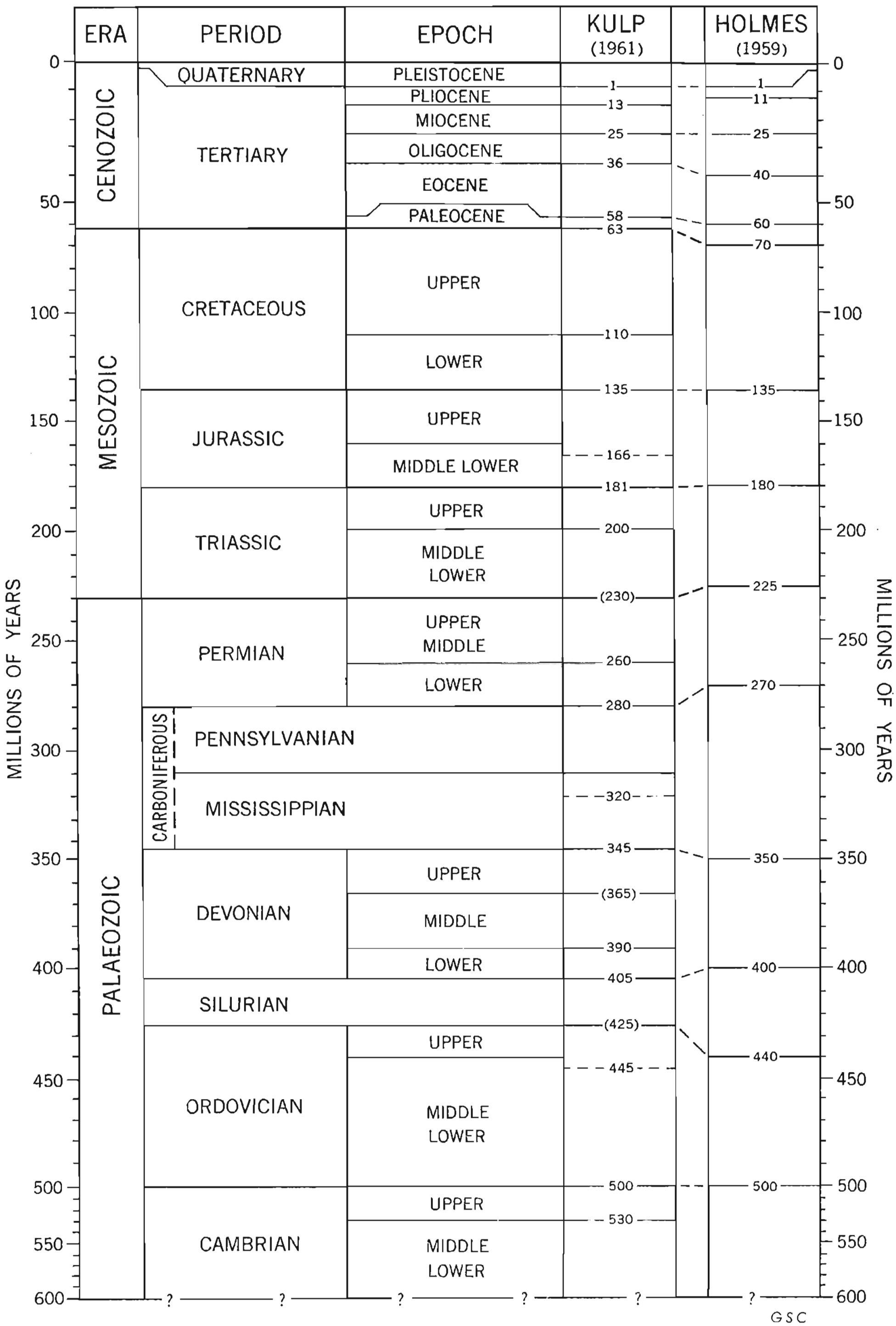

Figure 1. Geological time scale, after Kulp and Holmes

ERRATUM

GSC Paper 62-17.

Determination GSC 61-151:
Coordinates should read 47°37'20"N
81°50'40"W

ISOTOPIC AGES—REPORT 4

Compiled by J. A. Lowdon

British Columbia

Precambrian Rocks South of White Creek Batholith

GSC 62-1 — Muscovite, K-Ar age 695 m.y.

K 8.74%, Ar^{40}/K^{40} .0493; radiogenic argon 100%. Concentrate; clean concentrate of coarse muscovite. The flakes contain a small amount of very fine quartz specks and a few blisters between (001) sheets.

(82 F)[1] From cross-cutting pegmatite in Moyie Sill. In very large Moyie Sill west of White Creek about 1.88 miles south of the White Creek batholith; 49°47'18"N, 116°18'54"W. Map-unit 7, GSC Map 1053A. Sample W29RA-1. Collected by M.G. Williams. Interpreted by J.E. Reesor.

(For interpretation see determination GSC 62-3).

GSC 62-2 — Biotite, K-Ar age 126 m.y.

K 6.95%, Ar^{40}/K^{40} .00765; radiogenic argon 100%. Concentrate; impure concentrate of orange-brown biotite. Impurities, totalling about 20%, consist of pale green chlorite and hornblende fragments. The total chlorite content is about 15%.

(82 F) From meta-diorite. Top of the large Moyie Sill south of the contact of White Creek batholith; 49°47'18"N, 116°18'54"W. Map-unit 7, GSC Map 1053A. Sample W30RA-1. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 62-3).

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[1] Numbers in parentheses are National Topographic System map numbers.

British Columbia

GSC 62-3 Biotite, K-Ar age 138 m.y.

$K\ 7.15\%$, Ar^{40}/K^{40} .00837; radiogenic argon 100%. Concentrate; reasonably clean concentrate of brown biotite. The biotite flakes contain small inclusions of quartz and epidote along the edges and fractures. Minor impurities consist of hornblende fragments and green chlorite flakes. The total chlorite content is about 4%.

(82 F) From biotite bearing phase of the Moyie Sill. Top of lowest large sill west of White Creek, 3.8 miles south of White Creek batholith; 49°45'42"N, 116°19'48"W. Map-unit 7, GSC Map 1053A. Sample W32RA-1. Collected by M.G. Williams. Interpreted by J.E. Reesor

These specimens (GSC 62-1, GSC 62-2, and GSC 62-3) were collected south of White Creek batholith in order to determine, if possible, the distant effect of the emplacement of this late Mesozoic pluton (70-80 m.y.) on the K-Ar ages from the enclosing Precambrian rocks (Reesor, 1958). The 695 m.y. (GSC 62-1) from very coarse muscovite in a pegmatite dyke, in a very thick Moyie Sill, is not surprising in view of Leech's findings some miles to the south (Leech, 1962). Furthermore, as this age is identical to those found by Leech to the south, far from any large Mesozoic intrusion, White Creek batholith apparently has not affected this pegmatite, 1.88 miles to the south.

Although this may be a minimum age, and may be much less than the true age, White Creek batholith does not appear to have been instrumental in lowering it. In this connection, the cordierite-mica-quartz schist found in Lower Aldridge sedimentary rocks above the large Moyie Sill at this locality in 1951 is of considerable interest. At that time the schist was dismissed as being of Mesozoic age related to the intrusion of White Creek batholith (Reesor, 1958, p. 59). It must now at least be considered to be of possible Precambrian age in view of the Precambrian age preserved in the pegmatite.

Interpretation of the two biotite ages (GSC 62-2 and GSC 62-3) from points near the upper contact of the large sill is not simple. They were collected respectively 1.8 and 3.8 miles south of White Creek batholith. The ages may simply reflect a meaningless hybrid of the true Precambrian age of the sill, or they may truly reflect the age of principal Mesozoic folding and deformation of the sill and the enclosing rocks. If the latter is the case, then these ages reflect a late Jurassic, early Cretaceous period of deformation. White Creek batholith (70-80 m.y.) then was clearly emplaced as a post-tectonic mass as previously deduced from structural evidence (op. cit.).

British Columbia

Individual Plutonic Masses in the Purcell-Selkirk Arc in Southeastern British Columbia (Ref. Map 932A - British Columbia)

Lost Creek Stock

GSC 62-4 Biotite, K-Ar age 119 m.y.

K 7.99%, Ar^{40}/K^{40} .00718; radiogenic argon 100%. Concentrate; reasonably clean concentrate of brown biotite. About 30% of the flakes exhibit a distinct (001) splitting and contain very small specks of quartz between (001) sheets. Minor impurities consist of muscovite-chlorite and biotite-quartz intergrowths. The flakes contain a few prismatic inclusions of apatite. The total quartz content is about 1%. The total chlorite content is about 2%.

From biotite quartz monzonite.
(82 F) 4.9 miles up Lost Creek Road from the new Salmo Creston cutoff; 49°5'36"N, 117°10'12"W. Map-unit 19, GSC Map 1090A. Sample L2RA-1. Collected and interpreted by J.E. Reesor.

This small intrusive pluton occurs on Lost Creek, southeast of Salmo. It consists principally of a coarse leucoquartz monzonite similar in appearance to the core rocks of White Creek batholith and some phases of Bayonne batholith. The age of 119 m.y. indicates a Lower Cretaceous age that is not in conflict with available stratigraphic evidence for the age of satellites of the Nelson batholith (Little, 1960, pp. 85-87).

Porcupine Creek Stock

GSC 62-5 Biotite, K-Ar age 128 m.y.

K 7.69%, Ar^{40}/K^{40} .00778; radiogenic argon 100%. Concentrate; clean concentrate of olive-green biotite. The biotite flakes contain minute inclusions of quartz. A few flakes are altered to chlorite and hematite. The total chlorite content is about 1%.

From granodiorite.
(82 F) 0.35 mile west of the east contact of Porcupine Creek stock in the creek bottom just below the road; 49°15'N, 117°05'W. Map-unit 19, GSC Map 1090A. Sample P-1-RA-1. Collected and interpreted by J.E. Reesor.

British Columbia

The sample is from the Porcupine Creek stock. This small intrusive pluton occurs on Porcupine Creek east of Ymir. It is surrounded completely by incompetent Ordovician Active Formation, which consists principally of shale. Again the age of 128 m.y., indicating Lower Cretaceous emplacement, does not contradict available stratigraphic evidence (Little, 1960).

Bayonne Batholith

GSC 62-6 — Biotite, K-Ar age 100 m.y.

K 7.97%, Ar^{40}/K^{40} .00598; radiogenic argon 100%. Concentrate; clean concentrate of olive-green and olive-brown biotite. The flakes contain small inclusions of quartz. Chlorite not detected.

(82 F) From quartz monzonite. 25.0 miles south of Kootenay Bay ferry landing on the highway to Creston; 49°24'30"N, 116°44'18"W. Map-unit 17, GSC Map 603A. Sample MW52RA-1. Collected by F. M. G. Williams. Interpreted by J.E. Reesor.

(For interpretation see determination GSC 62-7).

GSC 62-7 — Biotite, K-Ar age 33 m.y.

K 8.23%, Ar^{40}/K^{40} .00197; radiogenic argon 100%. Concentrate; clean concentrate of greenish brown biotite. The flakes contain very small specks of quartz and a few inclusions of apatite. Chlorite not detected.

(82 F) From biotite-granodiorite. 1.8 miles south of Kuskanook on the Creston highway; 49°16'30"N, 116°39'00"W. Map-unit 17, GSC Map 603A. Sample BAY5RA-2. Collected and interpreted by J.E. Reesor.

Bayonne batholith straddles the south end of Kootenay Lake. It consists of a variety of massive granitic rock types ranging from mafic-rich granodiorite to leucoquartz monzonite. The two ages, 100 m.y. (GSC 62-6) and 33 m.y. (GSC 62-7) presented here bracket the age of 77 m.y. published by Baadsgaard et al (1961, p. 697). Furthermore the 33 m.y. age was obtained from a hornblende-biotite granodiorite that might be expected to represent an early phase of the batholith. Therefore it may be deduced, for the present, that the age of 100 m.y. from leucoquartz monzonite, an apparently young phase, must represent a minimum age for Bayonne batholith. This indicates its emplacement at least in Lower Cretaceous. This conclusion violates neither stratigraphic nor structural information.

Reference: Rice (1941).

Fry Creek Batholith

GSC 62-8 Muscovite, K-Ar age 83 m.y.

K 8.51%, Ar^{40}/K^{40} .00499; radiogenic argon 100%. Concentrate; consists of about 80% clean muscovite flakes and about 20% of the muscovite flakes with attached fragments of biotite and opaque inclusions. Impurities consist of 5% feldspar and 2% quartz.

From leucoquartz monzonite.

(82 F) Six miles up Campbell Creek, then due north at altitude 7,800 feet; 49°59'0"N, 116°44'12"W. Map-unit 17, GSC Map 603A. Sample FIRA-1. Collected and interpreted by J. E. Reesor.

(For interpretation see determination GSC 62-12).

GSC 62-9 Muscovite, K-Ar age 97 m.y.

K 8.90%, Ar^{40}/K^{40} .00584; radiogenic argon 100%. Concentrate; clean concentrate of muscovite. Chlorite not detected.

From quartz monzonite.

(82 K) Altitude 7,250 feet southeast of the junction of Fry Creek and Gillis Creek; 50°01'54"N, 116°39'42"W. Map-unit 28, GSC Map 12-1957. Sample F2RA-1. Collected and interpreted by J. E. Reesor.

(For interpretation see determination GSC 62-12).

GSC 62-10 Muscovite, K-Ar age 91 m.y.

K 8.05%, Ar^{40}/K^{40} .00546; radiogenic argon 100%. Concentrate; muscovite flakes vary from colourless to greenish grey. About 30% of the flakes are intergrown with opaque and reddish grains, quartz, and feldspar. The estimated amounts of impurities are 1% chlorite, 3% quartz, and 5% feldspar.

From leucoquartz monzonite.
(82 K) On ridge southeast from Mt. Pambrun; 50°5'24"N, 116°33'24"W. Map-unit 28, GSC Map 12-1957. Sample F3RA-1. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 62-12.)

GSC 62-11 Biotite, K-Ar age 86 m.y.

K 8.01%, Ar^{40}/K^{40} .00514; radiogenic argon 100%. Concentrate; consists mainly of clean olive-green biotite. A few flakes are coated with yellow crusts, are slightly chloritized along the edges, and contain a few quartz inclusions. Chlorite not detected.

From leucoquartz monzonite.
(82 K) On ridge southeast of Mt. Pambrun; 50°5'24"N, 116°33'24"W. Map-unit 28, GSC Map 12-1957. Sample F3RA-1. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 62-12.)

GSC 62-12 Biotite, K-Ar age 76 m.y.

K 7.94%, Ar^{40}/K^{40} .00452; radiogenic argon 100%. Concentrate; clean concentrate of green biotite. About 10% of the biotite flakes contain inclusions of quartz along fractures. A few flakes are altered to chlorite. The total chlorite content is about 6%.

From quartz monzonite.
(82 F) Altitude 7,800 feet in 'tail' of Fry Creek batholith, east of the head of St. Mary River; 49°52'N, 116°34'W. Map-unit 17, GSC Map 603A. Sample F8RA-1. Collected and interpreted by J.E. Reesor.

Fry Creek batholith lies across the 50th parallel of latitude, east of upper Kootenay Lake. The principal rock in this mass is a leucoquartz monzonite of remarkably consistent composition, though of variable texture, from locality to locality. Most varieties contain muscovite, a few both muscovite and biotite. Rarely, varieties may be found in which tourmaline, as individual grains or as knots, is the only dark mineral present.

British Columbia

Three of the specimens (sample numbers F1, F2, F3) reported here are typical of the leucoquartz monzonite of Fry Creek batholith and were collected in the main mass of the pluton. Specimen F8 was collected from the southern "tail" of the batholith. The first three specimens show a consistent result from 83 m.y. (GSC 62-8) to 97 m.y. (GSC 62-9). This consistency is further emphasized by the biotite-muscovite pair of specimen F3 that has given ages of 86 m.y. (GSC 62-11) and 91 m.y. (GSC 62-10) for biotite and muscovite respectively. This specimen was taken near the north contact of the pluton, on the southeast shoulder of Mt. Pambrun. The specimen collected from the "tail" of the pluton yields an age of 76 m.y. (GSC 62-12). A previous specimen collected at the north contact, on lower Fry Creek, gave a muscovite age of 63 m.y. (GSC 60-18) and a biotite age of 45 m.y. (GSC 60-19). In this specimen, petrographically younger muscovite gave the older "age" (Lowdon, 1961).

It may be reasonably assumed, judging from the compositional consistency of this pluton and from the consistency of the older ages from widely separated specimens ($\pm$90 m.y.), that it has been emplaced at a time not less than 90 m.y. ago or in the Upper Cretaceous. Since the rocks surrounding Fry Creek batholith are of late Precambrian and/or early Palaeozoic age, no stratigraphic evidence is available further to corroborate this conclusion. It is however consistent with patterns from other masses within this region.

The younger ages, from rocks of similar composition, on the northwest contact and from the southern tail, therefore may represent later modifications as a result of late structural disruptions and recrystallization that affected only the boundary of the mass. The specimen from the northwest contact clearly shows the effect of later recrystallization and shows also a faint foliation. Although specimen F8, from the southern tail, shows no evident foliation or other visible effect of later disruption, at the locality collected, it is nevertheless in a structural position such that it would be more easily affected by later events than the central mass of the pluton (See, for example, the discussion of Toby Stock below).

References: Rice (1941), Reesor (1957).

Toby Stock

GSC 62-13 Biotite, K-Ar age 232 m.y.

K 8.09%, Ar^{40}/K^{40} .0144; radiogenic argon 100%. Concentrate; clean concentrate of biotite. The flakes vary from olive-green to olive-brown and contain rare inclusions of quartz. Minor impurities (less than 1%) consist of a few flakes of bright green chlorite.

British Columbia

(82 K) From biotite-hornblende granodiorite. Altitude 8,600 feet on the south end of Toby Glacier; 50°12'36"N, 116°33'24"W. Map-unit A, GSC Map 12-1957. Sample TIRA-1. Collected and interpreted by J. E. Reesor.

(For interpretation see determination GSC 62-14.)

GSC 62-14 Biotite, K-Ar age 179 m.y.

K 7.80%, Ar^{40}/K^{40} .0110; radiogenic argon 100%. Concentrate; clean concentrate of greenish brown biotite. The biotite flakes contain quartz inclusions. Minor impurities consist of about 3% green chlorite and a few fragments of exsolution perthite. The total chlorite content is about 3%.

(82 K) From granodiorite. Altitude 7,750 feet on 'tail' of Toby Stock on ridge top south of large Alpine Lake, north of upper Carney Creek; 50°11'N, 116°34'W. Map-unit A, GSC Map 12-1957. Sample T-3RA-1. Collected and interpreted by J. E. Reesor.

Toby stock is a conformable, syntectonic, pluton lying at the head of Toby Creek. Rock types present range from massive hypersthene-bearing monzonite to a mildly foliated hornblende-biotite granodiorite, to an intensely lineated hornblende-biotite augen granodiorite gneiss derived from the slightly foliated granodiorite. Toby massif is roughly comparable in range of composition and rock types present, to the Adamant pluton in the northern Selkirk Range (see discussion of Adamant Batholith below; determination GSC 62-24).

Specimen T-1 is a foliated, epidote bearing, biotite granodiorite from the central part of the mass, at the head of Toby Glacier. It yields an age of 232 m.y. on biotite (GSC 62-13). Specimen T-3 is a highly lineated, much deformed, epidote-bearing, biotite granodiorite augen gneiss apparently derived from a rock similar to that of the previous specimen, but which has undergone more intense deformation at the south end of the "tail" of the mass. The biotite from this specimen yields an age of 179 m.y. and clearly shows, on one uniform rock type, the effect of greater intensity of post-crystalline deformation on the K-Ar "age" obtained.

Although neither of these ages may in fact be the true time of emplacement of this mass, the older age clearly corroborates the structural evidence that the mass was emplaced early in the deformation and has been involved in at least one later phase of deformation that involved both the pluton and the enclosing rocks. The similarity of the composition of this mass and Adamant batholith and the older ages obtained in Adamant (281 m.y., GSC 61-21; and 200 m.y., GSC 61-23) gives evidence of possible earlier structural and plutonic events in the Purcell-Selkirk Mountain chain.

Reference: Reesor (1957).

Glacier Creek Stock

GSC 62-15 Biotite, K-Ar age 145 m.y.

K 8.08%, Ar^{40}/K^{40} .00880; radiogenic argon 100%. Concentrate; clean, consisting of mainly brown biotite but containing about 20% greenish flakes. The flakes contain a few inclusions of quartz and some small specks along the edges of the grains. A few fragments of epidote are present as an impurity. Chlorite not detected.

From granodiorite.
(82 K) From the south side of a glacier on top of the pluton; 50°23'12"N, 116°47'42"W. Map-unit A, GSC Map 12-1957. Sample GIRA-2. Collected and interpreted by J.E. Reesor.

Glacier Creek stock straddles Glacier Park about 10 miles above its mouth. Although this stock bears the same structural relation to the surrounding rocks as noted for Toby stock above, it consists predominantly of a more massive biotite granodiorite. Much of it is however, covered by an extensive ice field and other rock types similar to those of Toby stock may well occur.

These two specimens were collected at the south end of the ice field, only a few hundred yards apart. Specimen GIRA-2 yields an age of 145 m.y. (GSC 62-15) but GIRA-1 yields an age of 127 m.y. (GSC 61-18). No recognizable significant difference in texture or composition exists between these two specimens and possibly an age of 136 $\pm$ 9 m.y. is at least the youngest possible date for emplacement of this pluton. This date, of latest Jurassic or earliest Lower Cretaceous age, does not contradict available stratigraphic information in the surrounding region indicating a period of deformation of post Middle Jurassic age. Although Glacier stock is syntectonically enclosed in the surrounding sedimentary rocks in the same way as Toby stock, it does not confirm (or deny) an earlier period of deformation and plutonic activity suggested by the Toby and Adamant massifs.

Reference: Reesor (1957).

British Columbia

Horsethief Creek Batholith

GSC 62-16 Biotite, K-Ar age 108 m.y.

K 8.19%, Ar^{40}/K^{40} .00648; radiogenic argon 100%. Concentrate; reasonably clean concentrate of brown biotite. Some flakes contain a few prismatic inclusions of apatite, rare zircons surrounded by double-rimmed pleochroic haloes and thin crusts of goethite. About 20% of the flakes are split along (001) planes and slightly chloritized. The total chlorite content is about 3%.

From quartz monzonite.
(82 K) Altitude 8,400 feet in saddle east of North Star Peak; 50°36'12"N, 116°30'42"W. Map-unit 28, GSC Map 12-1957. Sample H2RA-1. Collected and interpreted by J.E. Reesor.

Horsethief Creek batholith lies at the head of Howser Creek, astraddle the Purcell Divide. It consists of two principal rock types, a coarse biotite granite along the western fringe, and a porphyritic quartz monzonite and leucoquartz monzonite in the main part of the pluton. Megacrysts of potash feldspar in the latter are euhedral, and may be up to 2 inches by 1 inch or more.

Two "ages" from this massif are available, one of 205 m.y. (GSC 61-19) from the coarse granite, and one of 108 m.y. (GSC 62-16) from the porphyritic quartz monzonite. Two such disparate ages from this mass are difficult or impossible to interpret without further information. Thus if two separate emplacements are considered, it is difficult to imagine the intrusion of the main mass of Horsethief Creek pluton at 108 m.y. without completely obliterating nearby older K-Ar ages from the western fringe. If, on the other hand, an early emplacement is postulated, then it is difficult to imagine a major lowering of the original age without evident structural or petrogenic effects such as visible foliation or visible recrystallization. Neither of these is evident in Horsethief Creek pluton, and since neither of the above interpretations is satisfactory, significant conclusions on the emplacement and subsequent history of Horsethief batholith must await further determinations both by K-Ar and other methods.

References: Reesor (1957), Walker (1926).

British Columbia

Bugaboo Batholith

GSC 62-17 Biotite, K-Ar age 132 m.y.

K 8.10%, Ar^{40}/K^{40} .00798; radiogenic argon 100%. Concentrate; consists of brown biotite containing tiny inclusions and a few dark pleochroic haloes. Some flakes are slightly bleached. Chlorite/biotite 0.05.

From quartz monzonite.
(82 K) Head of the easternmost fork of East Creek at the eastern edge of the glacier, east-northeast of Howser Spires; 50°45'36"N, 116°49'6"W. Map-unit 28, GSC Map 12-1957. Sample B2RA-1. Collected and interpreted by J. E. Reesor.

(For interpretation see determination GSC 62-18.)

GSC 62-18 Muscovite, K-Ar age 138 m.y.

K 8.83%, Ar^{40}/K^{40} .00839; radiogenic argon 100%. Concentrate; reasonably clean, consisting of muscovite containing small inclusions of quartz. Impurities total less than 5% and consist of biotite and minor chlorite. The total chlorite content is less than 1%.

From quartz monzonite.
(82 K) Head of the easternmost fork of East Creek at the eastern edge of the glacier east-northeast of Howser Spires; 50°45'36"N, 116°49'6"W. Map-unit 28, GSC Map 12-1957. Sample B2RA-1. Collected and interpreted by J. E. Reesor.

The Bugaboo massif lies across the Purcell Divide at the head of Bugaboo Creek and northwest of the Horsethief Creek pluton. It consists of at least three principal rock types, a western mass of biotite granodiorite, an eastern mass of coarse leucoquartz monzonite with large euhedral megacrysts of potash feldspar, and a massive, medium-grained, leucoquartz monzonite of uniform texture. The porphyritic leucoquartz monzonite at the head of East Creek appears to truncate sharply and intrude the mafic-rich granodiorite of the western extremity of Bugaboo massif. Structures in the surrounding late Precambrian metasediments are greatly affected around the boundary of the pluton and are visibly deflected and thrust aside from their normal northwestward trend. Thus the pluton appears to be post-tectonic or at least later than the main phase of folding in these rocks.

British Columbia

Interpretation of the available ages is difficult, for an age of 100 m.y. is reported for a biotite from the western granodiorite (GSC 61-20), but a biotite-muscovite pair from the apparently later leucoquartz monzonite of the eastern mass yields a consistent result of 132 m.y. (GSC 62-17) for biotite and 138 m.y. (GSC 62-18) for muscovite. We must therefore consider the latter a minimum time (Lower Cretaceous) for emplacement of the eastern part of the mass, but that for some reason the apparently older western mass yields a younger age. Clearly the significance of this, in the interpretation not only of internal relations of phases within the pluton, but of relations of these phases to similar phases in other similar plutons elsewhere in this region may be judged only by further work.

Reference: Reesor (1957).

Battle Batholith

GSC 62-19 Biotite, K-Ar age 94 m.y.

K 7.83%, Ar^{40}/K^{40} .00565; radiogenic argon 100%. Concentrate; the biotite flakes vary from brownish to greenish and some contain numerous inclusions of apatite and zircon (the latter surrounded by pleochroic haloes). A few flakes are slightly altered to chlorite and epidote. The total chlorite content is about 3%.

(82 N) From quartz monzonite. Freeze Cirque, Battle Range; 51°03'N, 117°30'W. Map-unit B, GSC Map 4-1961. Sample WB-137W-6. Collected by J. O. Wheeler. Interpreted by J.E. Reesor.

(For interpretation see determination GSC 62-22.)

GSC 62-20 Biotite, K-Ar age 92 m.y.

K 7.36%, Ar^{40}/K^{40} .00551; radiogenic argon 100%. Concentrate; reasonably clean concentrate of biotite. The biotite flakes vary from brown to greenish. A few flakes are slightly altered to chlorite and epidote. Impurities, totalling about 10%, consist mainly of chlorite and minor muscovite. The total chlorite content is about 7%.

(82 N) From quartz monzonite. Freeze Cirque, north of Battle Brook in Battle Range; 51°03'N, 117°30'W. Map-unit B, GSC Map 4-1961. Sample WB-137W-7. Collected by J. O. Wheeler. Interpreted by J. E. Reesor.

(For interpretation see determination GSC 62-22.)

British Columbia

GSC 62-21 Muscovite, K-Ar age 91 m.y.

K 8.30%, Ar^{40}/K^{40} .00546; radiogenic argon 100%. Concentrate; impure concentrate of muscovite. About 80% of the muscovite flakes contain inclusions of quartz along the edges and a few flakes are intergrown with biotite. Impurities total about 20% and consist mainly of feldspar and of some muscovite-feldspar-quartz intergrowths. Chlorite not detected. Feldspar makes up 15-20%, and quartz 2-3%.

From quartz monzonite.
(82 N) Freeze Cirque, north of Battle Brook in Battle Range; 51°03'N, 117°30'W. Map-unit B, GSC Map 4-1961. Sample WB-137W-7. Collected by J.O. Wheeler. Interpreted by J.E. Reesor.

(For interpretation see determination GSC 62-22.)

GSC 62-22 Muscovite, K-Ar age 120 m.y.

K 8.80%, Ar^{40}/K^{40} .00723; radiogenic argon 100%. Concentrate; clean concentrate of muscovite. About 70% of the muscovite flakes exhibit (001) parting and contain rare specks of quartz on the surface. Chlorite not detected.

From aplite.
(82 N) Freeze Cirque in Battle Range granite; 51°03'N, 117°30'W. Map-unit B, GSC Map 4-1961. Sample WB-137W-8. Collected by J.O. Wheeler. Interpreted by J.E. Reesor.

Battle batholith lies within Battle Range, from the head of the Duncan River to the Incomappleux River. Its precise limits and relations to the surrounding country rock are not yet known. Wheeler, in the course of field work in Golden Map-area, west-half, in 1961, collected three specimens representing the principal rock types of Battle batholith. They were collected in the area north of Battle Brook, north of a large septa of metasedimentary rocks that separates the northern part of the pluton from the main southern mass (Wheeler, J.O., personal communication, 1962).

Measurements of K-Ar ages on two of the specimens, a biotite-muscovite pair from WB-137W-7, a fine-grained quartz monzonite, and biotite from WB-137W-6, a coarse quartz monzonite with megacrysts of potash feldspar, yield remarkably uniform results, ranging from 91 m.y. (GSC 62-21) and 92 m.y. (GSC 62-20) for the biotite muscovite pair respectively, and 94 m.y. (GSC 62-19) for the biotite alone. On the other hand a combined aplite and pegmatite vein gave an age of 120 m.y. (GSC 62-22). The pegmatite cuts the former two rocks, neither of which show any evidence of subsequent deformation. The muscovite of the pegmatite is significantly coarser than that in specimen WB-137W-7. It would thus appear that this massif cannot be younger than 120 m.y. in spite of the apparent consistency of the significantly younger ages in both the general rock types found enclosing the pegmatite. There is a possibility, of course, that later plutonic events within this mass have affected the massive, though finer grained micas of the country granite, but left relatively less affected the coarse muscovite of the pegmatite. Clearly more reconnaissance K-Ar measurements are necessary to establish younger phases within this pluton that could account for these effects.

Fang Stock

GSC 62-23 — Biotite, K-Ar age 168 m.y.

K 7.28%, Ar^{40}/K^{40} .0103; radiogenic argon 100%. Concentrate; consists of olive-green biotite with about 20% of bright green chlorite. The biotite flakes contain minor inclusions of epidote and quartz. The total chlorite content is about 20%.

From granodiorite.
(82 N) West side of Tangier River; 51°20'N, 117°50'W. Map-unit B, GSC Map 4-1961. Sample WB-129W-9. Collected by J.O. Wheeler. Interpreted by J.E. Reesor.

Fang stock occurs west of Tangier River and south of Mt. Moloch in Selkirk Range north of the Canadian Pacific Railroad main line.

This specimen of hornblende-biotite quartz-monzonite containing 14.9% coarse megacrysts of potash feldspar, was collected by Wheeler in 1961. The age, 168 m.y. appears anomalous if this mass is considered typical of the small post-tectonic intrusive masses in this region. If this result is accepted as the youngest possible date for the mass then some adjustment of this conclusion is necessary. Perhaps Fang stock has been emplaced early in the tectonic cycle, and has later acted as a competent, resistant mass during later structural episodes. In this case it seems likely that this stock is in fact older, and the above age must be considered as a minimum. (See discussion of Nelson batholith below; determination GSC 62-32).

Adamant Batholith

GSC 62-24 — K-Feldspar, K-Ar age 92 m.y.

K 9.80%, Ar^{40}/K^{40} .00550; radiogenic argon 100%. Concentrate; about 70% of the feldspar fragments are exsolution perthite. About 25% of the fragments are untwinned and non-perthitic. The total plagioclase content is 10-15%.

British Columbia

From granodiorite.
(82 N) North side of Wotan Glacier, 1 mile northeast of Wotan Peak; 51°44'30"N, 118°44'00"W. Map-unit Ba, GSC Map 4-1961. Sample 5FK-7-2. Collected by P. E. Fox. Interpreted by J. E. Reesor.

Adamant batholith occurs on the divide of the northern Selkirk Mountains, south of Kinbasket Lake. Four ages have previously been reported from this massif (GSC 61-21, GSC 61-22, GSC 61-23, and GSC 61-24) of 281 m.y., 200 m.y., 131 m.y., and 90 m.y. A potash feldspar concentrate was separated from a granodiorite near the locality and from the same rock type that produced the older ages recorded above. The feldspar yields an age of 92 m.y., identical with that found on biotite from a late quartz-rich vein in the granodiorite. Thus the "age" of the potash feldspar appears to agree well with the latest, identifiable, major event in the complex evolution of Adamant massif. This complex history of Adamant batholith possibly involves early intrusion of hypersthene monzonite, with later deformation and reintrusion and associated metamorphism of the early monzonite to a mafic granodiorite (P. E. Fox, Ph. D. Thesis in preparation, Carleton University, Ottawa; personal communication). In view of this complexity, and in view of the thorough petrological study being undertaken by Mr. Fox, it is best to defer any specific interpretation of these age determinations. A Rb/Sr age determination on potash feldspar from the monzonite core of Adamant massif is now being undertaken.

GSC 62-25 Hornblende, K-Ar age 116 m.y.

K 1.70%, Ar^{40}/K^{40} .00700; radiogenic argon 61%.

From granodiorite.
(82 N) South of Fip Granite Glacier, elevation 6,500 feet; 51°46'08"N, 117°51'30"W. Map-unit B, GSC PS Map 4-1961. Sample FK-A-3. Collected by P. E. Fox. Interpreted by J. E. Reesor.

The hornblende for this determination was separated from the same specimen as the biotite that yielded a previously reported age of 200 m.y. (GSC 61-23). It is evident that hornblende in this case has not retained argon better than the associated biotite, but rather is more comparable with the associated potash feldspar (GSC 62-24) in recording the youngest events in Adamant pluton. (See above discussion of other ages from Adamant).

The "age" of the above hornblende cannot be considered, at this stage of our knowledge of the Adamant batholith, to represent a separate event in its formation. Rather it represents imposition of a late event (90 m.y. ?) on minerals of a considerably older age.

British Columbia

Major Plutonic Masses Lying Between the Shuswap Metamorphic Complex and the Line of Minor Plutonic Intrusions to the East in the Purcell-Selkirk Arc (Reference: Map 932A - British Columbia)

Nelson Batholith

GSC 62-26

Biotite, K-Ar age 165 m.y.

K 7.57%, Ar^{40}/K^{40} .0101; radiogenic argon 100%. Concentrate; clean, consisting of biotite flakes varying from brown to green. Some flakes contain small inclusions of quartz and some have yellowish coatings. The chlorite content is about 3%.

From granodiorite.

(82 F) In a cirque just west of Arlington Park; 49°45'48"N, 117°13'30"W. Map-unit 19a, GSC Map 1090A. Sample NIRA-1. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 62-32).

GSC 62-27

Biotite, K-Ar age 159 m.y.

K 7.90%, Ar^{40}/K^{40}.00973; radiogenic argon 100%. Concentrate; clean concentrate of biotite varying from brown (80%) to green (20%). Some of the flakes contain small inclusions along slightly altered edges. The chlorite content is less than 2%.

From granodiorite.

(82 F) In cirque just east of, and below, Pontiac Peak; 49°46'24"N, 117°4'30"W. Map-unit 19, GSC Map 1090A. Sample N2RA-1. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 62-32).

GSC 62-28

Biotite, K-Ar age 171 m.y.

K 6.90%, Ar^{40}/K^{40}.0105; radiogenic argon 100%. Concentrate; reasonably clean concentrate of biotite varying from brown to green. About 30% of the biotite flakes are chloritized along the edges and contain inclusions of epidote in the chloritized areas. The concentrate contains about 5% chlorite as free grains and a few prisms of dark green hornblende.

British Columbia

The chlorite: biotite ratio for the concentrate as a whole is 0.25.

From granodiorite.
(82 F) In Springer Creek Canyon on the upstream side of the second bridge on the road from Slocan. Elevation 4,700 feet; British Columbia. 49°47'00"N, 117°22'24"W. Map-unit 19, GSC Map 1090A. Sample N9RA-1. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 62-32).

GSC 62-29 Biotite, K-Ar age 163 m.y.

K 7.56%, Ar^{40}/K^{40} .00998; radiogenic argon 100%. Concentrate; reasonably clean concentrate of biotite varying from olive-brown (75%) to green (25%). Some flakes are coated with yellow crusts. Total impurities are less than 5% and consist of small fragments of quartz, feldspar, and a few flakes of chlorite. The chlorite content is less than 1%.

From quartz monzonite.
(82 F) On roadcut at 6,500 feet on the road to Arlington, 10.2 miles from Slocan on Springer Creek Road; 49°46'54"N, 117°20'18"W. Map-unit 19, GSC Map 1090A. Sample N11RA-1. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 62-32).

GSC 62-30 Biotite, K-Ar age 171 m.y.

K 7.87%, Ar^{40}/K^{40} .0105; radiogenic argon 100%. Concentrate; clean concentrate of green biotite. Biotite flakes contain a few inclusions of apatite, zircon, and rutile. Chlorite not detected.

From granodiorite.
(82 F) Altitude 7,900 feet in basin north of Mt. Carlyle in the northernmost, partly separate mass, of the Nelson batholith; 49°56'N, 117°08'W. Map-unit 19a GSC Map 1090A. Sample N-16RA-1. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 62-32).

British Columbia

GSC 62-31 Biotite, K-Ar age 105 m.y.

K 7.62%, Ar^{40}/K^{40} .00630; radiogenic argon 100%. Concentrate; reasonably clean concentrate of green biotite. Some flakes are orangy brown. About 20% of the flakes exhibit a distinct (001) splitting and are slightly altered to chlorite. Minor impurities consist of about 2% hornblende and about 2% free chlorite. The total chlorite content is about 10%.

From leucogranite.

(82 F) 10.9 miles east of Nelson Bridge on the highway corner; 49°36'36"N, 117°7'54"W. Map-unit 17, GSC Map 1090A. Sample MW48RA-1. Collected and interpreted by J. E. Reesor.

(For interpretation see determination GSC 62-32).

GSC 62-32 Biotite, K-Ar age 63 m.y.

K 7.96%, Ar^{40}/K^{40} .00375; radiogenic argon 100%. Concentrate; clean concentrate of biotite consisting of brown flakes (60%) and of greenish flakes (40%). The flakes contain minor inclusions of quartz and feldspar, and a few are slightly chloritized along the edges. The total chlorite content is about 2%.

From granodiorite.

(82 F) From a rock cut where the natural gas pipeline crosses the highway, 2.4 miles from the traffic circle at the west end of Nelson; 49°29'18"N, 117°20'30"W. Map-unit 19, GSC Map 1090A. Sample MW35RA-2. Collected and interpreted by J. E. Reesor.

The Nelson batholith is here restricted to the massive granitic pluton between Kootenay and Slocan Lakes, and principally north of Kootenay Arm, though a narrow projection of the mass continues across Kootenay Arm as far south as Ymir Creek. (See, however, Little, 1960, pp. 81-82 for a more inclusive definition of Nelson batholith). In spite of the above limitation of the area of Nelson batholith, this massif outcrops over 900 square miles. The composition of rock types present varies from hornblende-biotite granodiorite, typically containing large megacrysts of potash feldspar, to biotite granodiorite and leucoquartz monzonite. The hornblende bearing granodiorite is the dominant rock type, but the more leucocratic varieties are found throughout the batholith not only as irregular masses of large extent, but also as dykelets and veinlets in the dark granodiorite. Along the west and southwest fringe of the batholith, hornblende syenodiorite and augite-hornblende monzonite may be found as a later intrusion.

Structurally, much of this pluton is massive, though both vertical foliation and steep lineation may be found within it. The western boundary, along Slocan Lake and southward, is marked by a profound break that has been a locus of deformation and later intrusion over a long period (Reesor, 1963).

Crosby (unpublished thesis, Harvard University, 1960) described what he considered a protoclasis or deformation and cataclasis synchronous with the emplacement of the pluton along part of the eastern edge of Nelson pluton, north of Kootenay Arm. In 1962 the writer examined the "tail" of the massif outcropping along Ymir Creek. The rocks there show strong post-crystalline deformation, and an intense lineation is parallel with the fold axes and cleavage-bedding intersection lineation in the enclosing rocks. Thus the narrow southern "tail" of Nelson batholith has been involved in at least the latest period of intense structural deformation that affected the enclosing sedimentary and metamorphic rocks.

Ten K-Ar age determinations are available from localities throughout the main mass of Nelson batholith, north of Kootenay Arm and Kootenay River. The "ages" fall into three groups; an old group, a young group, and an intermediate group.

The old group consists of ages reported here from the massive hornblende-biotite granodiorite. Two samples, one from a point a few miles east of the south end of Slocan Lake and one from the northernmost, nearly separate mass of Nelson batholith, both yield ages of 171 m.y. (GSC 62-28 and GSC 62-30). Three further specimens, taken in a rough east-west line across the central part of the pluton respectively near Arlington Peak (163 m.y., GSC 62-29), Nansen Mountain (165 m.y., GSC 62-26), and Pontiac Peak (159 m.y., GSC 62-27) yield approximately similar ages.

The young group is represented by two specimens previously reported, GSC 60-21 from a leucoquartz monzonite at the head of Duhamel Creek and GSC 60-22, from a hornblende-granodiorite about 9 miles downstream from the above specimen, and yield respectively 49 m.y. and 55 m.y. A further, young age reported here, specimen MW35RA-2, a biotite granodiorite, 2 1/2 miles west of the town of Nelson, yields an age of 63 m.y. (GSC 62-32).

Intermediate ages between these two extremes range from 86 m.y. to 131 m.y. GSC 61-17 from Mt. Chapman in the north-east part of the pluton at 131 m.y. is the oldest. Specimen MW48RA-1 of hornblende-biotite granodiorite, was collected on the main highway about 11 miles east of Nelson, and yields an age of 105 m.y. (GSC 62-31). Finally an age of 86 m.y. is reported by Little (1960, pp. 86-87) from a specimen collected west of Nelson.

Although much work remains to be done on this structurally and petrogenetically complex mass, a tentative suggestion as to the broad outlines of its formation and emplacement seem warranted at this time. This is particularly so since structural relations and K-Ar dates within this massif are not apparently contradictory. It may be suggested that Nelson batholith developed in three main stages:

1. Emplacement and consolidation of a large massif of hornblende-biotite granodiorite, at greater depth than now, before 171 m.y. These ages must be considered a minimum and this episode may well be considerably older. The older ages have been preserved only because the early granodiorite reacted to later structural events as a passive competent mass, and was not penetratively redeformed.

2. Mobilization and re-intrusion of a relatively passive mass resultant upon an intense structural episode that affected the region generally. This might have taken place at, or later than 131 m.y. or latest Jurassic - earliest Cretaceous.

3. Further emplacement of both leucocratic quartz monzonite in, and around the fringe of the batholith. Still later emplacement of augite-hornblende monzonite and syenodiorite west and southwest of the main batholithic mass.

It is proposed to continue further structural and petrologic studies, as well as further isotopic age determinations by the Rb-Sr method, to test or to discard the above tentative hypothesis of the evolution of Nelson batholith.

Kuskanax Batholith

GSC 62-33 Biotite, K-Ar age 66 m.y.

K 7.60%, Ar^{40}/K^{40} .00394; radiogenic argon 100%. Concentrate; reasonably clean concentrate of reddish brown biotite. About 30% of the biotite flakes are slightly altered and contain very fine specks of quartz and epidote, and long needle-like inclusions. The total chlorite content is about 7%.

British Columbia

(82 K) From quartz monzonite.
2 miles south, on roadside from Galena Bay; 50°41'N, 117°53'W. Sample K-15RA-2. Collected and interpreted by J. E. Reesor.

(For interpretation see determination GSC 62-34).

GSC 62-34 Muscovite, K-Ar age 90 m. y.

K 8.99%, Ar^{40}/K^{40} .00542; radiogenic argon 100%. Concentrate; clean concentrate of muscovite. About 50% of the muscovite flakes contain minor inclusions of quartz and feldspar, and a few small euhedral crystals of biotite. Total feldspar content is about 3%. Chlorite not detected.

(82 K) From quartz monzonite.
2 miles south, on roadside from Galena Bay; 50°41'N, 117°53'W. Sample K-15RA-2. Collected and interpreted by J. E. Reesor.

Kuskanax batholith is an extensive plutonic mass north of Nelson batholith, within the concave, western side of the Purcell-Selkirk Mountain arc. Kuskanax massif consists principally of a leucocratic pyroxene-hornblende monzonite. Variations occur ranging from pyroxene monzonite and quartz monzonite to syenite and quartz-syenite. K-Ar determinations have so far not been possible as mica has not been found in some 50 specimens collected at regular intervals throughout the massif. Nevertheless the above specimen, K-15RA-2, a muscovite-biotite leucogranodiorite, from a small mass at the north end of the batholith just south of Galena Bay on Upper Arrow Lake, yielded a muscovite-biotite pair giving ages of 90 m. y. (GSC 62-34) and 66 m. y. (GSC 62-33) on muscovite and biotite respectively. No specific conclusion as to emplacement of Kuskanax batholith may be made as a result of this determination. However, the muscovite determination at 90 m. y. is comparable to the results in Battle batholith to the northeast.

Shuswap Metamorphic Complex

GSC 62-35 Biotite, K-Ar age 64 m. y.

K 7.69%, Ar^{40}/K^{40} .00384; radiogenic argon 100%. Concentrate; clean concentrate of brown biotite. Minor impurities (about 2%) consist of hornblende, zircon and quartz. About 10% of the biotite flakes are slightly altered to chlorite. The total chlorite content is about 3%.

British Columbia

From augen gneiss.
(82 L) Glaciated knoll at the east end of the main glacier, altitude 7,000 feet; 50°33'12"N, 118°4'54"W. Map-unit 1, GSC Map 1059A. Sample M3RA-1. Collected and interpreted by J. E. Reesor.

(For interpretation see determination GSC 62-37).

GSC 62-36 Biotite, K-Ar age 89 m.y.

K 8.22%, Ar^{40}/K^{40} .00531; radiogenic argon 100%. Concentrate; clean concentrate of brown biotite. Some flakes are slightly bleached and contain small inclusions of quartz. Chlorite not detected.

From paragneiss or coarse schist.
(82 L) Altitude 7,500 feet on a nose east of Mount Odin; 50°32'N, 118°02'W. Map-unit 1, GSC Map 1059A. Sample M-13RA-1. Collected and interpreted by J. E. Reesor.

(For interpretation see determination GSC 62-37).

GSC 62-37 Biotite, K-Ar age 127 m.y.

K 7.21%, Ar^{40}/K^{40} .00767; radiogenic argon 100%. Concentrate; clean concentrate of brown biotite. About 15% of the biotite flakes are partly altered to pale green chlorite and epidote. The total chlorite content is about 10%.

From leucocratic rock.
(82 L) On Highway 1 at a large road cut, west end of Salmon Arm on Shuswap Lake, Tappen Mountain Lookout; 50°46'N, 119°20'W. Map-unit 18, GSC Map 1059A. Sample Mt. Ida 1RA-1. Collected and interpreted by J. E. Reesor.

The Shuswap Metamorphic Complex is here considered to extend from Okanagan Lake to Slocan Lake, and from the Internationa Boundary northward in a narrowing belt to at least the 52nd parallel of latitude. In its southern part the metamorphic complex has been intruded by massive granitic rocks of at least two principal ages, early quartz monzonite, both with and without large megacrysts of potash-feldspar, and a later monzonite and syenite (Coryell).

British Columbia

At least two principal structural episodes have affected the rocks of the Shuswap. The earlier resulted in a penetrative east-west minor folding, the later resulted in the superimposition of northward trending fold axes and lineation. All K-Ar dates available so far from this terrain presumably reflect the youngest, penetrative structural episode, for dates from widespread localities yield consistent results ranging up to 102 m.y. (see Reesor, in Lowdon 1961, and Lowdon et al, 1963). The ages presented here (GSC 62-35 at 64 m.y. and GSC 62-36 at 89 m.y.) are no exception to this general pattern. Ages discussed in this paper by Craig from the Blanket Mountain area follow a similar pattern (see discussion on determinations GSC 62-44, GSC 62-45, GSC 62-46, GSC 62-47 and GSC 62-48). From the total of at least 35 ages from both the Valhalla Complex and from the Monashee Group of the Shuswap Metamorphic Complex, it must be concluded that the youngest episodes will not be penetrated by K-Ar determinations. Older events must be determined by other methods and these are now being carried out in Valhalla Complex by the determination of a Rb-Sr whole rock isochron. No conclusions as to the age or ages of earlier folding and metamorphism can be reached before these and other determinations have been made.

Rocks of the Mt. Ida Group, north of Vernon (Jones, 1959, pp. 8 and 17) are considered a part of the Shuswap. Earlier determinations on these rocks (GSC 61-1, GSC 61-2, and GSC 61-3) gave consistent results of 140 m.y., 135 m.y., and 140 m.y., the last two from a biotite-muscovite pair respectively. These determinations were made on a gneiss and a schist. The age presented here from specimen Mt. Ida 1 of 127 m.y. (GSC 62-37) is from a massive leucoquartz monzonite intrusive into the Mt. Ida Group. This somewhat younger age appears to indicate Lower Cretaceous intrusion into an older metamorphic complex.

GSC 62-38 — Potash feldspar, K-Ar age 126 m.y.

K 8.7%, Ar^{40}/K^{40} .00763; radiogenic argon 100%. Concentrate; most of the feldspar is clouded with minute inclusions of what is probably quartz. The quartz content is estimated at 10%. Neither chlorite, kaolinite, nor sericite appeared in the diffractometer pattern.

From greenish grey porphyritic trachyte.

(82 G) On ridge between Howell and Twentynine Mile Creeks; 49°13'45"N, 114°43'00"W. Map-unit A, GSC Map 35-1961. Sample PF-107A. Collected and interpreted by R.A. Price.

British Columbia

The trachyte occurs in a small stock that cuts Purcell (Precambrian) and Cambrian beds of the Lewis thrust sheet. It is one of a group of small leucocratic alkalic intrusive bodies that occur in rocks as young as the lowest beds of the Lower Cretaceous Blairmore Group. The age of these alkalic rocks relative to late Cretaceous and/or early Cenozoic thrust faulting in this region has not been clearly established from field relationships.

The intrusive bodies were emplaced before late Eocene or early Oligocene time when coarse detritus derived from them was incorporated in conglomerates of the Kishenehn Formation. The date obtained indicates that they are older than the thrust faulting and that their emplacement may be correlated with the deposition of alkalic igneous detritus in the middle part of the Blairmore Group.

GSC 62-39 Biotite, K-Ar age 69 m.y.

K 7.08%, Ar^{40}/K^{40} .00413; radiogenic argon 100%. Concentrate; reasonably clean. The biotite flakes vary from brown to greenish. Impurities in the form of very fine fragments of hornblende and chlorite constitute less than 10% of the concentrate. About 6% of the biotite is altered to chlorite.

From quartz monzonite.
(82 F) At bridge across Caribou Creek, 2.8 miles east of Burton; 49°59'14.3"N, 117°50'00"W. Map-unit 19a, GSC Map 1090A. Sample HQ 6-1. Collected and interpreted by D. W. Hyndman.

The specimen was collected from Nelson Granite more than one mile from the nearest known country rocks.

Biotite occurs as small clusters of grains (1/2-2mm) interstitial to the felsic minerals (2-5mm), in many cases associated with sphene and to a lesser extent hornblende. It is strongly pleochroic, red-brown to pale yellow. The whole rock has suffered intergranular crushing. Edges of biotite grains are ragged and commonly chloritized. Quartz has been segmented into a mosaic of small grains with complexly interlocking boundaries.

Apart from vaguely aligned mafic minerals or megacrysts at a few localities and a moderately strong lineation adjacent to some of its contacts, the granitic body is essentially massive. It intrudes, 3 1/2 miles north, actinolitic hornfels that underlies Slocan-like argillaceous rocks. Shuswap-like schists and paragneisses underlie similar hornfels 3 miles farther northwest.

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A single specimen is not sufficient basis for geological conclusions, but should give an approximation. The age determined is presumably roughly the youngest date at which the specimen could have crystallized. The true age of the rock could be older, if the critical isotherm below which no appreciable argon diffusion takes place was reached at a date much later than formation of the rock (because of slow cooling or a later metamorphism) or if crystal granulation (as noted above) and chloritization caused loss of argon.

GSC 62-40 — Biotite, K-Ar age 221 m.y.

K 7.37%, Ar^{40}/K^{40} .0137; radiogenic argon 100%. Concentrate; clean concentrate consisting of about 75% brown and 25% greenish biotite. Less than 5% muscovite and chlorite occur as impurities. Chlorite/biotite 0.03.

From quartzite.
(82 F) 2 miles west of Alki Creek; 49°37'24"N, 116°15'51"W. Map-unit 2, GSC Map 15-1957. Sample LD-ML8. Collected and interpreted by G. B. Leech.

(For interpretation by Leech see Part II of this Paper).

GSC 62-41 — Muscovite, K-Ar age 555 m.y.

K 5.71%, Ar^{40}/K^{40} .0377; radiogenic argon 100%. Concentrate; impure, consisting of 60-65% muscovite and 35-40% quartz albite intergrowths. The approximate contents of quartz and albite are 20% and 15% respectively.

From argillite.
(82 F) 2 miles west of Alki Creek; 49°37'24"N, 116°15'51"W. Map-unit 2, GSC Map 15-1957. Sample LD-ML7. Collected and interpreted by G. B. Leech.

(For interpretation by Leech see Part II of this Paper).

GSC 62-42 — Muscovite, K-Ar age 398 m.y.

K 8.27%, Ar^{40}/K^{40} .0259; radiogenic argon 100%. Concentrate; contains 70-75% clean muscovite; 20-25% muscovite-quartz-feldspar intergrowths; and

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a few flakes of biotite. Approximately 1% chlorite, 2% quartz and 5% feldspar are present as impurities.

From quartzite.

(82 F) 2 miles west of Alki Creek; 49°37'24"N, 116°15'51"W. Map-unit 2, GSC Map 15-1957. Sample LD-ML8. Collected and interpreted by G. B. Leech.

(For interpretation by Leech see Part II of this Paper).

GSC 62-43 Biotite, K-Ar age 118 m.y.

K 7.90%, Ar^{40}/K^{40} .00712; radiogenic argon 100%. Concentrate; consists mainly of greenish brown biotite containing rare prismatic inclusions of apatite. About 5% of the flakes are partly altered to chlorite along the edges and contain small inclusions of quartz and epidote along cleavage planes. The estimated chlorite content is 4%.

From granodiorite.

(82 F) 2 1/4 miles from the mouth of Angus Creek; 49°33'N, 116°08'36"W. Map-unit 11, GSC Map 15-1957. Sample LDML-5. Collected and interpreted by G. B. Leech.

The biotite is from medium-grained granodiorite that cuts the late Precambrian Creston Formation east of Angus Creek, St. Mary Lake area. The outcrop is part of, or just west of, a drift-covered stock of porphyritic biotite granodiorite. This and similar stocks have been assumed to be Mesozoic but stratigraphic proof is lacking because the youngest strata intruded anywhere are Cambrian.

This particular intrusion was chosen for dating because it is the one closest to the non-biotitic granodiorite intrusions and related metamorphic rocks that have recently been shown to be Precambrian (Leech, 1962). It is within half a mile of the Precambrian Hellroaring Creek stock but separated from it by the St. Mary Fault which truncates the latter.

GSC 62-44 Biotite, K-Ar age 70 m.y.

K 7.82%, Ar^{40}/K^{40} .00418; radiogenic argon 100%. Concentrate; consists of ginger-brown to pale buff-biotite. Some flakes are slightly chloritized along the fractures. A few flakes contain inclusions of

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sillimanite and tourmaline. About 11% of the biotite is altered to chlorite.

(82 L) From medium-grained biotite-muscovite quartzite. Altitude 7,600 feet, 4 miles north of Blanket Mountain; 50°49'13"N, 118°15'09"W. Map-unit 1A, GSC Map 1059A. Sample CO-61-180. Collected and interpreted by D. B. Craig.

(For interpretation see determinations GSC 62-45 and GSC 62-48.)

GSC 62-45 Muscovite, K-Ar age 65 m.y.

K 8.64%, Ar^{40}/K^{40} .00388; radiogenic argon 100%. Concentrate; muscovite flakes contain minor quartz and sillimanite. Concentrate contains about 5% impurities of quartz and sillimanite and minor biotite.

(82 L) From medium-grained biotite-muscovite quartzite. Altitude 7,600 feet, 4 miles north of Blanket Mountain; 50°49'13"N, 118°15'09"W. Map-unit 1A, GSC Map 1059A. Sample CO-61-180. Collected and interpreted by D. B. Craig.

Determinations (GSC 62-44 and GSC 62-45) were made on biotite and muscovite from the same specimen of quartzite. Grain size and other textural characteristics are similar for both minerals. Ages are similar to well within the stated limits of analytical error. It appears that the conditions necessary for argon retention occurred at approximately the same time for both minerals.

(See also the discussion following determination GSC 62-48.)

GSC 62-46 Muscovite, K-Ar age 73 m.y.

K 8.89%, Ar^{40}/K^{40} .00438; radiogenic argon 100%. Concentrate; is clean and most flakes are colourless but some are slightly creamy buff. About 20% of the flakes are stained with iron oxide on the surface. Only a trace of chlorite is present.

(82 L) From coarse-grained tourmaline-muscovite quartzite. Altitude 7,700 feet, 4 miles north of Blanket Mountain; 59°49'00"N, 118°15'30"W. Map-unit 1A,

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GSC Map 1059A. Sample CO-61-138. Collected and interpreted by D. B. Craig.

(For interpretation see determination GSC 62-48).

GSC 62-47 Biotite, K-Ar age 76 m.y.

K 7.63%, Ar^{40}/K^{40} .00452; radiogenic argon 100%. Concentrate; consists of reddish brown biotite. About 10% of the biotite flakes are partly bleached and contain prisms of hornblende in the bleached areas. About 3% of the biotite flakes are altered to chlorite.

From coarse-grained biotite granite.
(82 L) Altitude 6,300 feet, 2 1/2 miles northwest of Blanket Mountain; 50°47'24"N, 118°15'16"W. Map-unit 1, GSC Map 1059A. Sample CO-61-162. Collected and interpreted by D. B. Craig.

(For interpretation see determination GSC 62-48).

GSC 62-48 Biotite, K-Ar age 81 m.y.

K 7.61%, Ar^{40}/K^{40} .00484; radiogenic argon 100%. Concentrate; clean concentrate of ginger-brown biotite. Some flakes are bleached and partly chloritized and contain needle-like inclusions. About 4% of the biotite is altered to chlorite.

From paragneiss.
(82 L) Altitude 7,200 feet, 1 1/2 miles north of Blanket Mountain; 50°46'44"N, 118°14'26"W. Map-unit 1, GSC Map 1059A. Sample CO-61-184. Collected and interpreted by D. B. Craig.

Six age determinations (GSC 61-8, GSC 62-44, GSC 62-45, GSC 62-46, GSC 62-47, and GSC 62-48) have been made on micas from Monashee Group rocks of the Shuswap Terrane, in the vicinity of Blanket Mountain. Two of the samples were from intrusive bodies within paragneiss - one a pegmatitic, biotite granite sill, the other a muscovite-quartz-feldspar pegmatite. Four of the samples were from metamorphic rocks - three from quartzite, one from migmatized, biotite-quartz-plagioclase paragneiss. Of these six determinations, three were from biotite and three from muscovite. The object of making these determinations was to learn the date of metamorphism of this part of the Shuswap Terrane and possibly to relate age differences to structural position, degree and time of deformation and migmatization. It was also desired to determine the time of cooling of certain minor intrusions within the metamorphic rocks.

The undeformed intrusions, geologically the youngest rocks, are indicated to be 76 and 81 million years old. The age of deformed, migmatized paragneiss is given as 81 million years and the ages of quartzites as 65, 70, and 73 million years. The average of the three determinations from biotite is similar to the average of the three determinations from muscovite, there being less than three million years difference. A biotite-muscovite pair from the same specimen give similar ages to within five million years, well within the limits of analytical error of the method.

No clear pattern is shown by the group of ages. No relationship with known structural or stratigraphic position is recognizable. During or after the post-deformational intrusion and consolidation of the pegmatites, the entire assemblage was probably above the temperature necessary for argon retention. Age differences greater than those that can be attributed to analytical error well might have resulted from uneven loss of argon due to uneven cooling of the assemblage. A somewhat greater age for the pegmatites than the quartzites is suggested, which might be attributable to a difference in grain size. The micas in the intrusive rocks are much coarser than those in the metamorphic rocks, which might result in greater argon retention and greater indicated age, since argon diffusion might be slower from the larger grains. This condition would appear to hold when the pegmatite ages are compared with those of the quartzites. This condition does not hold when the pegmatite ages are compared with that of the paragneiss as the mica in the paragneiss is similar in grain size to that in the quartzites, yet the age of the paragneiss is indicated to be the same as that of the older and coarser of the pegmatites. The best interpretation that can be made from these determinations is that the entire assemblage, including pegmatites, cooled below the temperature necesary for argon retention in the Upper Cretaceous and indicated differences in the ages are largely due to uneven cooling resulting in uneven argon retention. This cooling was essentially the last event in the geological history of these rocks and so the age determinations thus far do not enable one to recognize, or confirm, relationships within the assemblage.

It is appropriate to consider these ages in the light of previously expressed views on the age of Shuswap metamorphism. Jones (1959, p. 128), on the basis of probable unconformable relationships and structural dissimilarity with unmetamorphosed younger rocks, suggests the age of Shuswap deformation and contemporary metamorphism to be pre-Permian and possibly pre-Windermere. Reesor (1960, personal communications) considers the Shuswap to have been involved in Cordilleran Mesozoic deformation with structural and metamorphic differences from other rocks, which had been involved in this deformation, to be due to the greater depths of the Shuswap rocks within the earth's crust at the time of deformation.

Although the age determinations do not preclude earlier metamorphism, they do indicate the end of a period of metamorphism in the Upper Cretaceous. Since, as stated previously, the retention of argon occurred very late in the geological history of the rocks, the ages are consistent with Mesozoic metamorphism and thus lend support to the views of Reesor.

GSC 62-49 — Biotite, K-Ar age 73 m.y.

K 7.17%, Ar^{40}/K^{40} .00434; radiogenic argon 100%. Concentrate; clean concentrate of red-brown biotite containing minor bleached patches and inclusions of epidote in the bleached areas. Chlorite/biotite 0.02.

From schist.
(82 N) 6 miles south, 81° west of the mouth of Swan Creek; 51°54'10"N, 117°56'08"W. Map-unit la, Rogers Pass Map-area, GSC Paper 62-32. Sample WB-120-1-61. Collected and interpreted by J. O Wheeler.

(For interpretation see determination GSC 62-52.)

GSC 62-50 — Muscovite, K-Ar age 72 m.y.

K 7.68%, Ar^{40}/K^{40} .00432; radiogenic argon 100%. Concentrate; muscovite flakes are mostly clean but some are coated with thin yellow crusts and contain minor amounts of quartz inclusions. A few black specks, believed to be graphite, are also present. Impurities consist of less than 1% chlorite and 1% quartz.

From schist.
(82 N) 6 miles south, 81° west of mouth of Swan Creek; 51°54'10"N, 117°56'08"W. Map-unit la, Rogers Pass Map-area, GSC Paper 62-32. Sample WB-120-1-61. Collected and interpreted by J. O. Wheeler.

(For interpretation see determination GSC 62-52.)

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GSC 62-51 Biotite, K-Ar age 119 m.y.

K 7.50%, Ar^{40}/K^{40} .00720; radiogenic argon 100%. Concentrate; biotite varies from brown to greenish. About 70% of the flakes are clean. About 30% of the flakes contain small inclusions, some colourless and some opaque. A few biotite flakes are interleaved with muscovite. The total chlorite content is less than 1%.

From schist.
(82 N) 0.5 mile south, 34° west of Six Mile Pass; 51°34'55"N, 117°38'4"W. Map-unit 1a, Rogers Pass Map-area, GSC Paper 62-32. Sample NB-121-1-61. Collected and interpreted by J. O. Wheeler.

(For interpretation see determination GSC 62-52.)

GSC 62-52 Muscovite, K-Ar age 124 m.y.

K 8.74%, Ar^{40}/K^{40} .00753; radiogenic argon 100%. Concentrate; consists of mainly clean muscovite but about 20% of the flakes are partly coated with yellow crusts and have adhering fragments of biotite. About 5% contain opaque platy inclusions (possibly graphite). Chlorite not detected.

From schist.
(82 N) 0.5 mile south, 34° west of Six Mile Pass; 51°34'55"N, 117°38'4"W. Map-unit 1a, Rogers Pass Map-area, GSC Paper 62-32. Sample NB-121-1-61. Collected and interpreted by J. O. Wheeler.

A large part of the northern Selkirk Mountains is underlain by the late Precambrian Horsethief Creek Group (Map-unit 1a, Rogers Pass Map-area, GSC Paper 62-32) metamorphosed to schists and gneisses locally reaching kyanite grade. The metamorphic rocks contain numerous bodies of pegmatite considered to be coeval with the metamorphism. Beds of the Horsethief Creek Group have been severely bent and disrupted around the Adamant batholith.

Biotite-muscovite pairs (GSC 62-49, GSC 62-50) and (GSC 62-51, GSC 62-52) from the metamorphic rocks give ages of 73 m.y., 72 m.y., and 119 m.y., 124 m.y. respectively. Muscovite books (GSC 61-28) from within 1/2 mile of the first pair give an age of 107 m.y. The ages of 119 m.y. and 124 m.y. from the schists, and 107 m.y. from the pegmatite support the idea that the schists and the pegmatite are broadly coeval. Such ages suggest a period of metamorphism in late Lower Cretaceous time (Kulp, 1961).

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The ages of 72 m.y. and 73 m.y. are younger than expected. Reasons for this young age are puzzling. It might be argued that the schists, being finer grained than the pegmatite, may have lost more argon to give a younger age. On the other hand, the schists giving the younger age of 72 m.y. and 73 m.y. are coarser than those giving the older ages of 119 m.y. and 124 m.y. Some other process affecting the argon content of these rocks must then have been operative.

The age data suggest that regional metamorphism was later than the crystallization of biotite in the Adamant batholith (giving ages of 200 m.y., GSC 61-23, and 281 m.y., GSC 61-21) but broadly contemporaneous with the formation of micas in pegmatites that cut the batholith (having ages of 131 m.y., GSC 61-22, and 90 m.y., GSC 61-24). If the Permo-Triassic age for the batholith is valid then it follows that the batholith was unaffected by later regional metamorphism and must have remained as a solid mass during Mesozoic deformation, when only the surrounding rocks were disrupted.

In view of the three groups of ages in this region (200 + m.y., 107-124 m.y., and 72-90 m.y.) many more ages must be determined by different methods in order to test the validity of these groups of ages. Only then will we begin to understand whether the region has undergone Permo-Triassic intrusion and later selective polymetamorphism and what the relationship is between the Adamant batholith and the disturbed rocks surrounding it.

GSC 62-53 Biotite, K-Ar age 146 m.y.

K 7.13%, Ar^{40}/K^{40} .00889; radiogenic argon 100%. Concentrate; clean concentrate of pale brown to buff biotite. The biotite flakes contain inclusions of rutile, quartz, and zircon. About 10% of the biotite flakes are altered to chlorite and some epidote. The total chlorite content is about 10%.

From mica schist.
(82 N) 0.65 mile north 69° east of Cupola Mountain; 51°34'05"N, 117°33'30"W. Map-unit 1a, GSC Map 4-1961. Sample WB-151-AD-61. Collected and interpreted by J.O. Wheeler.

(For interpretation see determination GSC 62-54.)

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GSC 62-54 Muscovite, K-Ar age 205 m.y.

K 6.02%, Ar^{40}/K^{40} .0127; radiogenic argon 100%. Concentrate; impure concentrate of muscovite. Muscovite flakes contain opaque inclusions and small adhering specks of altered biotite. Some flakes are intergrown with quartz, chlorite and feldspar. Total chlorite content is about 10%; quartz about 15-20%; and feldspar less than 10%.

From mica schist.
(82 N) 0.65 mile north 69° east of Cupola Mountain; 51°34'05"N, 117°33'30"W. Map-unit 1a, GSC Map 4-1961. Sample WB-151-AD-61. Collected and interpreted by J. O. Wheeler.

Specimen WB-151-AD-61 (GSC 62-53 and GSC 62-54) is the third of a series of samples taken from metamorphic rocks of the Horsethief Creek Group in the northern Selkirk Mountains. The sample was taken from near the southeastern end of the metamorphic terrain where the metamorphic grade is considerably less than to the northwest. The rocks in the vicinity of WB-151-AD-61 are slightly crenulated mica schists containing porphyroblasts up to 1/4 inch in diameter of biotite and phlogopite. In hand specimen the porphyroblasts are randomly oriented and appear to have crystallized after the development of the crenulations in the matrix. A thin section of the rock shows porphyroblasts of biotite that have shouldered aside muscovite crystals that elsewhere show a well-developed crenulation. Very small crystals of muscovite appear to cut the porphyroblasts and hence some muscovite may be contemporaneous with or slightly later than the biotite.

A relatively impure concentrate of the larger muscovite crystals (GSC 62-54) from the matrix gave an age of 205 m.y. A reasonably clear concentrate from the biotite (GSC 62-53) porphyroblasts gave an age of 146 m.y.

It seems hardly likely that the crystallization of the biotite represents a later period of metamorphism 146 m.y. ago. Otherwise, virtually all the argon would have been lost from the muscovite at temperatures at which the biotite probably formed. It is more probable, however, that the region around specimen WB-151-AD-61 was slightly reheated at some later time sufficient to cause relatively little loss of argon from the muscovite but a much greater loss of argon from the biotite. The early metamorphism probably took place the same time as plutonism elsewhere in southeastern British Columbia, as evidenced by ages of 200 m.y. or more from the Adamant batholith, part of the Horsethief batholith, and Toby stock. It is uncertain when the younger reheating took place. Other ages in the metamorphosed Horsethief Creek Group of 124 m.y. (GSC 62-52), 119 m.y. (GSC 62-51), 72 m.y. (GSC 62-50) and 73 m.y. (GSC 62-49) give younger and younger ages with an increase in the grade of the metamorphism. The answer to this problem may come from a statistical study of age determinations resulting from a widespread sampling in this polymetamorphic terrain.

GSC 62-55 — Biotite, K-Ar age 186 m.y.

K 7.17%, Ar^{40}/K^{40} .01147; radiogenic argon 100%. Concentrate; clean concentrate consisting of pale buff and fluffy biotite flakes. Nearly half of the flakes have rims of bright green chlorite. Chlorite/biotite 0.05.

From pyroxenite.

(92 H) About 500 feet upstream from the junction of Skwum Creek with Lawless (Bear) Creek; 49°34'N, 120°54'W. Map-unit 4, GSC Map 888A. Sample FJT 61-1834B. Collected and interpreted by D.C. Findlay.

This result is in good agreement with field evidence and is considered to establish the age of the Tulameen Ultramafic Complex (Rice, 1947) within narrow limits. The Tulameen Complex is intrusive into metavolcanic and metasedimentary rocks of the Nicola Group (late Triassic) and is older than the nearby Eagle granodiorite (143 m.y. GSC 62-56).

GSC 62-56 — Biotite, K-Ar age 143 m.y.

K 7.55%, Ar^{40}/K^{40} .00868; radiogenic argon 95%. Concentrate; reasonably clean concentrate of brown biotite flakes containing fine-grained specks of epidote along the fractures. About 10% of the biotite flakes show chloritization along the edges. Chlorite/biotite 0.06.

From granodiorite.

(92 H) 1,000 feet east of the junction of Siwash (M'Gee) Creek with Tulameen River; 49°31'N, 120°55'W. Map-unit 5, GSC Map 888A. Sample FJT 61-1798B. Collected and interpreted by D.C. Findlay.

The Eagle Granodiorite (Rice, 1947) has been considered to be a member of the Coast Intrusions. On the basis of rather scanty field evidence it was believed to be younger than the Tulameen Ultramafic Complex (Camsell, 1913; Rice, 1947). The two ages, 143 m.y. for the Eagle Granodiorite and 186 m.y. for the Tulameen Ultramafic Complex (GSC 62-55) are in good agreement with the field evidence.

GSC 62-57 Hornblende, K-Ar age 286 m.y.

K 0.86%, Ar^{40}/K^{40} .0181; radiogenic argon 100%. Concentrate; reasonably clean concentrate of pleochroic (olive-bluish-green) hornblende. Minor impurities (about 10%) consist mainly of pyroxene and of small brown biotite flakes which coat the cleavage fractures in the hornblende. Chlorite not detected. The biotite is present only as a trace.

From hornblende pyroxenite.
(92 H) 2 1/2 miles at south 29° east from the southeast corner of Lodestone Lake, 2,500 feet north of Badger Creek; 49°26'N, 120°48'W. Map-unit 4, GSC Map 888A. Sample FJT61-1344Hb. Collected and interpreted by D. C. Findlay.

This sample is from the hornblende pyroxenite unit of the Tulameen Ultramafic Complex, Yale District (Rice, 1947, Map 888A, unit 4). The ultramafic rocks intrude Nicola Group metavolcanic rocks of late Triassic age, and may be, in part, truncated by the Eagle Granodiorite (Rice, 1947, Map 888A, unit 5) which has been dated at 143 m.y. (GSC 62-56). Biotite of pyroxenite from a small outlier body believed to be equivalent in age to the main ultramafic intrusion gave an age of 186 m.y. (GSC 62-55). This age is in good agreement with the geological relationships. The age from the present sample (286 m.y.) thus appears to be too great by about 100 m.y.

GSC 62-58 Biotite, K-Ar age 245 m.y.

K 4.25%, Ar^{40}/K^{40} .0153; radiogenic argon 100%. Concentrate; consists of a mixture of fresh, partly chloritized, and completely chloritized biotite in the following estimated proportions: fresh brown biotite - 30%; partly chloritized biotite - 40%; chlorite - 30%.

From quartz diorite.
(92 I) 7,000 feet east-southeast of the east end of Bose Lake on south side of BX Road; 50°30'03"N, 120°56'25"W. Map-unit 4, GSC Map 886A. Sample CA-4-61. Collected and discussed by R.B. Campbell.

(For discussion see determination GSC 62-63).

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GSC 62-59 — Biotite, K-Ar age 227 m.y.

K 5.33%, Ar^{40}/K^{40} .0141; radiogenic argon 100%. Concentrate; contains an estimated 30-35% unaltered biotite, 60-65% partly chloritized biotite, and 5% chlorite containing epidote inclusions. The total chlorite content is estimated at about 40%.

From quartz diorite.
(92 I) In small creek gully 500 feet east of BX Road, 1/4 mile northwest of Foot Lake; 50°29'25"N, 120°55'05"W. Map-unit 4, GSC Map 886A. Sample CA-3-61. Collected and discussed by R. B. Campbell.

(For discussion see determination GSC 62-63).

GSC 62-60 — Biotite, K-Ar age 237 m.y.

K 4.15%, Ar^{40}/K^{40} .0148; radiogenic argon 100%. Concentrate; consists of a mixture of fresh biotite, partly chloritized biotite, and biotite altered completely to chlorite in the following estimated proportions: fresh brown biotite - 25%; partly chloritized biotite - 50%; completely chloritized - 25%. A minor amount of hornblende is present as an impurity.

From quartz diorite.
(92 I) 500 feet east of BX Road (east of Bethlehem Copper); 50°29'00"N, 120°55'00"W. Map-unit 4, GSC Map 886A. Sample CA-2-61. Collected and described by R. B. Campbell.

(For discussion see determination GSC 62-63).

237 m.y.
GSC 62-61 — Biotite, K-Ar age 230 m.y.

.0148 100%
K 6.47%, Ar^{40}/K^{40} .0143; radiogenic argon 100%. Concentrate; consists of about 60% fresh brown biotite, 30% slightly altered biotite with epidote inclusions around the edges of the flakes, and 10% biotite flakes with green chloritized edges. The total estimated chlorite content is about 12%.

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From quartz diorite.

(92 I) 400 ft. east of Outrider Road, 1 mile north of Highland Valley Road; 50°28'55"N, 120°55'40"W. Map-unit 4, GSC Map 886A. Sample CA-5-61. Collected and discussed by R. B. Campbell.

(For discussion see determination GSC 62-63.)

GSC 62-62 Biotite, K-Ar age 242 m.y.

K 7.40%, Ar^{40}/K^{40} .0151; radiogenic argon 100%. Concentrate; consists of reasonably clean pale brown biotite. The flakes are slightly bleached around the edges and contain very small needle-like inclusions along fractures. Chlorite not detected.

From granodiorite.

(92 I) From the most northerly trench on Bethsaida Road, about 2,500 feet south of Highland Valley Lodge; 50°29'10"N, 121°03'30"W. Map-unit 1, GSC Map 1010A. Sample CA-6-61. Collected and described by R. B. Campbell.

(For discussion see determination GSC 62-63.)

GSC 62-63 Biotite, K-Ar age 224 m.y.

K 7.18%, Ar^{40}/K^{40} .0139; radiogenic argon 100%. Concentrate; consists of about 90% brown biotite containing some inclusions of epidote along fractures and edges of flakes. About 10% of the flakes are greenish and contain numerous inclusions of epidote. The estimated chlorite content is less than 2%.

From granodiorite.

(92 I) Most northerly trench of Bethsaida Road about 2,500 feet south of Highland Valley Lodge; 50°29'10"N, 121°03'20"W. Map-unit 1, GSC Map 1010A. Sample CA-7-61. Collected and discussed by R. B. Campbell.

The Guichon or Guichon Creek batholith (GSC Mem. 262, Map-unit 1; GSC Mem. 249, Map-unit 4) seems certainly to intrude Upper Triassic rocks of the Nicola Group though evidence for this is not completely conclusive.

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The batholith consists of a number of distinct phases. The oldest phase and quantitatively most important is the Guichon or older quartz diorite; this is cut by intrusions of Bethlehem or younger quartz diorite, and still younger is the Bethsaida granodiorite (White et al, 1957). The older quartz diorite (GSC 62-58 and GSC 62-59), the younger quartz diorite (GSC 62-60 and GSC 62-61), and the Bethsaida granodiorite (GSC 62-62 and GSC 62-63) are indistinguishable in terms of the K-Ar ages of the biotites.

No interpretation is offered to explain the fact that the K-Ar ages of the biotite are about Middle Permian whereas the rocks of which the biotite is a constituent are part of a batholith that apparently intrudes Upper Triassic rocks. Study of the problem is continuing.

GSC 62-64 Biotite, K-Ar age 187 m.y.

K 4.92%, Ar^{40}/K^{40} .01148; radiogenic argon 100%. Concentrate; consists of: about 35% clean brown biotite; about 40% biotite showing partial bleaching and inclusions of epidote; about 25% chloritized biotite containing epidote inclusions; and a few fragments of hornblende. The chlorite content is about 23%.

From granodiorite.

(93 A) 1,800 feet east-southeast of the southern peak of a volcanic cone on the summit of Takomkane Mountain; 52°06'00"N, 120°55'03"W. Map-unit 10a, GSC Map 42-1961. Sample 469-CAc-2b. Collected and interpreted by R. B. Campbell.

The granitic rocks of Takomkane Mountain are part of a large batholith that evidently intrudes unfossiliferous Mesozoic strata. If the K-Ar age of 187 m.y. for the biotite can be taken as the minimum age for the rock, then the Mesozoic rocks can be no younger than Upper Triassic. However, much more work should be done before any firm conclusion can be reached.

GSC 62-65 Biotite, K-Ar age 143 m.y.

K 7.05%, Ar^{40}/K^{40} .00867; radiogenic argon 100%. Concentrate; most of the biotite flakes are brown but a few are ginger yellow and some are slightly bleached to an olive-buff and contain small inclusions. Impurities present are: muscovite, chlorite, hornblende, and quartz. The chlorite is less than 2%.

British Columbia

From quartz-mica schist.
(93 O) Outcrop on Hart Highway; 55°10'49"N, 122°45'55"W.
Map-unit 4, GSC Map 11-1961. Sample 110F.
Collected and interpreted by J. E. Muller.

(For interpretation see determination GSC 62-66.)

GSC 62-66 Muscovite, K-Ar age 136 m.y.

K 8.51%, Ar^{40}/K^{40} .00823; radiogenic argon 100%.
Concentrate; consists of about 70% clean muscovite; 20% muscovite with small adhering fragments of biotite and quartz; and 10% quartz-biotite intergrowths. The estimated quartz content is 10-15%.

From quartz-mica schist.
(93 O) Outcrop on Hart Highway; 55°10'49"N, 122°45'55"W.
Map-unit 4, GSC Map 11-1961. Sample 11 OF.
Collected and interpreted by J. E. Muller.

The two similar dates (GSC 62-65, and GSC 62-66) were obtained from biotite and muscovite in the same sample of Misinchinka schist. The original sediments, late-Precambrian sandstone and conglomerate, are metamorphosed to a fine-grained quartz-mica schist, with mainly muscovite and less biotite and minor alkali-feldspar.

The indicated time of metamorphism, according to the present absolute age-scale, is at the end of the Jurassic epoch. An orogenic event is recorded about that time by the beginning of deposition of great thicknesses of coarse clastic beds of the lowermost Cretaceous Bullhead Group.

It is to be noted that this metamorphism is considerably older than a group of 5 dates between 69 m.y. and 78 m.y. on metamorphic rocks of the Wolverine Complex, on the other side of the Rocky Mountain Trench (GSC 61-30, GSC 61-31, GSC 61-32, GSC 61-33, and GSC 62-67).

GSC 62-67 Biotite, K-Ar age 78 m.y.

K 7.08%, Ar^{40}/K^{40} .00464; radiogenic argon 100%.
Concentrate; consists of brown biotite with very fine-grained quartz inclusions along fractures. Some flakes are chloritized along edges and show prominent (001) splitting. Chlorite/biotite 0.07.

British Columbia

From biotite granite.
(93 O) Point 4695 at the head of Lignite Creek; 55°5'20"N, 123°18'50"W. GSC Map 11-1961. Sample H 40. Collected and interpreted by J. E. Muller.

The granite occurs as a stock within mica schist and gneiss of the Wolverine Complex. Four K-Ar dates determined on metamorphic rocks of the complex (GSC 61-30, GSC 61-31, GSC 61-32 and GSC 61-33) are in the narrow range of 69 m.y. to 77 m.y. while two others on pegmatite and skarn (GSC 60-23 and GSC 60-24) are 22 m.y. and 29 m.y. The date of 78 m.y. indicates that the granite crystallized at the same late-Cretaceous time as the metamorphic rocks of the complex. The result is unexpected insofar as it suggests the granite to be considerably older than some of the pegmatite believed to be directly associated with it. However, it again supports the conclusion that metamorphism and granitization of the Wolverine Complex are late-Mesozoic rather than pre-Mississippian.

GSC 62-68 Muscovite, K-Ar age 139 m.y.

K 8.72%, Ar^{40}/K^{40} .00843; radiogenic argon 100%. Concentrate; consists of mainly clean muscovite. A few flakes are intergrown with biotite and quartz and contain some brownish yellow stained patches. Chlorite not detected.

From granite.
(94 L) 5.6-mile bridge, S20°W from the south end of Dall Lake; 58°27'N, 127°42'W. Map-unit 11, GSC Map 57-1959. Sample GAC 17/8/61-A2. Collected and interpreted by H. Gabrielse.

(For interpretation see determination GSC 62-69).

GSC 62-69 Biotite, K-Ar age 123 m.y.

K 7.96%, Ar^{40}/K^{40} .00741; radiogenic argon 100%. Concentrate; consists of clean reddish brown to greenish biotite. Inclusions of zircon are fairly common. A few flakes are intergrown with quartz along the edges. Chlorite not detected.

From granite.
(94 L) 5.6-mile bridge, S20°W from the south end of Dall Lake; 58°27'N, 127°42'W. Map-unit 11, GSC Map 57-1959. Sample GAC 17/8/61-A2. Collected and interpreted by H. Gabrielse.

British Columbia

The absolute age determined for the granitic rocks that are part of the Cassiar batholith is reasonable in the light of meager field evidence. To the southwest the granitic rocks cut Lower Jurassic strata. It is evident that granitic rocks included in the Cassiar Intrusions were probably emplaced at different times during Mesozoic and possibly early Tertiary time. The ages of GSC 62-68 and GSC 62-69 may be representative, however, of a large bulk of the intrusions.

GSC 62-70 Muscovite, K-Ar age 178 m.y.

K 8.00%, Ar^{40}/K^{40} .0109; radiogenic argon 100%. Concentrate; about 30% of the muscovite flakes contain small inclusions of quartz and yellowish brown stained patches on the surface of the flakes. The chlorite content is less than 2%.

From muscovite-quartz gneiss.
(104 J) On ridge, 5.4 miles east of Hankin Lake; 58°58'36"N, 130°01'24"W. Map-unit B, GSC Map 21-1962. Sample GA 21/9/61-4. Collected and interpreted by H. Gabrielse.

The mica-quartz schists represented by this specimen form a belt of metamorphic rocks about 6 miles wide within the Cassiar Intrusions. They are continuous with the "Oblique Creek Schists and Gneisses" exposed in Tuya-Teslin Map-area to the northwest (see Watson, 1944). The regional metamorphism these rocks have undergone cannot be related directly to contact metamorphism by the Cassiar Intrusions. The specimen submitted for age determination was obtained about 3 miles from the nearest exposed granitic rock.

The absolute age date confirms field evidence indicating that the regional metamorphism of these rocks pre-dated the emplacement of the bulk of the Cassiar Intrusions. The date may be slightly too young, in that Upper Triassic (Karnian and Norian) rocks in the area are nowhere metamorphosed to a significant degree and thus a pre-Upper Triassic age for the regional metamorphism seems most likely from field data.

GSC 62-71 Biotite, K-Ar age 193 m.y.

K 6.55%, Ar^{40}/K^{40} .0119; radiogenic argon 100%. Concentrate; reasonably clean, consisting of about 65% fresh brown biotite and 30% partly chloritized biotite containing inclusions of quartz. Minor hornblende and chlorite are present as impurities. Chlorite/biotite 0.08.

British Columbia

From granite.
(104 I) On Cassiar-Stewart Road; 58°08'30"N, 129°52'00"W. Map-unit 15b, GSC Map 29-1962. Sample GA 2/9/61-2A. Collected and interpreted by H. Gabrielse.

This specimen is considered typical of the granitic rocks of a batholith exposed in the Hotailuh and Three Sisters Ranges of the Cassiar Mountains. The granitic rocks are intrusive into volcanic rocks and minor sedimentary rocks which to the west in Dease Lake Map-area have yielded a Karnian (early Upper Triassic) fauna. In this region the Karnian rocks are commonly overlain conformably by Norian (mid Upper Triassic) limestone and it is assumed that the granitic rocks are younger than Norian. Rocks of Rhaetian age have never been reported in the region and the Karnian rocks near the batholith are overlain unconformably by Lower Jurassic strata. On Mt. Meehaus, south of the confluence of Tanzilla and Stikine Rivers, (see GSC Map 21-1962) conglomerate in the Lower Jurassic sequence carries pebbles and cobbles of granitic rocks similar in lithology to those represented by specimen GSC 62-71. The absolute age for the granitic rocks therefore fits very well with field evidence as it supports data indicating a disturbance during Rhaetian time.

GSC 62-72 Biotite, K-Ar age 124 m.y.

K 7.68%, Ar^{40}/K^{40} .00750; radiogenic argon 100%. Concentrate; biotite flakes vary from brown to pale greenish. Some are bleached, intergrown with quartz and contain needle-like inclusions, epidote prisms, and minor zircon. Impurities consist of about 3% muscovite and 7% chlorite.

From mica-albite - quartz gneiss.
(104 O) Mile 764, Alaska Highway; 59°57'N, 131°58'W. GSC Paper 44-25, Group A. Sample VIII-M-59. Collected by J.E. Muller. Interpreted by H. Gabrielse and W.H. Poole.

(For interpretation see determination GSC 62-73.)

GSC 62-73 Muscovite, K-Ar age 194 m.y.

K 8.21%, Ar^{40}/K^{40} .0119; radiogenic argon 100%. Concentrate; muscovite flakes contain inclusions of quartz, euhedral epidote and a few adhering fragments of greenish biotite. The quartz content is about 3%. Chlorite not detected.

British Columbia

From mica-albite - quartz gneiss.
(104 O) Mile 764, Alaska Highway; 59°57'N, 131°58'W.
GSC Paper 44-25, Group A. Sample VIII-M-59.
Collected by J. E. Muller. Interpreted by
H. Gabrielse and W. H. Poole.

The sample is a greenish grey gneiss with predominant quartz and albite and less muscovite, biotite, and chlorite. In thin section, the rock has a distinct crystalloblastic texture; quartz and albite contain numerous inclusions. Micas appear fresh; most of the chlorite comprises distinct crystals.

The gneiss is representative of a northwest-trending zone, hundreds of miles long, of regionally recrystallized and metamorphosed upper Palaeozoic sedimentary and volcanic rocks. The zone is flanked to the east and west by late Palaeozoic and Mesozoic strata with no significant regional metamorphism and with intruded Cretaceous and Tertiary granitic rocks. In recent years, the metamorphic rocks a few miles north of the sample locality have been mapped as Mississippian or earlier in Teslin map-area (GSC Paper 54-20, map-unit 1) and as Upper Devonian and Lower Mississippian in Wolf Lake map-area (GSC Map 10-1960, map-unit 7d). Some 60 miles to the southeast along the zone, Watson and Mathews (1944) mapped similar metamorphic rocks which they called the Oblique Creek Formation of unknown age. Farther southeast, the rocks appear in Dease Lake map-area (GSC Map 21-1962, map-unit B).

The muscovite date of 194 m.y. is in general accord with dates from earlier determinations on muscovite from two samples collected within the zone of metamorphic rocks, viz: 214 m.y. from a composite sample in Teslin map-area (GSC 59-9) and 222 m.y. near mile 777.7, Alaska Highway (GSC 61-42). Biotite from a granodiorite in Whitehorse map-area to the northwest was dated as 223 m.y. (GSC 59-10). On Kulp's recent time scale (1961), these dates indicate a mid-Triassic age, if no argon has been lost. Two other dates from within the belt are younger and perhaps have lost some argon during the orogeny accompanying the emplacement of Cretaceous batholiths, viz: muscovite from gneiss within Dease Lake map-area was dated as 178 m.y. (GSC 62-70) and biotite from the present sample gave 124 m.y. (GSC 62-72).

Field relations suggest that the metamorphism in this zone (and other zones elsewhere in the region) pre-dates the emplacement of Cretaceous batholiths. The isotopic dates confirm this contention. Upper Triassic sedimentary and volcanic rocks lying adjacent to these metamorphic rocks in Dease Lake map-area are unmetamorphosed and, hence, probably post-date the metamorphism (GSC Map 21-1962). Permian strata are nowhere known to make up part of the metamorphic zone despite their widespread occurrence southwest of the zone. Indeed, Permian conglomerate containing fragments of metamorphic rock and granite lie northeast of the zone in Wolf Lake map-area (GSC Map 10-1960); the significance of the conglomerate in relation to the metamorphic zone remains much in doubt. The metamorphism must have occurred post-Lower Mississippian and pre-Upper Triassic; it may have occurred either before or after (or both) the deposition of extensive Permian strata and isolated conglomerate. The isotopic ages support an early Triassic age.

GSC 62-74 Muscovite, K-Ar age 57 m.y.

K 8.42%, Ar^{40}/K^{40} .00340; radiogenic argon 100%. Concentrate; reasonably clean concentrate of muscovite. However, about 30% of the flakes contain inclusions of quartz and about 10% are stained brown. The chlorite content is less than 1% and the total quartz content about 3%.

From gneiss.

(104 P) 2 miles east of the south end of Horse Ranch Lake at elevation 5,250 feet; 59°30'40"N, 128°55'45"W. Map-unit 2, GSC Map 54-10. Sample GA 22/9/61-3. Collected and interpreted by H. Gabrielse.

The specimen is considered representative of the granitized terrain that outcrops at least 30 miles east of the closest known granitic rocks of the Cassiar Intrusions. Relations between rocks of this terrain, the Horse Ranch Group, and adjacent rocks are poorly known because of faults and overburden. The rocks are, however, somewhat similar to rocks in Aiken Lake map-area (see Roots, 1954) where metamorphic rocks that have been granitized are included in the Wolverine Complex.

Many age determinations of plutonic rocks in the northwestern Cordillera have given values in the same order of magnitude as the specimen from the Horse Ranch Range. This indicates a widespread emplacement of post-tectonic granitic rocks and at least some recrystallization of non-granitic rocks. It seems unlikely, however, that extensive metamorphic terrains such as the Horse Ranch Group and the Wolverine Complex are entirely as young as the absolute age indicates. Possibly the specimens dated are dating the emplacement of the post-tectonic plutons and metamorphic rocks recrystallized to some extent at that time.

British Columbia

GSC 62-75 Biotite, K-Ar age 69 m.y.

K 5.59%, Ar^{40}/K^{40} .00412; radiogenic argon 100%. Concentrate; consists of about 70% fresh brown biotite, 20% partly chloritized biotite flakes containing inclusions of epidote, 10% chlorite intergrown with coarse epidote, and a few amphibole fragments. The chlorite content is about 20%.

From quartz monzonite.
(104 K) Head of Stuhini Creek; 58°34'24"N, 133°8'00"W. Map-unit 6a, GSC Map 6-1960. Sample SE-70b-61. Collected and interpreted by J.G. Souther.

Throughout western British Columbia and southwestern Yukon one of the youngest phases of the Coast Intrusions is a coarse-grained, quartz monzonite, typically with flesh coloured feldspar and clear or smoky quartz. It occurs as small discordant bodies along the eastern edge of the Coast crystalline belt and as large batholithic masses that intrude the older crystalline rocks in the centre of the belt. This specimen is from a typical body of quartz monzonite having an area of about 50 square miles and intrusive into Lower Jurassic sediments and Upper Triassic volcanic rocks.

In Tulsequah area, quartz monzonite of this type bears a spatial relationship to the Sloko Group of volcanic rocks and their hypabyssal equivalents. Locally the quartz monzonite grades vertically through a fine-grained, commonly brecciated phase, into pyroclastic rocks of the Sloko Group. Tuffaceous beds belonging to the Sloko Group contain fossil plants that are considered to be Upper Cretaceous or Lower Tertiary. The 69 m.y. age of this specimen confirms the relatively young age of this major phase of the Coast Intrusions and, in addition, it supports the evidence for a genetic relationship between the quartz monzonite and volcanic rocks of the Sloko type.

GSC 62-76 Biotite, K-Ar age 227 m.y.

K 3.14%, Ar^{40}/K^{40} .0141; radiogenic argon 100%. Concentrate; clean concentrate of chloritized biotite flakes containing epidote inclusions along fractures and around edges. The chlorite content is estimated at about 75%.

From granodiorite boulder in conglomerate.
(104 K) 5 miles southwest of King Salmon Lake; 58°34'40"N, 133°2'30"W. Map-unit 9, GSC Map 6-1960. Sample SE-70c-61. Collected and interpreted by J.G. Souther.

(For interpretation see determination GSC 62-77.)

British Columbia

GSC 62-77 Biotite, K-Ar age 206 m.y.

K 3.82%, Ar^{40}/K^{40} .0128; radiogenic argon 100%. Concentrate; clean concentrate of chloritized biotite containing numerous inclusions of yellowish epidote. The chlorite content is estimated at about 75%.

(104 K) From granodiorite boulder in conglomerate. 5 miles southwest of King Salmon Lake; 58°34'40"N, 133°2'30"W. Map-unit 9, GSC Map 6-1960. Sample SE-70a-61. Collected and interpreted by J.G. Souther.

These boulders (GSC 62-76 and GSC 62-77) are from a conglomerate near the base of the Lower Jurassic, Takwahoni Group that outcrops along the northeastern edge of the Coast Range crystalline belt. The group lies unconformably on older phases of the Coast plutonic rocks and is intruded by younger phases. The conglomerate bed from which the specimens were taken is both overlain and underlain by unmetamorphosed siltstones containing well preserved Toarcian fossils. Stratigraphic evidence indicates that the boulders were derived from the Coast crystalline belt to the southwest.

The Takwahoni beds lie disconformably on moderately folded, unmetamorphosed Upper Triassic volcanic and sedimentary rocks. These are underlain by highly folded, sheared and moderately metamorphosed sedimentary and volcanic rocks of Middle Triassic and Carboniferous age. This evidence, combined with the absence of Lower Triassic strata in the Western Cordillera, suggests a period of uplift, folding and regional metamorphism between Permian and Upper Triassic time. The 206 to 227 m.y. age of the Takwahoni boulders confirms the geological evidence and shows, moreover, that the folding and metamorphism were accompanied by granitic intrusion. The appearance of granitic debris in Lower Jurassic sediments has been noted at many other points in western British Columbia and Yukon. This wide distribution suggests that the early Triassic was one of the major periods of granitic intrusion in the Coast Range.

Yukon Territory

GSC 62-78 Biotite, K-Ar age 102 m.y.

K 7.66%, Ar^{40}/K^{40} .00613; radiogenic argon 100%. Concentrate; biotite flakes vary from brown to buff and contain small inclusions of quartz and rare apatite. About 15% of the flakes are partly altered to chlorite and contain inclusions of epidote. The total chlorite content is about 7%.

From biotite quartz monzonite.
(106 D) 1 1/2 miles west of Hanson Lake; 64°01'50"N, 135°25'50"W. Map-unit 2a, GSC Map 15-1962 in Paper 62-7. Sample GC 61-10. Collected and interpreted by L. H. Green.

The specimen is from a stock of biotite quartz monzonite that intrudes low rank metamorphic rocks of post-Devonian(?) age. The age of 102 m.y. is in general agreement with ages obtained from a number of stocks and batholiths northeast of Tintina Trench.

(See also discussion on determination GSC 62-81.)

GSC 62-79 Biotite, K-Ar age 134 m.y.

K 6.19%, Ar^{40}/K^{40} .00814; radiogenic argon 100%. Concentrate; clean, consisting of ginger brown biotite with inclusions of epidote, minor apatite and zircon. About 20% of the flakes are partly altered to chlorite and epidote. Chlorite content is approximately 15%.

From biotite-feldspar porphyry.
(116 A) About one mile west of Peak 5864; 64°09'25"N, 137°40'00"W. Map-unit 21b, GSC Map 14-1962 in Paper 62-7. Sample GC 61-349I. Collected by G.R. Turnquist. Interpreted by L.H. Green.

The specimen is from a small body intrusive into an Ordovician to Silurian chert-shale sequence. It lies near the eastern end of a belt of stocks, principally of hornblende-biotite syenite, which extends about 50 miles to the northwest. The age of 134 m.y. is somewhat older than most of the ages obtained from other granitic rocks northeast of Tintina Trench.

(See also discussion on determination GSC 62-81.)

Yukon Territory

GSC 62-80 Biotite, K-Ar age 106 m.y.

K 7.31%, Ar^{40}/K^{40} .00637; radiogenic argon 100%. Concentrate; consists of pale buff to medium brown biotite. Minor inclusions of quartz and zircon are present, the latter surrounded by pleochroic haloes. Impurities, totalling about 5%, consist of chlorite with epidote inclusions, and a few altered feldspar fragments. The total chlorite content is about 7%.

From granodiorite.

(106 D) Boulder in Dublin Gulch; 64°02'N, 135°50'W. Map-unit 21a, GSC Map 15-1962. Sample GC 61-48a. Collected and interpreted by L.H. Green.

The specimen is from a large granodiorite boulder in the placer workings at Dublin Gulch and is believed to have been derived from a stock exposed at the head of the Gulch. The stock is intrusive into low rank metamorphic rocks of Cambrian or Precambrian age. The age of 106 m.y. is in general agreement with a number of ages obtained from intrusive rocks north and east of Tintina Trench.

(See also discussion on determination GSC 62-81.)

GSC 62-81 Biotite, K-Ar age 81 m.y.

K 7.77%, Ar^{40}/K^{40} .00482; radiogenic argon 100%. Concentrate; is clean, consisting of reddish brown to brown biotite. The flakes contain numerous inclusions of apatite and rare zircons surrounded by pleochroic haloes. A few flakes of chlorite are present. The total chlorite content is about 2%.

From porphyritic quartz diorite.

(105 M) Small 4,000-foot peak, 5 miles northwest of Wilson's Cabin; 63°53'55"N, 134°46'15"W. Map-unit 7b, GSC Map 5-1956. Sample GC 61-48. Collected and interpreted by L.H. Green.

The specimen is from a small batholith intrusive into low rank metamorphic rocks of possible Palaeozoic age. The age is in general agreement with a number of ages obtained from intrusive rocks north and east of Tintina Trench.

Scattered batholiths and stocks of granitic rocks occur northeast of Tintina Trench, from near Watson Lake to the Yukon-Alaska boundary, a distance of approximately 250 miles. In addition to the above ages (GSC 62-78, 102 m.y.; GSC 62-79, 134 m.y., Yukon Territory

GSC 62-81, 81 m.y., and GSC 62-80, 106 m.y.). The following ages have been obtained from granitic rocks in the Pelly district, approximately 150 miles to the southeast:

Age	Rock Type	Reference
100 m.y.	Porphyritic Dacite	GSC 61-43 (Lowdon, 1962)
117 m.y.	Porphyritic Dacite	GSC 61-44 (Lowdon, 1962)
98 m.y.	Granodiorite	(Baadsgaard, Folinsbee, and Lipson, 1959)

In general, ages obtained along this belt appear to be in fairly close agreement.

Southwest of Tintina Trench, a number of ages obtained from the northern part of the Cassiar batholith and associated metamorphic rocks (Lowdon, 1961) are also close to 100 m.y., suggesting that widespread emplacement of granitic rocks occurred on both sides of Tintina Trench at this time.

GSC 62-82 Biotite, K-Ar age 202 m.y.

K 7.54%, Ar^{40}/K^{40} .0125; radiogenic argon 100%. Concentrate; the biotite varies from olive-brown to greenish grey and contains inclusions of quartz, epidote, and unidentified small needles. Some flakes are slightly bleached and chloritized. The total chlorite content is less than 2%.

From granodiorite.

(116 C) Bank of Sixtymile River, 2 miles above the mouth of California Creek; 64°02'00"N, 140°23'20"W. Map-unit E, GSC Paper 62-7. Sample Rd 61-475a. Collected by J. A. Roddick. Interpreted by L. H. Green.

The specimen is from a gneissic granodiorite which appears to have been derived from rocks of sedimentary origin. Earlier workers considered gneissic granitic and lower rank metamorphic rocks, both of which are widespread in the Yukon and Alaska, a product of Precambrian intrusion and metamorphism. Names used by these writers include: "Pelly gneiss" for gneissic rocks in both the Yukon and Alaska, "Nasina series" for metamorphosed sedimentary rocks in the Yukon and, "Birch Creek schist" for similar rocks in Alaska, "Klondike schist" for sheared igneous rocks in the Yukon, and "Yukon Group" to include all three types in the Yukon. Recently, Green and Roddick (1962) have suggested that a Precambrian age cannot be proven and that some of the metamorphic rocks are of Palaeozoic age.

Yukon Territory

This age determination and others from the Yukon Group elsewhere do not support the concept of Precambrian intrusion and metamorphism but rather suggest that the metamorphic rocks may have formed, or undergone a period of alteration, in Early Mesozoic time, prior to the emplacement of the Coast Range and Cassiar batholiths. Ages obtained from metamorphic rocks of the Yukon Group to the southeast have varied between 138 m. y. and 222 m. y. (Lowdon,1960, 1961) and contrast with the younger ages, generally 100 m. y. or less from fresher granitic rocks that appear to have intruded the Yukon Group and form the Coast Range and Cassiar batholiths. Granitic rocks related to an early Mesozoic alteration may have supplied the granitic debris that first appears in the early Jurassic conglomerates of the Whitehorse area (Wheeler, 1961, pp. 51-70). A granitic rock dated at 223 m. y. was collected in that area (GSC 59-10).

see RLC thesis

District of Franklin

GSC 62-83 Whole rock, K-Ar age 635 m.y.

K 1.6%, Ar^{40}/K^{40} .0441; radiogenic argon 100%.

(78 B) Victoria Island; 72°26'N, 111°25'30"W. Map-unit 9, GSC Map 20-61. Sample TC-26L9B. Collected and interpreted by R. Thorsteinsson.

The rock dated herein as 635 m.y. represents a specimen from a diabase sill that intrudes the Glenelg Formation (see GSC Paper and Map 61-12) of the Shaler Group in northwestern Victoria Island (Arctic Archipelago). The K-Ar date agrees with available field evidence.

GSC 62-84 Whole rock, K-Ar age 640 m.y.

K 1.1%, Ar^{40}/K^{40} .0447; radiogenic argon 100%.

(78 B) Victoria Island; 72°26'N, 111°25'30"W. Map-unit 9, GSC Map 20-61. Sample TC-26L9A. Collected and interpreted by R. Thorsteinsson.

The rock dated herein as 640 m.y. represents a specimen taken from a diabase sill that intrudes the Glenelg Formation (see GSC Paper and Map 61-12) of the Shaler Group in northwestern Victoria Island (Arctic Archipelago). The K-Ar date agrees with available field evidence.

GSC 62-85 Biotite, K-Ar age 1,590 m.y.

K 8.10%, Ar^{40}/K^{40} .1464; radiogenic argon 100%. Concentrate; clean concentrate of red-brown biotite containing very small specks of quartz along fractures. A few flakes are bleached and contain specks of iron oxides in bleached areas. Some flakes contain zircon inclusions surrounded by pleochroic haloes. Chlorite/biotite 0.02.

From gneiss.

(48 B) West shore of Yoeman Island; 72°17'N, 86°08'W. Map-unit 1, GSC Map 55-6. Sample 54R8B2. Collected and interpreted by R.G. Blackadar.

The rock is a well banded, dark grey, fine-grained gneiss with a granoblastic texture and is composed of quartz (55%), oligoclase (10%), biotite (15%), garnet (10%), serpentine (5%) and traces of microcline and pyrite. The biotite is unaltered.

District of Franklin

The gneiss is overlain by virtually flat-lying, pre-Ordovician sedimentary acid volcanic rocks of the Eqalulik Group and sedimentary rocks of the Ulukan Group which are cut by gabbro dykes.

The determined age gives an approximate maximum date for the two groups and, although somewhat younger than the prevalent age obtained in the Churchill province, suggests that this province extends to the northwest part of Baffin Island and that the gneiss was involved in the Hudsonian orogeny.

GSC 62-86 Biotite, K-Ar age 1,700 m.y.

K 7.63%, Ar^{40}/K^{40} .1615; radiogenic argon 100%. Concentrate; consists of mainly olive-brown biotite. A few flakes have inclusions of apatite. Minor hornblende occurs as an impurity. Chlorite not detected.

From gneiss.
(37 F) North end of Steensby Inlet; 70°30'N, 79°00'W. Map-unit 4c, GSC Map 4-1958. Sample 43-5-1956. Collected and interpreted by R. G. Blackadar.

This is a banded grey gneiss in which pink felsic bands alternate with darker bands rich in biotite. The rock has a granitic texture and is composed of microcline (40%), quartz (20%), plagioclase (15%), biotite (15%), magnetite (5%), and a trace of apatite and sphene. The biotite is unaltered.

The determined age serves to extend the Churchill province and the Hudsonian orogeny to the northern part of Baffin Island.

GSC 62-87A Whole rock. K-Ar age 241 m.y.

K 0.89%, Ar^{40}/K^{40} .0150; radiogenic argon 100%.

(69 F) In the vicinity of Isachsen; 78°45'N, 103°45'W. Map-unit 10, GSC Map 14-1959. Sample ISAC-A-1. Collected by J. Babbin. Interpreted by A. Larochelle and R. F. Black.

This diabase dyke is one of a group of dykes that cuts the well-dated Lower Cretaceous Deer Bay and Isachsen Formations. The dyke rocks have not been found to cut post-Cretaceous rocks (GSC Econ. Geol. Ser. No. 1, 1957).

District of Franklin

The sample was collected about one mile southwest of Isachsen at the head of Deer Bay. In thin section it was found to consist mainly of fine-grained feldspars with traces of biotite and chlorite.

The date of 241 m.y. given for it is incompatible with the probable Cretaceous or younger age indicated by stratigraphic and palaeomagnetic evidence.

(See also determination GSC 62-87B).

GSC 62-87B   Whole rock, K-Ar age 249 m.y.

K 0.89%, Ar^{40}/K^{40} .0155; radiogenic argon 100%.

(69 F)   In the vicinity of Isachsen; 78°45'N, 103°45'W. Map-unit 10, GSC Map 14-1959. Sample ISAC-10-8-BP. Collected by J. Babbin. Interpreted by A. Larochelle and R.F. Black.

Sample GSC 62-87B was collected about 4 miles from the site of sample GSC 62-87A and from the same dyke. The petrological characteristics of the two rocks are identical and they have the same geological history. The whole rock ages are also identical within the limits of precision of the method and the incompatibility between this age and that indicated by the stratigraphers cannot be explained at present.

District of Mackenzie

GSC 62-88 Biotite, K-Ar age 110 m. y.

K 7.73%, Ar^{40}/K^{40} .00662; radiogenic argon 100%. Concentrate; clean concentrate of reddish brown biotite. Biotite contains prismatic inclusions of apatite and very small specks of zircon surrounded by large pleochroic haloes. About 10% of the biotite flakes are partly altered to pale green chlorite. The total chlorite content is about 4%.

From quartz monzonite.
(95 E) On saddle 1 mile south by east from Pyramid Mountain; 61°53'3"N, 127°58'52"W. Equivalent to Map-unit 11, GSC Map 14-1961. Sample BU-67-A1. Collected and interpreted by S. L. Blusson.

This specimen is from one of several discordant stocks in the upper Flat River area. The date agrees well with that obtained from similar rocks in the Itsi Range to the northwest (Baadsgaard et al, 1959), and may be representative for most of the plutonic rocks in the region. Stratigraphic evidence is insufficient for a more precise dating than post-Ordovician.

GSC 62-89 Muscovite, K-Ar age 1,840 m. y.

K 8.14%, Ar^{40}/K^{40} .1822; radiogenic argon 100%. Concentrate; consists of about 80% yellowish-stained muscovite, 5% altered biotite, and 15% quartz and feldspar in about equal proportions.

From porphyritic granite.
(86 C) East shore of Margaret Lake; 64°29'45"N, 116°57'30"W. Map-unit C, GSC Map 697A. Sample SH-55-59. Collected and interpreted by C. H. Stockwell.

The muscovite (1,840 m. y.) is from the same sample on which biotite gave an age of 1,725 m. y. (GSC 60-42). The agreement between the two ages is good evidence that they indicate the time of crystallization of the granite.

GSC 62-90 Biotite, K-Ar age 1,800 m. y.

K 6.68%, Ar^{40}/K^{40} .1763; radiogenic argon 100%. Concentrate; this heterogeneous concentrate of biotite is composed of the following constituents:
1. About 20% 'old' biotite which consists of two main phases - greenish and brownish flakes with large

dark brown to opaque patches.
2. About 65% 'recrystallized' fine-grained biotite aggregates with minor quantities of quartz, feldspar and chlorite.
3. About 5% fine- and coarse-grained muscovite, and
4. About 10% free chlorite.

The total chlorite content is about 15%.

From granodiorite

(85 N) West shore of unnamed lake, 5 miles southwest of Basler Lake; 63°47'25"N, 116°15'25"W. Map-unit 3, GSC Map 690A. Sample SH-57-59. Collected and interpreted by C. H. Stockwell.

The biotite (1,800 m.y.) is from the same sample on which a muscovite age of 2,460 m.y. was reported previously (GSC 60-47). As seen in thin section the biotite (formerly reported as chlorite) occurs mainly as fine-grained matted aggregates taking the place of former much larger crystals. The nature of the former mineral is not known but the biotite is undoubtedly secondary after it.

The sample is from a granodiorite stock which has been intruded into sedimentary rocks of the Yellowknife Group and is overlain unconformably by slightly metamorphosed sediments of the Snare Group. The muscovite gives the expected Kenoran age for the time of primary crystallization of the stock. The secondary biotite, however, yields a Hudsonian age, being the time during which the Snare sediments were slightly metamorphosed. It therefore appears that the Hudsonian orogeny affected the older granodiorite sufficiently to cause crystallization of the secondary biotite but, at this locality, was not strong enough to bring about recrystallization of the muscovite or even to drive off its argon.

GSC 62-91 Muscovite, K-Ar age 2,400 m.y.

K 7.10%, Ar^{40}/K^{40} .2835; radiogenic argon 100%. Concentrate; muscovite flakes contain small remnants of fresh and altered biotite and are intergrown with some feldspar and quartz. The concentrate is estimated to contain 5% biotite, 2% chlorite, 10% quartz, and 10% feldspar.

From biotite-muscovite schist.

(85 N) South shore of Slemon Lake; 63°12'40"N, 116°06'20"W. Map-unit 2, GSC Map 690A. Sample SH-59-59. Collected and interpreted by C. H. Stockwell.

District of Mackenzie

The muscovite (2,400 m.y.) is from the same sample on which biotite gave an age of 1,900 m.y. (GSC 60-46). The sample represents metamorphosed sedimentary rocks of the Yellowknife Group close to the north contact of a body of granite which, on its north side, at least, intrudes rocks of the Snare Group. The Snare overlies the Yellowknife unconformably. The muscovite of the sample gives the expected Kenoran age for the main period of metamorphism of the Yellowknife but the biotite gives an age approaching that of the Hudsonian orogeny. It is concluded that the whole of the granite body is Hudsonian and that its effect on the nearby Yellowknife rocks was not strong enough to change the original argon content of the muscovite but caused biotite to crystallize in place of older chlorite which is present in the rock.

GSC 62-92 Biotite, K-Ar age 1,785 m.y.

K 6.69%, Ar^{40}/K^{40} .1739; radiogenic argon 100%. Concentrate; consists of dark olive-green biotite containing numerous needle-like inclusions. A minor amount of hornblende is present as impurity. Chlorite not detected.

From nepheline syenite.
(85 O) North tip of a large island at southern part of Big Spruce Lake; 63°33'N, 115°57'W. Map-unit A, GSC Map 690A. Sample BLO-28. Collected and interpreted by W.R.A. Baragar.

The rock is a massive nepheline syenite containing about 40% mafic minerals, largely aegerine-augite. Biotite forms less than 1% of the rock generally, but tends to be concentrated in scattered knots or clusters ranging up to 1 inch in diameter. Nepheline is the predominant leucocratic mineral.

The sample is one variety of a wide range of rock types that collectively form the Big Spruce Lake nepheline complex. The complex is roughly oval in plan and is surrounded by, and grades into, granitic rocks of the Slave province. In at least two places the gradation from nepheline-bearing rocks through syenites, and quartz syenites, to quartz-rich granitic rocks was observed. Age determinations from the Slave Province range generally from 2,000 m.y. to 2,500 m.y.; hence the age obtained from the nepheline syenite complex marks it as distinctly younger with an age more in keeping with the adjoining Bear or Churchill provinces. Lord (1942, p. 35) noted that the complex intrudes crystalline, banded limestone of probably Snare age. The age of the complex certainly places it in the age-range of the post-Snare intrusions.

District of Mackenzie

GSC 62-93 Biotite, K-Ar age 2,170 m.y.

K 6.43%, Ar^{40}/K^{40} .2379; radiogenic argon 100%. Concentrate; consists of reasonably clean brown biotite. Most of the biotite flakes are clean but about 15% are partly altered to green chlorite and acicular epidote, and 10% are almost opaque. Minor impurities (2%) consist of feldspar fragments and epidote grains. The total chlorite content is about 10%.

From syenogabbro.
(85 H) Peninsula on the north side of a large island directly west of Simpson Island, east arm of Great Slave Lake; 61°44'N, 112°51'W. Map-unit 13, GSC Map 377A. Sample BLO-O-W63. Collected and interpreted by W.R.A. Baragar.

The sample is from a differentiated biotite-bearing monzonite dyke or sill (GSC Map 377A, unit 13; GSC Map 50-28A, unit 8) that intrudes the Sosan Formation of the Great Slave Group and older granites and gneisses. The dyke is generally about 300 feet thick, dips about 50°S and has been traced for some 16 miles on Simpson and adjoining islands to the west. For part of its length it seems to form the boundary between the Sosan Formation and underlying granitic basement. Stockwell grouped this intrusion with a number of others that cut various parts of the Great Slave Group into a single subdivision post-dating the Great Slave Group. An age obtained recently from one such intrusion near Wilson Lake in the eastern part of the East Arm is 1,845 m.y. (GSC 61-78). The age of the present sample is significantly older and it raises doubts that all these intrusions are correlative. The Simpson Island dyke or sill might actually be penecontemporaneous with part of the Great Slave Group, possibly the volcanic member, whereas the Wilson Lake intrusion bears an age generally in accord with the Hudsonian orogeny. Of possible significance in this regard is the marked petrographic difference between these intrusions. The Wilson Lake body is a granodiorite with abundant quartz and minor potash feldspar whereas the Simpson Island dyke is fairly rich in potash feldspar but contains negligible quartz, even in the pegmatitic phase. Thus, 2,170 m.y. may represent an age within or immediately following the Great Slave Group itself.

GSC 62-94 Biotite, K-Ar age 1,750 m.y.

K 7.74%, Ar^{40}/K^{40} .1685; radiogenic argon 100%. Concentrate; reasonably clean concentrate of biotite. The biotite flakes vary from olive to brown. Approximately 20% of the biotite flakes are slightly bleached along fractures and contain small epidote inclusions in bleached areas. Approximately 5% of the biotite is partly altered to green chlorite and epidote along the edges. The total chlorite content is about 4%.

From paragneiss.

(75 A) North shore of an east bay of Wignes Lake; 60°10'10"N, 105°43'30"W. Map-unit 3, GSC Map 9-1959. Sample SH-89-59. Collected and described by C. H. Stockwell.

This is a light grey, well banded rock composed of quartz, oligoclase, and microcline with parallel flakes of fresh biotite and a few of muscovite. On the outcrop the gneiss of the sample is seen to be cut by a few dykes of pink granite. The K-Ar determination dates the metamorphism and orogeny.

District of Keewatin

GSC 62-95 Biotite, K-Ar age 1,810 m.y.

K 6.99%, Ar^{40}/K^{40} .1775; radiogenic argon 100%. Concentrate; consists of about 60% clean brown biotite and 40% biotite varying from brown to greenish and containing inclusions of epidote and quartz and some chloritized patches. Chlorite/biotite 0.12.

From granitic gneiss.
(65 O) Island in Tebesjuak Lake; 63°38'30"N, 99°10'00"W. Map-unit 6, GSC Map 55-17 (West sheet). Sample SH-102-59. Collected and described by C. H. Stockwell.

The granitic gneiss is a medium-grained rock in which pink layers alternate with grey. Constituents include quartz, microcline, oligoclase, biotite, and accessory apatite, magnetite, and zircon. In some bands the biotite is fresh but in others is completely altered to chlorite.

The sample is from an extensive area of pre-Dubawnt granitic and allied rocks and the age obtained is thought to date the orogeny and to give a maximum age for the Dubawnt.

GSC 62-96 Biotite, K-Ar age 1,770 m.y.

K 7.95%, Ar^{40}/K^{40} .1717; radiogenic argon 100%. Concentrate; clean concentrate of reddish brown biotite. The flakes contain a few inclusions of quartz, epidote, and apatite. About 5% of the flakes are slightly bleached and chloritized along the edges. The total chlorite content is about 1%.

From paragneiss.
(55 M) Peninsula in a north bay of Blakely Lake; 63°21'20"N, 95°02'00"W. Map-unit 5, GSC Map 55-17 (East sheet). Sample SH-110-59. Collected and described by C. H. Stockwell.

This is a rather fine-grained, grey paragneiss with biotite concentrated in layers. Constituents include quartz, oligoclase, garnet, biotite, and accessory apatite and magnetite. The biotite is fresh and appears to be of two generations. In the outcrop, the gneiss of the sample is associated with more abundant hornblende gneiss and the whole is interlayered with sheared, leucocratic granite-gneiss.

District of Keewatin

The age obtained on the biotite is thought to be that of the last period of crushing and shearing. The main period of metamorphism may be older, for a scattering of dates older than the Hudsonian orogeny have been found in the region extending for 400 miles to the west.

GSC 62-97 Biotite, K-Ar age 1,785 m.y.

K 7.23%, Ar^{40}/K^{40} .1743; radiogenic argon 99%. Concentrate; consists mainly of clean brown flakes. About 10-15% of the flakes have chloritized patches and inclusions of epidote. A few inclusions of zircon and apatite are present. Chlorite/biotite 0.09.

(65 K) From paragneiss. South shore of Nowleye Lake; 62°18'30"N, 101°00'00"W. Map-unit 6, GSC Map 55-17 (West sheet). Sample SH-99-59. Collected and described by C. H. Stockwell.

The paragneiss has a pronounced foliation and contains stringers and augen of white feldspar. The rock is composed of quartz, andesine, and plentiful biotite and hornblende with accessory apatite and magnetite. The biotite is mostly fresh but some flakes are interleaved with chlorite. In the outcrop the paragneiss is seen to be cut across the foliation planes by dykes of pink aplite.

The sample is from an extensive area mapped as pre-Dubawnt granitic and allied rocks and the age obtained is thought to date the orogeny and to give a maximum age for the Dubawnt.

Manitoba

GSC 62-98 Biotite, K-Ar age 1,770 m.y.

K 7.77%, Ar^{40}/K^{40} .1720; radiogenic argon 100%. Concentrate; consists of clean brown biotite. A few flakes contain inclusions of zircon surrounded by pleochroic haloes. Chlorite not detected.

From porphyritic granite.
(64 N) South of Nueltin Lake; 59°05'N, 100°30'W. Map-unit 7a, GSC Map 31-1962. Sample FD-207-61. Collected and interpreted by J. A. Fraser.

The biotite is from a concordant body of porphyritic granite exposed over an area of more than 600 square miles southwest of Nueltin Lake. The granite consists of euhedral insets of microperthite up to 2 inches long in a coarse-grained matrix of quartz, oligoclase, myrmekite, biotite, and magnetite.

The granite intrudes metasediments which may possibly be correlated with strata of the Hurwitz Group exposed in the southern District of Keewatin. The age of the biotite would then be a minimum for the Hurwitz Group. Compare the age of biotite from fluorite granite (GSC 61-113, 1,735 m.y.) south of Hasbala Lake.

GSC 62-99 Muscovite, K-Ar age 2,670 m.y.

K 8.69%, Ar^{40}/K^{40} .3438; radiogenic argon 100%. Concentrate; consists of reasonably clean muscovite. About 30% of the flakes have attached small specks of feldspar and quartz, and about 40% have small attached fragments of biotite. Approximately 1% chlorite, 2% quartz and 12% plagioclase feldspar are also present.

From meta-arkose.
(64 C) North shore of Granville Lake; 56°17'10"N, 100°39'10"W. Map-unit 8a, GSC Map 344A. Sample SH-28-59. Collected and interpreted by C. H. Stockwell.

This muscovite (2,670 m.y.) is from the same sample from which a biotite age of 1,650 m.y. was reported previously (GSC 60-77). The original clastic nature of the meta-arkose is still recognizable in thin section, especially by the presence of relatively large fragments of feldspar and quartz lying in a fine-grained matrix of the same minerals, but the metamorphism has been sufficiently strong to bring about recrystallization resulting in an interlocking mosaic of these minerals. For an interpretation of the K-Ar age

Manitoba

obtained on the muscovite it is essential to know whether the mineral is detrital or of later metamorphic crystallization. Some small flakes could well be detrital for they are enclosed within large feldspar grains which could have protected them, but most of the muscovite, which is chiefly in the matrix, is probably of metamorphic origin. Apart from the thought that this muscovite could hardly have escaped the metamorphism that brought about the quartz-feldspar mosaic texture, convincing evidence is found in the observation that some crystals have grown across crystal boundaries and others are part and parcel of the mosaic, forming irregular shaped grains filling spaces between the quartz and feldspar.

The sample is a metamorphosed equivalent of the Sickle Series of the Lynn Lake region. If it is conceded that the muscovite is largely metamorphic, the age of 2,670 m.y. is a minimum for the Sickle, which makes it Archaean. The unconformably underlying Wasekwan Series of the same region also becomes Archaean. The rocks lie within the Churchill structural province where the Hudsonian orogeny prevails, as represented by the 1,650 m.y. age on the biotite, but at this locality the Hudsonian was not strong enough to recrystallize the muscovite or even drive off its argon, so that the evidence for the Kenoran orogeny is preserved.

The argument may be carried to the Flin Flon region, 120 miles to the southwest, where the Missi and the unconformably underlying Amisk resemble the Sickle and Wasekwan. It is judged that the Missi and the Amisk are also Archaean although no K-Ar ages older than the Hudsonian have yet been found in the Flin Flon region. The formations of the Lynn Lake and Flin Flon regions are much less metamorphosed than the great expanses of paragneiss that characterize most of the Churchill province and they resemble many of the Archaean sedimentary and volcanic rocks of the Superior province.

GSC 62-100 Biotite, K-Ar age 2,005 m.y.

K 7.30%, Ar^{40}/K^{40} .2097; radiogenic argon 100%. Concentrate; consists of about 70% clean green biotite, 10% brown biotite, and 20% biotite flakes with chloritized patches and inclusions of epidote. Chlorite/biotite 0.18.

From granite.
(53 M) East shore of Seller Lake; 55°02'00"N, 94°27'40"W. Map-unit 9, GSC Map 55-8. Sample SH-151-59. Collected and described by C.H. Stockwell.

Manitoba

The granite is a medium-grained, grey, slightly gneissic rock composed of quartz, orthoclase, microcline, oligoclase, biotite and lesser amounts of epidote, titanite, apatite, and magnetite. The feldspars are somewhat sericitized and the biotite is partly altered to chlorite.

The sample was run in order to further the study of anomalously young ages in the Cross Lake subprovince of the Superior province (see GSC 61-125). The biotite age of 2,005 m.y. confirms the variability and irregularity of the ages obtained in this region.

Ontario

GSC 62-101 — Muscovite, K-Ar age 2,735 m.y.

K 8.78%, Ar^{40}/K^{40} .3597; radiogenic argon 100%. Concentrate; consists of reasonably clean muscovite. About 35% of the flakes contain rare inclusions of quartz and 5% are intergrown with altered biotite. The total estimated quartz content is 3%. Only a trace of chlorite is present.

From granite pegmatite.
(53 C) West shore of McInnes Lake; 52°6'40"N, 93°40'30"W. Possibly related to Map-unit 8, GSC Map 50-1960. Sample DF 60-A 14. Collected and interpreted by J.A. Donaldson.

The sample is from a dyke of granite pegmatite that intrudes a belt of folded metavolcanic and metasedimentary rocks along McInnes Lake. The dyke is post-tectonic and the muscovite age therefore establishes greater antiquity for not only volcanism and sedimentation, but also deformation and metamorphism of the belt.

This muscovite age ranks with the oldest mica ages determined by the Geological Survey of Canada (see GSC 59-67, GSC 59-68). Biotites from gneisses and granites typical of those enclosing the McInnes belt give ages 110 to 275 m.y. younger (e.g. GSC 60-91, GSC 60-97, GSC 60-100). Some reservation must be held in comparing biotite and muscovite ages (Lowdon, 1961, p. 121) but if the difference is real, it substantiates the concept of greenstone belts enclosed by gneiss, migmatite, and granite derived by metamorphism, granitization, and intrusion subsequent to metamorphism of the greenstone belts typified by the McInnes rocks.

GSC 62-102 — Muscovite, K-Ar age 2,285 m.y.

K 5.81%, Ar^{40}/K^{40} .2601; radiogenic argon 100%. Concentrate; consists of about 60% muscovite, 25% quartz, 10% chlorite, and 5% feldspar with traces of epidote and calcite.

From phyllite.
(52 C) At narrows, southwest end of Shoal Lake; 48°40'00"N, 92°39'50"W. Map-unit 8, GSC Map 98A. Sample SH-62-60. Collected and described by C.H. Stockwell.

The phyllite is a fine-grained, light grey rock with a platy cleavage and is composed predominantly of quartz with a little feldspar and plentiful, parallel, shreds and flakes of fine-grained muscovite. Other constituents include carbonate, chlorite and pyrite.

Ontario

The sample is from the Seine Series at its type locality and the age, being that of the metamorphism, is the minimum for the series. The age of 2,285 m.y. is considerably younger than that normally found in rocks involved in the Kenoran orogeny. And it is not yet known whether the cause is merely local or has regional tectonic significance.

According to A. C. Lawson (1913, pp. 59-79) the Keewatin rocks of the area are intruded by the Bad Vermilion Granite and both are overlain unconformably by the Seine. A hurried effort was made to collect suitable material from the granite but that found was too highly altered to be suitable for dating by the K-Ar method.

GSC 62-103 Biotite, K-Ar age 2,520 m.y.

K 7.51%, Ar^{40}/K^{40} .3092; radiogenic argon 100%. Concentrate; consists of mainly reddish brown biotite, irregular in shape and containing minor inclusions of quartz and zircon. A few flakes of pale green chlorite are present. Chlorite/biotite 0.03.

From schist.
(42 M) South shore of Washi Lake; 51°23'43"N, 87°01'33"W. Map-unit 3, GSC Map 6-1962. Sample JD-100-4-1961. Collected and interpreted by G. D. Jackson.

This sample is from bedded quartz-biotite-plagioclase paraschists near the base of Map-unit 3 of GSC Map 6-1962. The K-Ar age of the biotite is in general agreement with ages determined for similar material elsewhere in the Superior Province. The determined age is believed to indicate the latest period of regional metamorphism. Similar ages, determined for younger granitic rocks in nearby areas indicate that the regional metamorphism and emplacement of these younger granitic rocks are related.

GSC 62-104 Hornblende, K-Ar age 1,860 m.y.

K 0.51%, Ar^{40}/K^{40} .1851; radiogenic argon 100%. Concentrate; consists of about 90% hornblende. The fragments are pleochroic and green to yellowish green. Impurities consist of quartz and altered biotite. Approximately 1% biotite, 2% chlorite and 5-10% quartz are present.

From amphibolite.
(42 M) South shore of Albany River, 4 1/2 miles west-northwest of Makokibatan Lake; 51°16'42"N, 87°37'3"W.

Ontario

Map-unit 2, GSC Map 6-1962. Sample JD-385-8. Collected and interpreted by G. D. Jackson.

The amphibolite is tentatively correlated with the metamorphosed basic volcanic rocks in the map-area (Map-unit 2, GSC Map 6-1962). The rock is fine grained, foliated, and contains about 70% blue-green hornblende, 22% plagioclase, 4% quartz, 2% mica, 1% sphene, and traces of magnetite, leucoxene, and chlorite. The mica is an alteration product of plagioclase and hornblende. The amphibolite is intruded by a leucocratic, pegmatitic granite, and possibly by a fine-grained foliated granodiorite that is presumably older than the granite.

The determined age is significantly younger than ages for other rocks in northwestern Ontario, which may be explained by loss of argon after regional metamorphism. This may have been due to: argon escaping more easily from hornblende than from mica; the effects of the granite intrusion; or minor deformation (see Map 6-1962). Mica and chlorite are not believed to be present in the concentrate in sufficient quantity to affect the age determination significantly. Except for the mica and chlorite, the mineral assemblage is correlated with the regional metamorphism, although some late, deformed, diabase dykes are amphibolized locally.

GSC 62-105 Muscovite, K-Ar age 2,445 m.y.

K 4.41%, Ar^{40}/K^{40} .2926; radiogenic argon 100%. Concentrate is impure, consisting of about 40% muscovite and 60% sericitized feldspar, quartz, and altered biotite. The estimated abundances of the impurities are: 40% feldspar, 8% quartz, and 12% chlorite.

From granodiorite.
(41 J) Highway 129, 2.6 miles northeast of bridge over the Mississagi River; 46°55'00"N, 83°12'42"W. Map-unit 16, GSC Map 1063A. Sample SH-83-60. Collected and interpreted by C. H. Stockwell.

The granodiorite is a medium-grained, massive, pink rock with scattered phenocrysts of pink feldspar. As seen under the microscope the rock consists chiefly of quartz and saussuritized oligoclase with lesser amounts of microcline, muscovite, and chlorite derived by virtually complete alteration of biotite. Minor constituents include magnetite, apatite, and fluorite.

Ontario

The granodiorite is mapped as post-Huronian but the K-Ar age of 2,445 m.y. indicates that it is Archaean and was intruded during the Kenoran orogeny. The sample was collected at a point about 35 miles north of the Huronian contact and like other samples from the pre-Huronian basement of this region shows extensive chloritization of biotite. In spite of this, however, the muscovite gives a reliable Archaean age. Compare with the age of 2,455 m.y. on muscovite from the basement close to the contact where biotite is also chloritized (GSC 60-105).

GSC 62-106 Muscovite, K-Ar age 1,405 m.y.

K 8.18%, Ar^{40}/K^{40} .1222; radiogenic argon 100%. Concentrate; contains about 60% clean muscovite flakes; 35% muscovite-quartz intergrowths, and 5% fresh and altered biotite flakes. About 4% chlorite and 15% quartz are present.

From quartzite.
(41 I) About 1 mile west of Espanola Bay; 46°20'45"N, 81°45'30"W. Map-unit 3, Ontario Dept. Mines Map 1952-1. Sample SH-95-60. Collected and described by C.H. Stockwell.

The quartzite is a fine-grained, light grey, schistose rock composed of quartz and plentiful, parallel shreds and flakes of fine-grained muscovite. The formation is shown as Mississagi Quartzite (Huronian) on Geological Survey of Canada Map 291A but the author of the Ontario Dept. of Mines Map 1952-1 thinks that the quartzite could be early Precambrian (Archaean). In any case the date obtained on the muscovite indicates the time of metamorphism, which is somewhat too young to have been caused by the Hudsonian orogeny.

GSC 62-107 Muscovite, K-Ar age 1,485 m.y.

K 8.94%, Ar^{40}/K^{40} .1325; radiogenic argon 100%. Concentrate; clean but most of the flakes contain inclusions of quartz and small red-brown specks of iron oxide, and small attached fragments of brown biotite. Chlorite not detected.

From granophyre.
(41 I) 1 mile east and 1 mile south of the northeast corner of Mongowin tp.; 46°11'05"N, 81°47'50"W. Map-unit 5, Ontario Dept. Mines Prel. Map P105, Espanola Sheet (whereon the rock is incorrectly designated - pre-Huronian granite). Sample 61-RF-1258. Collected and interpreted by S.M. Roscoe.

Ontario

The sample was obtained from a potassium-rich granophyric zone that separates arkose, correlative with the Cobalt Group, from a small ultrabasic body. The granophyre was probably formed through contact metamorphism and potash metasomatism of arkose at the time of intrusion of the ultrabasic body.

The ultrabasic body is the only one known to intrude Huronian rocks but one is found far to the east in Grenville terrain. An "offset" dyke from the Sudbury irruptive 24 miles northeast extends to within 10 miles of the ultrabasic body. The ultrabasic body is astride a lineament that parallels diabase dykes believed to be of Keweenawan (Grenville) age. It is about 15 miles north of the projection of the Grenville front, which passes less than 10 miles south of the south rim of the Sudbury Irruptive.

The age of 1,485 m.y. is in agreement with field evidence, which indicates that the ultrabasic rock is younger than metagabbro sills (+ 1,800 m.y.), younger than regional metamorphism of Huronian rocks, and thus possibly about the same age or younger than the Sudbury Irruptive. Most of the published K-Ar ages (all biotites) for the irruptive are greater (1,630 m.y. to 1,810 m.y.) but the sample is within the 1,200 m.y. to 1,840 m.y. range found for all types of ages on the irruptive. The age corresponds most closely with K-Ar muscovite and zircon ages on Cutler granite 30 miles to the west.

GSC 62-108 Biotite, K-Ar age 1,440 m.y.

K 6.87%, Ar^{40}/K^{40} .1263; radiogenic argon 100%. Concentrate; reasonably clean concentrate of brown biotite. Some biotite flakes are intergrown with chlorite, hornblende, feldspar, quartz, and muscovite. Impurities consist of about 10% free chlorite, minor hornblende, quartz and feldspar. The total chlorite content is 10-15%.

From paragneiss.

(41 I) On the south bank of the Spanish River, approximately 50 chains southeast of High Falls, Lot 12, Concession I, Drury tp.; 46°22'24"N, 81°38'22"W. Map-unit 4bg. GSC Map 291A. Sample CD-61-87. Collected by K.D. Card, Ontario Dept. of Mines. Interpreted by M.J. Frarey.

(For interpretation see determination GSC 62-109).

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GSC 62-109 Biotite, K-Ar age 1,600 m.y.

K 7.37%, Ar^{40}/K^{40} .1471; radiogenic argon 100%. Concentrate; reasonably clean concentrate of reddish brown biotite. The flakes contain numerous inclusions of zircon surrounded by dark pleochroic haloes. About 30% of the biotite flakes are intergrown with feldspar, quartz, chlorite, and hornblende. The total impurity content consists of about 7% chlorite, 1% quartz, 5% feldspar, and 1% hornblende.

From meta-conglomerate.
(41 I) Lot 12, Concession II, Hyman tp.; 46°22'55"N, 81°41'15"W. GSC Map 291A. Sample A-34A. Collected by K.D. Card, Ontario Dept. of Mines. Interpreted by M.J. Frarey.

The 1,600 m.y. age (GSC 62-109) falls within the 1,550-1,850 m.y. range representative of Hudsonian orogeny (Stockwell in Lowdon, 1961) and thus is logically interpreted as derived from the metamorphism of a Huronian quartz-pebble conglomerate during that period.

The 1,440 m.y. age (GSC 62-108) falls below the indicated Hudsonian range, and above the Grenville range of dates. The figure may represent a resultant date, produced by Grenville orogeny effects on an earlier (e.g. Hudsonian) mineral generation. The host rock, according to the location given, belongs to the McKim Formation of GSC Map 291A.

GSC 62-110 Biotite, K-Ar age 1,120 m.y.

K 7.24%, Ar^{40}/K^{40} .0897; radiogenic argon 100%. Concentrate; consists of over 90% clean red-brown biotite flakes containing large dark pleochroic haloes. Impurities consist mainly of pyroxene. Chlorite/biotite 0.04.

From diabase.
(42 C) Roadcut on Highway 17, just south of small stream 8 1/2 miles north of Catfish Lake; 48°12'N, 84°53'W. Map-unit 3, GSC Map 1972. Sample SH-87-60. Collected by C.H. Stockwell. Interpreted by W.F. Fahrig.

The sample is an olivine diabase dyke and the age of the biotite reported here is believed to be the age of the dyke intrusion. The significance of this date will be established when, as a result of further work, this dyke is related to the series of diabase intrusions that intersect this part of the Shield.

GSC 62-111 Whole rock, K-Ar age 1,995 m.y.

K 0.41%, Ar^{40}/K^{40} .2077; radiogenic argon 100%.

From diabase dyke.
(41 J) 1 1/2 miles northeast of the town of Desbarats; 46°22'N, 83°55'W. Map-unit 12, GSC Map 32-1962. Sample FC-1-62. Collected and interpreted by M.J. Frarey.

The sample is from a diabase dyke cutting the Lorrain Formation of Huronian age.

This age determination apparently dates the intrusion of this dyke and provides a minimum age for the Lorrain Formation. As a nearby parallel dyke gives a substantially lower age (GSC 62-112, 1,600 m.y.), further determinations on the diabase dykes of the district are required to substantiate this date and provide more information regarding the igneous history.

GSC 62-112 Whole rock, K-Ar age 1,620) 1,580) average 1,600 m.y.

K 2.2%, Ar^{40}/K^{40} .1501 .1444; radiogenic argon 100%. 100%.

From diabase dyke.
(41 J) 1 1/2 miles northeast of the town of Desbarats; 46°22'N, 83°55'W. Map-unit 12, GSC Map 32-1962. Sample FC-2-62. Collected and interpreted by M.J. Frarey.

The sample is from a diabase dyke cutting the Lorrain Formation of Huronian age.

The age of 1,600 m.y. is regarded as analytically reliable, as it is the average of two separate determinations (1,620 m.y. and 1,580 m.y.). The appreciably lower age than that given by nearby sample GSC 62-111 may indicate two ages of diabase intrusion, or that sample GSC 62-112 has suffered argon loss. Further work is required to establish this as an actual date of diabase intrusion.

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GSC 62-113 — Muscovite, K-Ar age $\frac{1,210\ \text{m.y.}}{1,195\ \text{m.y.}}$ (Average 1,202 m.y.)

K 8.87%, Ar^{40}/K^{40} $\begin{matrix}.0991\\.0997\end{matrix}$; radiogenic argon $\begin{matrix}100\%.\\100\%.\end{matrix}$
Concentrate; muscovite flakes are mostly clean but some contain small inclusions of feldspar and quartz. About 5% quartz and 5% feldspar are present. Chlorite not detected.

From quartzite.
(41 H) Easternmost of two small islands off the northeast corner of George Island, 1 mile east of the town of Killarney; 45°57'50"N, 81°30'00"W. Map-unit Co2, GSC Map 221A. Sample SH-94-60. Collected and described by C. H. Stockwell.

The sample is a fine-grained, pale pink, schistose, impure quartzite, containing, in addition to the dominant quartz, scattered grains of potash feldspar and parallel flakes of muscovite. On the outcrop the bedding is noticeable as parallel ridges a foot or two thick. According to Quirke and Collins (1930, pp. 43-45) the rock represents an early stage of granitization of the Lorrain quartzite, of the Cobalt Group, which by further alteration passes gradually into the Killarney granite, which gave a biotite age of 1,170 m.y. (GSC 61-158). The age obtained on muscovite from the quartzite agrees well with that on biotite from the granite and, although somewhat older than the prevalent K-Ar age for the Grenville orogeny, appears to be about the true age of crystallization of the Killarney granite.

GSC 62-114 — Biotite, K-Ar age 1,540 m.y.

K 7.70%, Ar^{40}/K^{40} .1394; radiogenic argon 100%.
Concentrate; clean concentrate of olive-grey biotite. Nearly half of the flakes contain needle-like inclusions. Chlorite/biotite 0.01.

From gneissic granite.
(31 L) On Highway 11, east of the south end of Jumping Caribou Lake; 46°52'00"N, 79°46'40"W. Map-unit 4, Plate 2, Bull. Geol. Soc. Am., vol. 65. Sample SH-5-60. Collected and described by C. H. Stockwell.

The sample is a dark reddish grey granitic rock in which relatively undeformed crystals of microcline and plagioclase lie in a matrix of granulated feldspar and quartz associated with hornblende and biotite. The biotite is much bent and broken but is unchloritized. The crushed feldspar is highly altered to sericite, zoisite, and epidote. The sample was taken from the Superior province at a point 3/4 mile north of the Grenville front and just west of a fault. The cataclastic texture may be due to the fault and it is uncertain whether the abnormally young age obtained on the biotite is due to the fault or to the proximity of the Grenville front. Compare with the abnormal 1,395 m.y. date on biotite from the Grenville province 3 1/3 miles south of the front (GSC 61-159).

GSC 62-115 Biotite, K-Ar age 940 m.y.

K 5.57%, Ar^{40}/K^{40} .0711; radiogenic argon 97%. Concentrate; consists of about 60% clean biotite flakes; 25% flakes showing bleached areas and numerous inclusions; and 15% biotite flakes with patches of green chlorite, and biotite-hornblende intergrowths. Chlorite/biotite 0.17.

From banded gneiss.
(31 L) On Highway 11, 3 miles north of North Bay; 46°21'20"N, 79°28'20"W. Sample SH-3-60. Collected and described by C.H. Stockwell.

This is a coarse-grained, grey gneiss in which layers rich in hornblende and biotite alternate with others composed chiefly of andesine. As seen on the outcrop the banding is contorted but as seen in thin section the constituent minerals are undeformed. The sample was collected at a locality far from the Grenville front and the biotite gives an age that is typical of the Grenville orogeny.

GSC 62-116 Biotite, K-Ar age 1,050 m.y.

K 8.29%, Ar^{40}/K^{40} .0822; radiogenic argon 100%. Concentrate; clean concentrate of colourless to buff-coloured biotite. Chlorite not detected.

From marble.
(31 D) 225° from the south bay of Alder Lake, 3/5 of a mile south of Alder Lake; 44°51.48'N, 78°09.25'W. Map-unit 3, Ontario Dept. Mines Map 1957-b. Sample DB-319-61. Collected and interpreted by K.R. Dawson.

The coarse-grained, weakly foliated marble with bed-like concentrations of mica and actinolite occurs in a conformable unit from a few hundred feet to a mile wide in the wall-rocks north and east of the Anstruther batholith. The marble is intruded by white pegmatite and adamellite dykes. The most recent period of metamorphism occurred at the time of intrusion of the adamellite and granodiorite of the batholith.

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GSC 62-117 Biotite, K-Ar age 915 m.y.

K 6.89%, Ar^{40}/K^{40} .0689; radiogenic argon 100%. Concentrate; consists of about 40% clean, brown biotite; 30% pale brown biotite; 25% partly chloritized biotite flakes with epidote inclusions and about 5% hornblende. The total chlorite content is about 7%.

From meta-gabbro.

(31 D) 203° from the south bay of Alder Lake, 1/2 mile south of Alder Lake; 44°51.48'N, 78°08.94'W. Map-unit 4, Ontario Dept. Mines Map 1957-b. Sample DB-318-61. Collected and interpreted by K. R. Dawson.

The coarse-grained, foliated black meta-gabbro contains abundant hornblende porphyroblasts, from 1/2 inch down, embedded in a finer grained matrix. It occurs in a lens-shaped body a few hundred feet wide by a 1/2 mile long, conformable within the plagioclase-amphibolite wall-rocks northeast of the Anstruther batholith. The most recent period of metamorphism coincides with the time of intrusion of the batholithic adamellite and granodiorite.

GSC 62-118 Biotite, K-Ar age 930 m.y.

K 8.04%, Ar^{40}/K^{40} .0703; radiogenic argon 100%. Concentrate; consists of clean olive green biotite. A few flakes have tiny specks along fractures and a few red inclusions of iron oxide. Approximately 5% of the biotite flakes are chloritized. Chlorite/biotite 0.05.

From adamellite.

(31 D) West of Highway 28, approximately 4 miles north of Apsley; 44°48.43'N, 78°06.63'W. Map-unit 8, Ontario Dept. Mines Map 1957-b. Sample DB-317-61. Collected and interpreted by K. R. Dawson.

The sample is from a medium- to coarse-grained, massive to weakly foliated biotite adamellite consisting of plagioclase An_O 44.6%; microcline 21.0%, quartz 23.5%, biotite 4.2%; muscovite 1.9%; magnetite 1.7%; and accessory sphene, pyrite, apatite, allanite, white opaque mineral, zircon, and hematite.

The specimen was collected from a conformable lens-shaped apophysis extending northeast into the plagioclase amphibolite wall-rock from the Anstruther batholith. The Proterozoic age suggested by its association with interbedded plagioclase amphibolites and marbles has been confirmed by the K-Ar age determination.

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GSC 62-119 Muscovite, K-Ar age 481 m.y.

K 8.25%, Ar^{40}/K^{40} .0321; radiogenic argon 99%. Concentrate; consists of 80% clean muscovite; 10% muscovite with feldspar and quartz inclusions; 10% muscovite, stained yellowish with iron oxides and containing small specks of altered biotite. About 1% chlorite, 1% quartz and less than 10% feldspar are present.

From granite.
(21 L) On Granite Hill, 2 miles south of the city of Thetford Mines; 46°04'00"N, 71°17'48"W. Quebec Dept. Mines Prel. Map 1030. Sample Q-61-6. Collected by J. Béland. Interpreted by W.H. Poole and J. Béland.

(For interpretation see determination GSC 62-120).

GSC 62-120 Muscovite, K-Ar age 477 m.y.

K 8.23%, Ar^{40}/K^{40} .0318; radiogenic argon 100%. Concentrate; consists of muscovite flakes containing tiny inclusions of quartz and a few adhering specks of altered biotite. About 5% of altered feldspar and quartz are present as impurities. The quartz content is estimated at 3%. The chlorite content is less than 2%.

From pegmatitic granite.
(21 L) Southern part of the village of Black Lake; 46°02'19"N, 71°21'16"W. Quebec Dept. Mines Prel. Map 1030. Sample Q-61-5. Collected by J. Béland. Interpreted by W.H. Poole and J. Béland.

The quartz monzonite sample (GSC 62-119) is a medium-grained, equigranular, light grey-buff rock with distinct crude parting, streaking by biotite, and moderately well developed parallel arrangement of muscovite, all resulting from weak cataclasis. In thin section, quartz is seen to be strained and strongly recrystallized, potash feldspar has mottled extinction, and plagioclase has strongly sericitized cores. About 2% of the rock is biotite, pleochroic tan to dark red-brown, bent and chloritized along some cleavage planes. Another 2% is muscovite which is straight and unaltered, and cuts across biotite.

The pegmatitic granite sample (GSC 62-120) is a coarse-grained, white to light grey rock with 5% warped muscovite. In thin section, original quartz crystals are sheared out into plates partly wrapped around feldspar crystals. Quartz crystals comprise a myriad of interlocking lenses and "shreds". Potash feldspar and plagioclase are clouded, fractured, bent, and partly granulated along their edges. Muscovite crystals are bent but clear and unaltered.

The two varieties of granitic rock are representative of the small irregular shaped granitic bodies and dykes that cut ultrabasic rocks in the asbestos-producing area of Thetford Mines-Black Lake (Riordon, 1954). The two samples were collected about 4 miles apart and on a line about parallel with the northeast trend of the country rocks.

The age of the granitic rocks lying within the belt of ultrabasic rocks has been in doubt (Neale et al, 1961). The ultrabasic rocks, which the granitic rocks cut, have intruded Middle Ordovician and older sedimentary and volcanic rocks presumably during the Taconic orogeny in Middle or Late Ordovician (Riordon, 1954). The granitic bodies are generally considered to be genetically related either to the ultrabasic rocks and hence Ordovician, or to the bulk of the Acadian granitic rocks in the Appalachian region and hence Devonian. The latter contention is supported by two K-Ar dates of 362 and 379 m.y. on biotite from two granitic bodies about 30 miles south of the ultrabasic belt and a third K-Ar date of 320 m.y. on biotite from a granitic rock that intruded serpentinite near Asbestos, Quebec, about 30 miles to the southwest (Lowdon, 1960, p. 37). However, the two present dates, 481 and 477 m.y., and their remarkable concordance indicate an Ordovician age for the granitic bodies within the ultrabasic belt. The two dated granitic bodies to the south may well be Devonian; the granitic rock near Asbestos may be Devonian or Ordovician with partly degassed biotite.

Insufficient modal and chemical analyses are available to indicate chemical similarities and dissimilarities of two possible families of granitic rock of different age. The granites south of the ultrabasic belt are normal granitic rocks generally with 20% to 30% quartz, similar proportions of potash feldspar and plagioclase, and less than 10% muscovite and biotite (Cooke, 1950). The granitic rocks within the ultrabasic rocks in the Thetford Mines-Black Lake area are cataclastic and altered, and contain from a few per cent to perhaps 30% quartz, variable proportions of potash feldspar and plagioclase, and less than 10% muscovite and biotite (Riordon, 1954; Dresser and Denis, 1944).

GSC 62-121 Muscovite, K-Ar age 414 m.y.

K 6.92%, Ar^{40}/K^{40} .0271; radiogenic argon 100%. Concentrate; consists of about 60% clean flakes of muscovite and 40% flakes with numerous needle like

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inclusions, probably rutile. Apatite inclusions are rare. Chlorite not detected.

From quartz-sericite schist.

(21 L) 2,300 feet west-northwest of Salaberry; 46°03'24"N, 71°26'26"W. Map-unit "Caldwell Group, Lower Series, undifferentiated schist", on Quebec Dept. Mines Map 1030 with Prel. Report 295 (Riordon, 1954). Sample RKW-3. Collected by P. H. Riordon, Asbestos Corporation Ltd., Thetford Mines. Interpreted by W. H. Poole and P. H. Riordon.

The schist is a fine-grained, light grey rock consisting almost entirely of quartz and muscovite. In thin section, laminae of muscovite are seen to be interlayered with laminae of granoblastic quartz. Muscovite crystals parallel lamination, giving rise to primary schistosity. Schistosity is crenulated and cut by a slip-cleavage which parallels the axial planes of crenulations.

The schist is typical of the Cambrian or older Caldwell Group in the Thetford Mines-Black Lake area. The rocks and their metamorphism are older than the unconformably overlying Beauceville Group (Riordon, 1962) which contain Middle Ordovician graptolites. If the slip-cleavage is also older than Beauceville Group, then the date on muscovite should be the age of metamorphism, providing no younger metamorphic effects caused leakage of argon from the muscovite.

The date of 414 m.y. falls about mid-Silurian on a recent geological time scale (Kulp, 1961). Evidently, argon has leaked from the muscovite.

The date does, however, compare favourably with K-Ar dates on muscovites of 420 m.y. (GSC 61-182) and 440 m.y. (GSC 61-183) from Cambrian or older greywacke and schist of the Sutton-Green Mountain anticlinorium lying about 80 miles on trend to the southeast of the present area. Indeed, the schistose rocks of both areas are reasonably continuous. The three dates taken together may represent a metamorphic event in Late Ordovician, the Taconic orogeny, during which micas formed in earlier metamorphic episodes were completely degassed and the time-clock returned to zero. Younger deformation (?Acadian in Devonian) affecting rocks lying mainly to the southeast of the area (Neale et al, 1961) may have caused some argon loss since Ordovician times.

The present date, 414 m.y., cannot at this time be reasonably related to the K-Ar dates of 477 m.y. and 481 m.y. (GSC 62-120 and GSC 62-119) on muscovites from cataclastic granitic bodies several miles from the present sample-site. There, the granitic bodies cut ultrabasic rocks that cut both the Caldwell and Beauceville Groups. If from these dates the minimum age of the

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Middle Ordovician is assumed to be about 480 m.y., then the 414 m.y. date reflects uncertain metamorphic event(s).

GSC 62-122 Biotite, K-Ar age 420 m.y.

K 7.24%, Ar^{40}/K^{40} .0276; radiogenic argon 100%. 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 inclusions surrounded by dark pleochroic haloes were noted. A few flakes of green hornblende and minor chlorite are present. Chlorite/biotite 0.05.

From granite.
(22 A) 48°57'24"N, 65°59'36"W. Map-unit 34, GSC Map 705A. Sample SDM 61-2742. Collected by I. D. MacGregor. Interpreted by C. H. Smith.

This sample is from the Jacques Cartier Granite shown on GSC Map 705A, Map-unit 34, as Lower or Middle Devonian. This interpretation is also shown on Quebec Dept. of Mines Map 1000.

The intrusion cuts Lower Ordovician sedimentary rocks. It is not in contact with younger strata.

The interpretation of a Devonian age is based on the presence of acidic volcanic rocks and quartz-feldspar porphyries of volcanic association in the Lower Devonian rocks to the south of the area. These rocks resemble the Jacques Cartier Granite only to the extent that they are all granitic in composition. In texture and level of emplacement they are quite different.

The K-Ar date of 420 m.y. suggests that the previous correlation of the Jacques Cartier Granite with the granitic porphyries is not correct. An attempt has been made to obtain biotite from the younger porphyries for dating, but without success. It now appears that the plutonic granites of the Jacques Cartier area are Silurian in age, and older than previously suspected. They are still younger than the ultramafic rocks of the area which were previously dated at 495 m.y. (GSC 61-186).

GSC 62-123 Whole rock, K-Ar age 1,255 m.y.

K 0.65%, Ar^{40}/K^{40} .1042; radiogenic argon 100%.

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(23 J) East shore of Maryjo Lake; 54°48'N, 66°48'W. Map-unit 13, GSC Map 1087A. Sample FA-307-61. Collected and interpreted by W.F. Fahrig.

The sample is rather fresh olivine diabase that cuts the Kaniapiskau Supergroup. It is believed that this whole rock age determination gives the approximate age of crystallization of the intrusion. As the intrusion is undeformed, the age of 1,255 m.y. provides the minimum age for any significant orogeny that has affected this section of the Labrador Trough.

GSC 62-124 Whole rock, K-Ar age 1,435 m.y.

K 0.98%, Ar^{40}/K^{40} .1256; radiogenic argon 100%.

(24 D) 56°16'N, 70°36'W. Map-unit 8, GSC Map 62-24. Sample FA-42-61. Collected and interpreted by W.F. Fahrig.

The sample is a fine-grained ophitic gabbro consisting of partly altered plagioclase, pyroxene, and iron-ores. Chlorite is the chief alteration product. The plagioclase shows undulatory extinction suggesting post crystallization deformation.

The age may be the age of crystallization of the intrusion. However, caution should be used in interpreting this date because of the altered nature of the rock.

GSC 62-125 Hornblende and minor biotite, K-Ar age 1,995 m.y.

K 0.62%, Ar^{40}/K^{40} .2076; radiogenic argon 100%. Concentrate; reasonably clean concentrate of green hornblende. Some fragments are intergrown with brown biotite and quartz. Minor biotite is present as free flakes. Estimated total biotite content is 5-10%.

From diabase.

(24 M) 59°24'N, 72°00'W. Map-unit 8, GSC Map 62-24. Sample FA-154(b)-61. Collected and interpreted by W.F. Fahrig.

The sample is coarse-grained gabbro with zoned plagioclase hornblende, iron ores, quartz, and reddish brown biotite. The hornblende forms about 40% of the rock and varies from a dark basaltic variety to a lighter coloured common variety.

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The age is partly the K-Ar age of the hornblende but biotite was present in the separate to the extent of 5-10% and has presumably made a potent contribution to the K-Ar age determination.

The age is approximately the age of crystallization of the intrusion.

GSC 62-126 Whole rock, K-Ar age 2,060 m.y.

K 0.36%, Ar^{40}/K^{40} .2166; radiogenic argon 95%.

(34 P) 59°10'N, 73°06'W. Map-unit 8, GSC Map 62-24. Sample FA-203(a)-61. Collected and interpreted by W.F. Fahrig.

The sample is from a chilled gabbro contact and consists of plagioclase and pyroxene phenocrysts in a matrix consisting partly of fine-grained plagioclase and iron-ores. Over much of the slide the very fine-grained minerals are set in large anhedral, poikilitic, deuteric hornblendes. A small amount of biotite is present, chiefly in areas that lack deuteric hornblende.

It is assumed that this age is the approximate age of crystallization of the intrusion.

GSC 62-127 Whole rock, K-Ar age 2,285 m.y.

K 0.25%, Ar^{40}/K^{40} .2606; radiogenic argon 100%.

(34 P) 59°32'N, 72°40'W. Map-unit 8, GSC Map 62-24. Sample FA-176-61. Collected and interpreted by W.F. Fahrig.

The sample is from a chilled gabbro contact and consists of small, sparsely distributed phenocrysts of plagioclase and pyroxene in a matrix of very fine-grained plagioclase, hornblende, iron-ores, quartz and biotite. Some hornblende forms larger poikilitic patches in the matrix.

The age is the approximate age of crystallization of the intrusion.

GSC 62-128 Whole rock, K-Ar age 2,190 m.y.

K 0.29%, Ar^{40}/K^{40} .2417; radiogenic argon 100%.

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(34 P) 59°46'N, 72°50'W. Map-unit 8, GSC Map 62-24. Sample FA-169(a)-61. Collected and interpreted by W.F. Fahrig.

The sample is a chilled border phase of a gabbro intrusion and consists of fine-grained equigranular plagioclase and hornblende with minor iron ores, quartz, and red-brown biotite. Pyroxene is present as sparsely distributed altered grains.

The age is the approximate age of crystallization of the intrusion.

GSC 62-129 Whole rock, K-Ar age 2,240 m.y.

K 0.23%, Ar^{40}/K^{40} .2513; radiogenic argon 100%.

(34 P) 59°01'N, 72°30'W. Map-unit 8, GSC Map 62-24. Sample FA-211(a)-61. Collected and interpreted by W.F. Fahrig.

The sample is a chilled marginal phase of an ophitic gabbro intrusion and consists of plagioclase, pyroxene, deuteric hornblende, iron ores, quartz, and red-brown biotite.

It is believed that this age is approximately the age of crystallization of the intrusion.

GSC 62-130 Biotite and hornblende, K-Ar age 2,125 m.y.

K 2.92%, Ar^{40}/K^{40}.2303; radiogenic argon 100%. Concentrate; consists of about 45% reddish brown biotite; 25-30% green hornblende which appears fresh; and 25-30% altered hornblende and chlorite. The biotite contains long acicular inclusions. Chlorite/biotite is 1.1.

From ophitic gabbro.

(34 I) 58°48'N, 72°03'W. Map-unit 8, GSC Map 62-24. Sample FA-209-61. Collected and interpreted by W.F. Fahrig.

The sample is a coarse-grained, green ophitic gabbro consisting of unaltered zoned plagioclase, pink pyroxene, deuteric hornblende, quartz, iron ores and about 1-2% reddish brown biotite.

It is believed that the analyzed concentrate establishes the age of the gabbro intrusion.

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GSC 62-131 — Whole rock, K-Ar age 2,675 m.y.

K 0.24%, Ar^{40}/K^{40} .3454; radiogenic argon 100%.

(34 I) 58°48'N, 72°03'W. Map-unit 8, GSC Map 62-24. Sample FA-209(a)-61. Collected and interpreted by W.F. Fahrig.

This whole rock K-Ar analysis was run on the same material as GSC 62-130. The age of 2,675 m.y. for GSC 62-131 is, however, much greater than that obtained from the biotite (GSC 62-130, 2,125 m.y.) of the same intrusive body. Furthermore, ages obtained from hornblende (GSC 62-125, 1,995 m.y.) and whole rocks (GSC 62-126, 2,060 m.y.; GSC 62-127, 2,285 m.y.; GSC 62-128, 2,190 m.y.; and GSC 62-129, 2,240 m.y.), from related igneous intrusions are all less than the age of whole rock GSC 62-131. For this reason, GSC 62-131 appears to be anomalous.

The general problems of dating this rock type are being investigated and results of this program will be discussed at a later date.

GSC 62-132 — Biotite, K-Ar age 1,590 m.y.

K 8.03%, Ar^{40}/K^{40} .1459; radiogenic argon 100%. Concentrate; very clean concentrate of brown biotite. Chlorite not detected.

From charnokitic gneiss.
(24 P) Northeast shore of Edward Lake; 59°53'30"N, 65°02'00"W. Sample SH-12-62. Collected and described by C.H. Stockwell.

The sample is a gneissic olive green rock composed of andesine, quartz, biotite, hornblende, and hypersthene with accessory apatite. The biotite is unaltered and its K-Ar age indicates the time of the orogeny.

GSC 62-133 — Biotite, K-Ar age 1,695 m.y.

K 8.24%, Ar^{40}/K^{40} .1605; radiogenic argon 100%. Concentrate; clean concentrate of red brown biotite. About 10% of the flakes are bleached and contain patches of greyish chlorite. A few biotite flakes carry acicular inclusions of sillimanite and rare zircons surrounded by pleochroic haloes. The total chlorite content is about 4%.

Quebec

From lit-par-lit gneiss.
(24 P) Small island in a fiord extending eastward from Keglo Bay; 59°03'30"N, 65°26'00"W. Sample SH-11-62. Collected and described by C.H. Stockwell.

The sample is composed of dark biotite-rich sedimentary layers containing metacrysts of feldspar alternating with light grey granitic layers. Constituent minerals include plentiful microcline, biotite, and quartz with smaller amounts of myrmekite, oligoclase, tourmaline, sillimanite, zircon, and pyrite. The biotite is fresh. The determined age gives the time of the orogeny.

GSC 62-134 Biotite, K-Ar age 1,660 m.y.

K 8.14%, Ar^{40}/K^{40} .1559; radiogenic argon 97%. Concentrate; clean concentrate of brown biotite. A few flakes are slightly bleached. Chlorite not detected.

From lit-par-lit gneiss.
(24 J) Unnamed lake, 9 miles west of George River; 58°29'15"N, 66°16'00"W. Sample SH-10-62. Collected and described by C.H. Stockwell.

The sample is a well banded granitic rock in which dark layers of biotite-rich material alternate with layers and lenses of grey and pink leucogranite. Constituent minerals include microcline, oligoclase, quartz, biotite, and small amounts of myrmekite, muscovite, magnetite, apatite, zircon, and carbonate. The biotite crystals are clean and fresh. The determined age is that of the orogeny and metamorphism.

GSC 62-135 Biotite, K-Ar age 1,580 m.y.

K 8.08%, Ar^{40}/K^{40} .1449; radiogenic argon 100%. Concentrate; clean concentrate of biotite. Biotite flakes vary from brown (70%) to greenish (30%). A few flakes are slightly chloritized. The total chlorite content is about 2%.

From granodiorite.
(24 J) Unnamed lake, 3 miles east of Tuktuk River; 58°11'00"N, 66°57'30"W. Sample SH-9-62. Collected and described by C.H. Stockwell.

The granodiorite is a medium-grained, pinkish grey, massive rock enclosing schlieren of biotite-rich material. The rock consists of oligoclase, microcline, quartz, biotite, and a little myrmekite, muscovite, magnetite, titanite, and apatite. The biotite is mostly fresh but a few crystals are interleaved with chlorite. The determined age probably indicates the approximate time of primary crystallization of the granodiorite.

GSC 62-136 Phlogopite, K-Ar age 1,575 m.y.

K 6.34%, Ar^{40}/K^{40} .1440; radiogenic argon 100%. Concentrate; consists of colourless phlogopite. Some flakes are clean but many are intergrown with green chlorite along the edges and contain some minute specks of carbonates on the surface. The total chlorite content is about 35%.

From limestone.

(24 F) South end of a large lake, 9 miles east of False River; 57°31'00"N, 68°06'00"W. Map-unit 14, GSC Map 55-37. Sample SH-20-62. Collected and described by C.H. Stockwell.

This is a fine-grained, granular, greenish, crystalline limestone or dolomite containing small flakes of phlogopite and some serpentine and chlorite. The limestone forms a thin bed in an area of predominantly lit-par-lit gneisses and highly granitized rocks. According to the author of the map the limestone is a metamorphosed equivalent of the Kaniapiskau Supergroup. The determined age gives the approximate age of metamorphism and is a minimum for the Kaniapiskau.

GSC 62-137 Biotite, K-Ar age 1,740 m.y.

K 7.95%, Ar^{40}/K^{40} .1675; radiogenic argon 100%. Concentrate; clean concentrate of biotite. Biotite flakes vary from brown (30%) to greenish (70%). Some flakes contain rare inclusions of epidote, quartz and zircon. The latter are surrounded by pleochroic haloes. The total chlorite content is less than 1%.

From porphyritic granite.

(24 G) Small island in an unnamed lake; 57° 25'30"N, 66°13'45"W. Sample SH-4-62. Collected and described by C.H. Stockwell.

The sample is from a porphyritic granite in which phenocrysts of pink microcline from 1 inch to 3 inches long lie in a dark grey, medium-grained groundmass composed of oligoclase, microcline, quartz, biotite, and hornblende. Minor constituents include myrmekite, magnetite, apatite, titanite, zircon, and veinlets of carbonate. The biotite is unchloritized. The large phenocrysts are distinctly aligned about parallel with one another probably due to flowage of partly crystallized magma rather than to post-crystallization deformation. The determined age is thought to be that of the primary crystallization of the rock.

GSC 62-138 Biotite, K-Ar age 1,220 m.y.

K 8.11%, Ar^{40}/K^{40} .1006; radiogenic argon 100%. Concentrate; clean concentrate of reddish brown biotite. Minor impurities (about 5%) consist of chlorite and muscovite flakes and of small grains of quartz. The total chlorite content is about 3%.

From lit-par-lit gneiss.
(24 H) Foot of rapids, 5 miles north of Ford River; 57°54'00"N, 64°35'00"W. Sample SH-16-62. Collected and described by C.H. Stockwell.

The sample consists of irregular streaks of biotite-bearing material alternating with streaks of lighter grey granitic material and the rock is probably a partly granitized paragneiss. The sample is composed chiefly of quartz but with considerable amounts of microcline, orthoclase, and biotite. Minor constituents include plagioclase, zircon and pyrite. The biotite is fresh and clear. The K-Ar age on the biotite apparently indicates the period of metamorphism and granitization.

GSC 62-139 Biotite, K-Ar age 1,375 m.y.

K 7.14%, Ar^{40}/K^{40} .1183; radiogenic argon 100%. Concentrate; reasonably clean concentrate of about 90% olive-green biotite and 10% bright green chlorite. Chlorite/biotite 0.13.

From tuffaceous sedimentary material.
(23 O) Southwest shore of Kalko Lake; 55°20'N, 66°24'W. Sample FC-50-141. Collected and interpreted by M.J. Frarey.

This date was obtained from tuffaceous sedimentary material from the Doublet Group within the Labrador Trough.

It suggests a date for the metamorphism of Trough rocks of the area and a minimum age for their deposition.

Quebec

GSC 62-140 Biotite, K-Ar age 920 m.y.

K 8.54%, Ar^{40}/K^{40} .0692; radiogenic argon 100%. Concentrate; very clean concentrate of brown biotite. The biotite flakes contain a few opaque inclusions. A few flakes of muscovite are also present. Chlorite not detected.

From paragneiss.
(23 B) In a creek bed a few hundred feet inland from the west shore of Harvey Lake; 53°32'15"N, 67°41'15"W. Map-unit 4F, Quebec Dept. Mines Map 1234. Sample SH-35-62. Collected and described by C.H. Stockwell.

(For descritpion see determination GSC 62-141).

GSC 62-141 Muscovite, K-Ar age 945 m.y.

K 9.15%, Ar^{40}/K^{40} .0716; radiogenic argon 100%. Concentrate; reasonably clean concentrate of muscovite. Minor impurities consist of micrographic intergrowths of muscovite, feldspar and quartz, and of a few opaque hexagonal flakes of graphite. Total impurities consist of 1% quartz and 2% feldspar. The total chlorite content is less than 1%.

From paragneiss.
(23 B) In a creek bed a few hundred feet inland from the west shore of Harvey Lake; 53°32'15"N, 67°41'15"W. Map-unit 4F, Quebec Dept. Mines Map 1234. Sample SH-35-62. Collected and described by C.H. Stockwell.

This muscovite (945 m.y.) is from the same sample as the biotite (920 m.y.) of GSC 62-140 and the two ages are in good agreement.

The rock is a medium-grained, grey paragneiss composed of quartz, oligoclase, microcline and plentiful parallel flakes of fresh biotite and muscovite. Minor constituents include apatite and zircon.

The paragneiss and associated iron-formation, quartzite and marble are metamorphosed equivalents of the Kaniapiskau Supergroup in its southern extension in the Grenville province. The sample has been involved in two major orogenies, the Hudsonian and the Grenville and, as expected, the mica ages show only the effect of the younger.

Quebec

The sample was collected from a place not far from GSC 59-88 which gave the surprisingly young muscovite age of 440 m.y. and which now appears to have only local significance.

GSC 62-142 Biotite, K-Ar age 930 m.y. (870-990 m.y.)

K 7.02%, Ar^{40}/K^{40} .0701; radiogenic argon 100%. Concentrate; consists of deep red-brown biotite with tiny inclusions along edges and fractures. Impurities make up approximately 10% of the concentrate and consist mainly of feldspar and lesser amounts of pyroxene, hornblende, and opaque grains. Chlorite not detected.

From titaniferous magnetite.
(22 P) Magpie Mountain; 51°25'N, 64°05'W. Sample RG-61-A-4. Collected and interpreted by E.R. Rose.

This sample of fine-grained, red-brown biotite was separated from the matrix of titaniferous magnetite from Magpie Mountain, in which it occurs as a primary mineral almost contemporaneous with the titano-magnetite, and with the gabbroic anorthosite with which the titaniferous magnetite is associated. The K-Ar age of 930 m.y. represents the age of emplacement of the Magpie titaniferous magnetite deposits and their associated gabbroic anorthosite host rocks. The K-Ar date corresponds remarkably well with others taken by the writer from titaniferous magnetite from Pontiac County, western Quebec (GSC 61-161, 940 m.y.), and from Indian Head, western Newfoundland (GSC 61-199, 900 m.y.), but shows some divergence from the K-Ar age of 890 m.y. for the Bignell ilmenite-hematite lode at St. Urbain, Quebec (GSC 60-114).

Judging from the single K-Ar measurements, the Magpie titaniferous magnetite and gabbroic anorthosite appear to be about 40 m.y. older than the St. Urbain ilmenite, and about 75 m.y. younger than the Lac Tio gabbroic anorthosite, but as these values come within the range of overlap of experimental error it is possible that they are all much closer in age than indicated by the single sample measurements, possibly falling within a range of 950 m.y. to 1,000 m.y.

GSC 62-143 Biotite, K-Ar age 1,025 m.y. (965-1,085 m.y.)

K 7.99%, Ar^{40}/K^{40} .0795; radiogenic argon 100%. Concentrate; consists of clean fresh biotite. A few flakes have slightly altered edges and rare quartz inclusions. The chlorite content is less than 2%.

Quebec

From pegmatite.
(12 L) Lac Tio deposit; 50°33'N, 63°24'W. Sample RG-60-1. Collected and interpreted by E.R. Rose.

This sample of fresh biotite came from a narrow granitic pegmatite dyke that penetrates coarsely crystalline gabbroic anorthosite near the eastern margin of the main Lac Tio ilmenite-hematite deposit. The rock in which the pegmatite dyke occurs forms a salient part of the hanging-wall that is more or less surrounded by massive ilmenite-hematite there, and appears to form a roof pendant in the ore. The pegmatite is penetrated in places by ilmenite-hematite veins and is therefore presumably older than the ore, but is not necessarily widely separated in age.

The emplacement of pegmatite dykes in many parts of the Grenville province is considered by many to represent the final phases of igneous activity culminating the Grenville orogeny, and for which the age of 1,000 $\pm$ 6% m.y. has been commonly accepted. With this the K-Ar age determination of 1,025 m.y. is in agreement.

The emplacement of the ilmenite-hematite ore is indicated to be at a later date.

GSC 62-144 Biotite, K-Ar age 875 m.y.

K 7.09%, Ar^{40}/K^{40} .0651; radiogenic argon 100%. Concentrate; reasonably clean concentrate of brown to greenish brown biotite. The flakes contain rare inclusions of quartz and hematite. Some hornblende and feldspar occur as impurities. Chlorite not detected.

From anorthosite.
(22 F) 49°43'N, 68°43'30"W. Sample HF-36-1961. Collected by W.W. Heywood.

GSC 62-145 Biotite, K-Ar age 1,015 m.y. (955-1,075 m.y.)

K 7.98%, Ar^{40}/K^{40} .0786; radiogenic argon 100%. Concentrate; consists mainly of fresh brown biotite. A few of the flakes are slightly bleached. About 2% of olive-green hornblende occurs as an impurity. Chlorite content is less than 1%.

Quebec

From diorite.
(21 M) Mine road, about 2 miles north-northwest of Baie St. Paul, 47°34'N, 70°32'W. Map-unit 2A, GSC Map 2106. Sample RG-59-3. Collected and interpreted by E.R. Rose.

This sample of fine-grained, brown biotite was concentrated from a marginal dioritic (gabbroic anorthosite) phase of the St. Urbain anorthosite. The single K-Ar age measurement of 1,015 m.y. indicates that the rock was formed about 125 m.y. before the emplacement of the Bignell ilmenite-hematite deposit, at 890 m.y. (GSC 60-114), into the St. Urbain anorthosite nearby. The indicated younger age of the ilmenite-hematite deposit is in harmony with field observations. There is also reasonable agreement in the measured and inferred ages of the gabbroic phases of the anorthosite at St. Urbain (1,015 m.y.) and at Lac Tio (1,025 m.y. $\pm$ 6%, GSC 62-143).

The wide spread of 10 m.y. to 125 m.y. indicated by K-Ar dates on the formation of the diorite (gabbroic anorthosite) and the ilmenite-hematite lode at St. Urbain may not be accurate, but it suggests a measure of the immensity of geological time involved in the emplacement of the anorthositic massif and its associated titaniferous ore. Further work will be required to attempt to find out whether the age range is as wide as indicated by the K-Ar measurements.

GSC 62-146 Biotite, K-Ar age 1,315 m.y.

K 7.64%, Ar^{40}/K^{40} .1110; radiogenic argon 100%. Concentrate; reasonably clean concentrate of brown biotite. Biotite flakes contain small inclusions of quartz, a few opaque grains and a few zircons surrounded by dark pleochroic haloes. About 5% of the biotite flakes are partly bleached and slightly altered to chlorite. Impurities, totalling about 5%, consist of chlorite and a few flakes of muscovite.

From paraschist.
(32 G) Road cut on Chibougamau Highway, 0.6 mile northwest of bridge over the narrows in Lac Dufresne; 49°35'15"N, 74°15'35"W. Map-unit 1, Quebec Dept. Mines Map 1236. Sample SH-55-62. Collected and described by C.H. Stockwell.

(For description see determination GSC 62-147).

Quebec

GSC 62-147 Muscovite, K-Ar age 1,060 m.y.

K 8.46%, Ar^{40}/K^{40} .0830; radiogenic argon 100%. Concentrate; reasonably clean concentrate of muscovite. Muscovite flakes contain inclusions of feldspar, quartz, and small adhering fragments of pale brown biotite, as well as small euhedral crystals of dark-brown biotite. Quartz content is about 1%. Feldspar content is less than 5%. Chlorite not detected.

From paraschist.

(32 G) Road cut on Chibougamau Highway, 0.6 mile northwest of a bridge over the narrows in Lac Dufresne; 49°35'15"N, 74°15'35"W. Map-unit 1, Quebec Dept. Mines Map 1236. Sample SH-55-62. Collected and interpreted by C.H. Stockwell.

This muscovite (1,060 m.y.) is from the same sample as the biotite of GSC 62-146 (1,315 m.y.).

The sample is a medium-grained, grey paraschist that has been derived from arkose and forms a steeply dipping bed from 1 foot to 2 feet thick in fine-grained, dark green, hornblende schist of volcanic origin. As seen microscopically, the paraschist consists of closely spaced irregular fragments of feldspar and a few of quartz lying in a fine-grained matrix of the same minerals together with metamorphic flakes of biotite and muscovite which wrap around the fragments. Minor constituents include chlorite, zircon, apatite, and pyrite.

The ages obtained on this sample, especially the 1,060 m.y. date on muscovite, serve to define the position of the Grenville front somewhere between the locality of this sample and that of GSC 60-107 (biotite, 1,840 m.y.), which are only 0.4 mile apart. In previous reports (Lowdon, 1961, and Lowdon et al, 1963) the front was presumed to lie along the northwest contact of gneissic terrain but it is now placed 1/2 mile farther northwest putting the paraschist and closely associated hornblende schist in the Grenville province as well.

But the main object in making these two determinations and the next seven (up to and including GSC 62-154) was to gain further knowledge about discrepant ages in a section across the Grenville front. Previously reported determinations pertaining to the problem at this locality include, on the Grenville side at a point 1.6 miles southeast of the front, a mica pair giving 1,270 m.y. for biotite (GSC 60-108) and 960 m.y. for muscovite (GSC 61-162) and, on the Superior side at a point 0.2 mile northwest of the front, a biotite at 1,840 m.y. (GSC 60-107) which is much younger than the normal age of about 2,500 m.y. for the Superior province generally.

Quebec

The problem of the difference in behaviour between biotite and muscovite in the same environment was discussed in last year's report (Stockwell, in Lowdon, 1963, pp. 127-133) where it was concluded that the muscovite gives the more reliable age. Also discussed was the question of why the biotite age on the older (Superior) side should be too young and that on the younger (Grenville) side should be too old. Any explanation for this phenomenon has to take into account the well established conclusion that argon is readily lost from biotite under conditions of mild metamorphism or during cooling but, quite to the contrary, is retained under intense metamorphic environment in the Grenville province near the front. The two opposing phenomena were thought to be genetically related and the preferred explanation was that, due to the effect of the Grenville orogeny, the argon that was lost from biotite on the Superior side was added to biotite on the Grenville side during the cooling period subsequent to crystallization of the mineral. The new data now being reported add substantially to the previous picture but no better explanation has yet been conceived.

Returning to a discussion of the present sample, the muscovite at 1,060 m.y., although somewhat older than the muscovite average for the Grenville province, is thought to indicate closely the age of crystallization. There can be little doubt that the biotite crystallized at about the same time but its K-Ar age of 1,315 m.y. is 255 m.y. older. This discrepancy is thought to be due to the addition of argon. The results found in this sample, so close to the front, are very similar to those previously found at 1.6 miles from the front where muscovite gave 960 m.y. and biotite gave 1,270 m.y.

GSC 62-148 — Biotite, K-Ar age 1,050 m.y.

K 7.82%, Ar^{40}/K^{40} .0823; radiogenic argon 100%. Concentrate; reasonably clean concentrate of brown biotite. Minor impurities consist of green chlorite and epidote. Total chlorite content is about 6%.

From micaceous gneiss.
(32 G) Road cut on Chibougamau Highway, 0.4 miles east of bridge over the narrows of Lac Dufresne; 49°34'30"N, 74°15'05"W. Map-unit 5a, Quebec Dept. Mines Map 1236. Sample SH-52-62. Collected and described by C.H. Stockwell.

(For description see determination GSC 62-149).

Quebec

GSC 62-149 Muscovite, K-Ar age 1,010 m.y.

K 9.17%, Ar^{40}/K^{40} .0781; radiogenic argon 100%. Concentrate; reasonably clean concentrate of muscovite. About 15% of the muscovite flakes contain inclusions of feldspar, quartz and a few specks of epidote. The total chlorite, quartz, and epidote content is less than 1%. The plagioclase content is about 5%.

From micaceous gneiss.

(32 G) Road cut on Chibougamau Highway, 0.4 mile east of bridge over the narrows in Lac Dufresne; 49°34'30"N, 74°15'05"W. Map-unit 5a, Quebec Dept. Mines Map 1236. Sample SH-52-62. Collected and described by C.H. Stockwell.

This muscovite (1,010 m.y.) and the biotite of the previous determination GSC 62-148 (1,050 m.y.) form a pair from the same sample.

The sample is a medium-grained, light grey gneiss which is strongly sheared with the development of plentiful, parallel flakes and shreds of muscovite and lesser amounts of biotite. Other constituents include abundant quartz, some feldspar and a little epidote, titanite, apatite, and pyrite.

The sample was collected at a point 0.8 mile southeast of the Grenville front, about half way between the two biotite-muscovite pairs discussed above under GSC 62-147, both of which gave anomalously old biotite. The present sample, however, shows good agreement between the ages of the two minerals. The reason for there being no significant loss of argon from this biotite is not fully understood but may be due to the highly sheared nature of the rock, the shearing having taken place somewhat later than the regional metamorphism and having driven off previously generated argon.

GSC 62-150 Biotite, K-Ar age 1,105 m.y.

K 8.14%, Ar^{40}/K^{40} .0878; radiogenic argon 100%. Concentrate; consists of greenish biotite. Approximately 5% of the flakes contain red crusts of hematite on the surface. Chlorite not detected.

From orthogneiss.

(32 G) On west side of Chibougamau Highway at mile 107.6, Ducharme tp.; 49°26'28"N, 74°08'58"W. Map-unit "Orthogneiss", Quebec Dept. Mines Prelim. Map 1069. Sample SH-7-59. Collected and described by C.H. Stockwell.

Quebec

The sample from which the biotite was concentrated is a medium-grained grey rock with contorted gneissic structure. It consists of quartz, oligoclase, biotite, hornblende, epidote, and minor muscovite, apatite, zircon, carbonate, and garnet.

The sample is from a locality 9.0 miles southeast of the Grenville front. The age of 1,105 m.y. is some 150 m.y. older than that normally found in biotite of the Grenville province and, even at this distance from the Superior province, the biotite seems to have had some argon added to it.

GSC 62-151 — Biotite, K-Ar age 950 m.y.

K 7.91%, Ar^{40}/K^{40} .0723; radiogenic argon 100%. Concentrate; clean concentrate of biotite with a few flakes (about 1%) of muscovite. The biotite flakes vary from reddish-brown (70%) to greenish (30%). The greenish flakes contain minute inclusions. Chlorite not detected.

From paragneiss.

(32 H) Northeast side of Chibougamau Highway at mile 71.9, near the north end of Lac d'Argenson (Lac Chigoubiche), Lorne tp.; 49°08'44"N, 73°35'04"W. Map-unit 1a, Quebec Dept. Mines Prelim. Map 1157. Sample SH-6-59. Collected and described by C.H. Stockwell.

(For description see determination GSC 62-152).

GSC 62-152 — Muscovite, K-Ar age 980 m.y.

K 5.96%, Ar^{40}/K^{40} .0752; radiogenic argon 100%. Concentrate; impure concentrate of muscovite composed of about 50% muscovite flakes, 5% biotite, 10% quartz, 35-40% alkali feldspar and about 3% chlorite.

From paragneiss.

(32 H) Northeast side of Chibougamau Highway at mile 71.9, near the north end of Lac d'Argenson (Lac Chigoubiche), Lorne tp.; 49°08'44"N, 73°35'04"W. Map-unit 1a, Quebec Dept. Mines Prelim. Map 1157. Sample SH-6-59. Collected and described by C.H. Stockwell.

Quebec

The muscovite (980 m.y.) was separated from the same sample as the biotite of GSC 62-151 (950 m.y.). The sample is from a locality well within the Grenville province at a point 40 miles southeast of the front. The biotite-muscovite pair show good agreement and give ages that are normal for the Grenville province as a whole.

The sample is a medium-grained, light grey paragneiss composed of biotite, hornblende, muscovite, quartz, microcline, oligoclase, garnet, and minor calcite, apatite, and magnetite. The micas are fresh.

GSC 62-153 Biotite, K-Ar age 1,815 m.y.

K 7.75%, Ar^{40}/K^{40} .1782; radiogenic argon 100%. Concentrate; clean concentrate of brown biotite. Some biotite flakes contain inclusions of quartz and are slightly altered to chlorite. The total chlorite content is about 4%.

From granodiorite.
(32 G) Island in Dauversiere Lake; 49°33'45"N, 74°23'45"W. Map-unit 6, Quebec Dept. Mines Map 1236. Sample SH-53-62. Collected and described by C.H. Stockwell.

(For description see determination GSC 62-154).

GSC 62-154 Muscovite, K-Ar age 2,340 m.y.

K 8.04%, Ar^{40}/K^{40} .2715; radiogenic argon 100%. Concentrate; impure concentrate of muscovite. About 40% of the muscovite flakes are clean. About 60% of the flakes are intergrown with feldspar and contain inclusions of quartz, epidote, apatite and zircon. The total chlorite, quartz, and epidote content is less than 1%. The plagioclase content is about 10%.

From granodiorite.
(32 G) Island in Dauversiere Lake; 49°33'45"N, 74°23'45"W. Map-unit 6, Quebec Dept. Mines Map 1236. Sample SH-53-62. Collected and described by C.H. Stockwell.

The muscovite and the biotite of the previous determination GSC 62-153 form a pair from the same sample of rock.

Quebec

The rock is a light grey, medium-grained, massive granodiorite composed of quartz, oligoclase, microcline, biotite, muscovite, and a little carbonate, epidote and titanite. The micas are primary and fresh and the rock shows no visible evidence of metamorphism. The sample is from the Superior province and was collected from the Lauversiere stock at a point about 5 miles northwest of the Grenville front.

The muscovite at 2,340 m.y. is reasonably close to the prevalent age of 2,500 m.y. for the Superior province and gives the approximate age of crystallization of the granodiorite magma. The biotite no doubt crystallized at virtually the same time but its K-Ar age at 1,815 m.y. is 525 m.y. younger. This is no doubt due to loss of argon, apparently because of the influence of the Grenville orogeny.

New Brunswick

GSC 62-155 Muscovite, K-Ar age 417 m.y.

K 6.20%, Ar^{40}/K^{40} .0273; radiogenic argon 100%. Concentrate; is impure containing: 60% reasonably clean muscovite; 35% muscovite-sillimanite-quartz intergrowths and sillimanite aggregates; 5% altered biotite; and a few grains of cordierite. Approximately 3% chlorite, 15% quartz and less than 10% feldspar are present.

From quartz-biotite gneiss.
(21 J) From hill 10,000 feet at N39°W from the mouth of M'Kiel Brook on southwest Miramichi River; 46°32'16"N, 66°58'33"W. Map-unit 1b, GSC P.S. Map 6-1963. Sample 5-33-8/PB. Collected and interpreted by W.H. Poole.

The quartz-biotite gneiss is a fine- to medium-grained rock with about 10% each of muscovite, sillimanite, and plagioclase. The muscovite is undeformed and unaltered. An age determination on biotite (GSC 61-188) from the same rock and location gave a date of 411 m.y. (For further discussion see determination GSC 62-156).

GSC 62-156 Muscovite, K-Ar 432 m.y.

K 7.74%, Ar^{40}/K^{40} .02843; radiogenic argon 100%. Concentrate; about half of the muscovite flakes are reasonably clean. The remainder are partly coated with thin yellow crusts and contain small remnants of biotite, opaque inclusions and a few quartz fragments. Chlorite not detected.

From biotite-muscovite schist.
(21 J) 2,300 feet south of the west end of Diamond Lake; 46°34'35"N, 67°00'07"W. Map-unit 1a, GSC P.S. Map 6-1963. Sample 5-29-16/PB. Collected and interpreted by W.H. Poole.

The mica schist is fine grained and quartzose. It has a few indistinct knots which in thin section appear as masses of very fine-grained sericite and relics of poikiloblastic cordierite. The muscovite is undeformed and unaltered.

The gneiss (GSC 62-155) grades structurally upwards into the schist (GSC 62-156) which, in turn, grades laterally into quartzite and slate believed to be Cambrian and/or Lower Ordovician (Map 6-1963). The high grade metamorphism is associated with granitic intrusion and is probably late Ordovician or early Silurian, as distinct from mid-Devonian deformation and granitic intrusion.

New Brunswick

The present two muscovite dates, 417 m.y. (GSC 62-155) and 432 m.y. (GSC 62-156), further confirm the existence of the early activity. They compare favourably with other dates obtained within an area of about 15 miles in diameter (Map 6-1963), namely:

GSC 61-188, Biotite from gneiss, 411 m.y.
GSC 61-190, Biotite from cataclastic granite, 410 m.y.
GSC 61-191, Muscovite from cataclastic granite, 435 m.y.

The muscovite dates are 10 to 20 m.y. (or 2% to 5%) older than the biotite dates. According to a recent time scale (Kulp, 1961), the Silurian lasted from 405 m.y. to 425 m.y. ago. The muscovite dates would indicate a late Ordovician activity, not inconsistent with geological deductions (Map 6-1963).

The 497 m.y. biotite date from one of the "old" granites (GSC 61-189) is anomalously too old, about the Cambro-Ordovician boundary. If this much older date is not the result of an undetected large analytical error, then it may indicate more closely the true age of all this pre-Devonian activity.

GSC 62-157 Muscovite, K-Ar age 392 m.y.

K 8.77%, Ar^{40}/K^{40} .02551; radiogenic argon 100%. Concentrate; consists mostly of clean muscovite flakes but about 20% of the flakes are partly coated with thin yellow crusts and contain yellow stained patches. Chlorite not detected.

From greisen.
(21 J) East bank of Burnthill Brook, 3,800 feet above the mouth; 46°35'05"N, 66°49'25"W. Map-unit 10b, GSC P.S. Map 6-1963. Sample 5-14-7B/PB. Collected and interpreted by W.H. Poole.

The greisen is a medium-grained muscovite-quartz rock formed by alteration of quartz monzonite bordering a quartz vein. The quartz vein, 1/2 inch thick contains abundant beryl and traces of native bismuth. Other veins in the general area, such as those of Burnthill Tungsten Mine, contain wolframite and molybdenite (Map 6-1963). Greisen is several inches wide and dark olive-green. In thin section, about half the rock consists of quartz; 35% muscovite, clean, sharp, and slightly bent; 10% chloritized biotite; and 5% fluorite and tourmaline.

(For further discussion see determination GSC 62-158).

New Brunswick

GSC 62-158 Biotite, K-Ar age 423 m.y.

$K\ 7.35\%,\ Ar^{40}/K^{40}\ .02778$; radiogenic argon 100%. Concentrate; consists of red-brown biotite containing a few inclusions of apatite. About 10% of the flakes are partly chloritized. A few fragments of hornblende are present as an impurity. Chlorite content is about 8%.

From granodiorite.
(21 J) Southwest Miramichi River, west bank, 2 1/2 miles north, 30° east of outlet of Miramichi Lake; 46°29'45"N, 66°56'27"W. Map-unit 20, GSC Map 37-1959. Sample 5-35-1/PB. Collected and interpreted by W.H. Poole.

The granodiorite is grey, coarse-grained, slightly porphyritic and massive. In thin section, nearly 25% is quartz, 50% clouded plagioclase, 6% microcline, and 19% biotite. Biotite is pleochroic tan to dark brown and relatively free of inclusions. Some biotite is partly chloritized and other biotite completely so.

The mica dates on determinations GSC 62-157 and GSC 62-158 were expected to confirm an early or Middle Devonian age of granitic bodies, that is, 365 m.y. to 405 m.y. according to a recent time scale (Kulp, 1961). The granodiorite and quartz monzonite with greisen are massive post-tectonic bodies typical of Devonian granites in at least central New Brunswick, K-Ar biotite dates on various bodies are 387 m.y. (GSC 61-187) and a range of 380 m.y. to 398 m.y. from four bodies (Tupper and Hart, 1961). Two biotite dates from similar Acadian granitic bodies, 312 m.y. (GSC 60-136) and 339 m.y. (GSC 61-192) appear to be anomalously low for uncertain reasons.

The 392 m.y. muscovite date (GSC 62-157) does fit well with these typical Acadian dates. Furthermore, as expected, growth of muscovite during greisenization is essentially the same age as that of the granitic host, and not a process occurring much later.

The 423 m.y. biotite date (GSC 62-158), however, is 20 to 30 m.y. (5% to 6%) older than expected, although the disparity is not greater than the analytical precision of about 7%. If the biotite and granodiorite are indeed older than other Acadian granitic bodies in central New Brunswick (Map 3-1963, Map 37-1959), it is interesting to note that the granodiorite contains more biotite and less potash feldspar than the other Acadian granitic bodies; that the youngest deformed strata in the area are Middle Silurian; and that the mica dates from the gneiss and schist, which are cut by the granodiorite, range from 411 to 432 m.y. (Map 6-1963).

New Brunswick

It is conceivable that the granodiorite was intruded during the late Silurian; that it degassed existing micas in schists and gneisses formed during the late Ordovician or early Silurian; and that during the early or middle Devonian, biotite quartz monzonites more typical of the Acadian granites were emplaced. Further age determinations are necessary.

Again, the 497 m.y. biotite date (GSC 61-189) from the granitic rock genetically associated with the gneisses is an unexplained anomaly.

GSC 62-159 Biotite, K-Ar age 508 m.y.

K 6.44%, Ar^{40}/K^{40} .03409; radiogenic argon 100%. Concentrate; biotite varies from buff to reddish brown. Zircon inclusions surrounded by pleochroic haloes are common. Nearly half the flakes show partial alteration to greenish chlorite and epidote. Total chlorite content is about 22%.

From biotite gneiss.
(21 G) Railway cut at Brookville; 45°20'08"N, 66°01'39"W. Map-unit 4, GSC Map 497A. Sample KA 400. Collected and interpreted by D.G. Kelley.

The sample was obtained from biotite gneiss that is interbedded with, and grades into, carbonate rocks of the Precambrian Green Head Group.

The minimum age of 508 m.y., if close to the actual age of the biotite, suggests that the biotite was formed during the Taconic orogeny.

GSC 62-160 Biotite, K-Ar age 500 m.y.

K 6.32%, Ar^{40}/K^{40} .0335; radiogenic argon 100%. Concentrate; consists mainly of clean biotite flakes varying from ginger brown to pale greyish brown with dark brown patches. Some of the flakes are slightly bleached and altered. A minor amount of pale green chlorite is also present. X-ray examination revealed that two types of biotite are present, and the ginger brown biotite has a considerably lower iron content than the brownish grey biotite. The total chlorite content of the concentrate is about 5%.

New Brunswick

From gabbro.
(21 H) Kennabecasis River, at the bridge of Highway 14, near Mechanics Settlement; 45°43'31"N, 65°12'25"W. Map-unit 4a, GSC Map 1109A. Sample PB1-1961. Collected by A. Y. Smith. Interpreted by W.H. Poole and E.D. Kindle.

The olivine gabbro sample is a massive, medium-grained, and equigranular rock which is dark grey to black and weathers brown. In thin section, well-twinned labradorite and clinopyroxene make up about 90% of the rock; both minerals are cut by pervasive fractures but are quite fresh. Olivine forms 10% of the rock and is almost completely altered to magnetite and serpentine along the fractures. A small per cent of the rock is biotite and green amphibole. Biotite is pleochroic, tan to red-brown, and secondary. It is cut by the fractures. Some biotite is enclosed within clinopyroxene.

The olivine gabbro body forms part of the presumed Precambrian Caledonian Complex. It has intruded sedimentary and volcanic strata of the Coldbrook Group near the northwest edge of the complex. Bodies of gabbro several miles to the southeast and east are enclosed within granites, and are highly altered and slightly schistose (GSC Map 1109A).

The 500 m.y. date indicates a Cambrian or Precambrian age. Certainly, the olivine gabbro is not Devonian. A Precambrian age is favoured.

GSC 62-161 Muscovite, K-Ar age 640 m.y.

K 8.97%, Ar^{40}/K^{40} .04456; radiogenic argon 100%. Concentrate; consists of mostly clean muscovite. A few inclusions of quartz and some partly coated grains are present. Chlorite not detected.

From granite.
(21 B) Southwest coast of Ross Island, halfway between Fish Fluke Point and Indian Camp Point; 44°39'43"N, 66°44'50"W. Map-unit 2, GSC Map 965A. Sample TA61-T146a. Collected and interpreted by F. C. Taylor.

Determination GSC 61-193 (Lowdon, 1962) is from the same conglomerate and gave an age of 590 m.y.

If there has been no argon loss since original formation, then the conglomerate and the Coldbrook Group are younger than 590 m.y.

New Brunswick

If, on the other hand, argon has leaked from the muscovite, then the muscovite is older than either or both the 590 m. and 640 m.y. ages and the conglomerate and Coldbrook Group are older or younger than 590 m.y. or 640 m.y.

Argon loss is a distinct possibility in this area which has been affected by Palaeozoic orogenies.

GSC 62-162 Biotite, K-Ar age 411 m.y.

K 7.21%, Ar^{40}/K^{40} .02685; radiogenic argon 100%. Concentrate; biotite flakes vary from greenish to brown and contain numerous needle-like inclusions. About 5% of the flakes are partly chloritized and contain inclusions of epidote. Chlorite content about 5%.

From granodiorite.
(21 B) North side of Pauls Cove, East Wolf Island; 44°58'N, 66°43'W. Map-unit A, GSC Map 964A. Sample TA 61-T143. Collected and interpreted by F. C. Taylor.

The sample is from a group of islands in the Bay of Fundy that are isolated from any other rock units.

These islands were considered to be Precambrian (Alcock, 1948). The age of 411 m.y. suggests that the rocks are uppermost Silurian according to Kulp's (1961) time scale.

Nova Scotia

GSC 62-163 Muscovite, K-Ar age 410 m.y.

K 8.30%, Ar^{40}/K^{40} .0269; radiogenic argon 100%. Concentrate; consists of reasonably good muscovite. Small quartz inclusions are present in about 40% of the flakes. About 10% of the flakes are stained and coated with greenish yellow crusts of iron oxides. Less than 10% quartz and feldspar are present. Chlorite not detected.

From granite.
(21 A) 1.25 miles north of New Ross, on Highway 12 on the west side of the road; 44°45'20"N, 64°28'00"W. Map-unit 7a, GSC Map 40-1961. Sample TA 61-T60. Collected and interpreted by F. C. Taylor.

(For interpretation see determination GSC 62-164).

GSC 62-164 Biotite, K-Ar age 400 m.y.

K 7.34%, Ar^{40}/K^{40} .0260; radiogenic argon 100%. Concentrate; biotite varies from reddish brown to buff and contains large pleochroic haloes. The concentrate contains not over 10% muscovite as an impurity. Chlorite not detected.

From granite.
(21 A) 1.25 miles north of New Ross, on Highway 12 on the west side of the road; 44°45'20"N, 64°28'00"W. Map-unit 7a, GSC Map 40-1961. Sample TA 61-T 60. Collected and interpreted by F. C. Taylor.

The muscovite granite body from which this sample was taken grades into the main biotite granite batholith that comprises a large part of southern Nova Scotia. These muscovite granites have been considered (Faribault, Armstrong and Wilson, 1939) to be younger than the biotite granites. No evidence for this interpretation was found during a more recent survey (Taylor, 1961).

The biotite granite intrudes fossiliferous Lower Devonian Torbrook Formation (Smitheringale, 1960). Ages from the granite range from 345 m.y. to 380 m.y. (Fairbairn et al, 1960) in the central part of the province.

The ages of 400 m.y. (GSC 62-164) on biotite, and 410 m.y. (GSC 62-163) on muscovite, the first from granite containing significant amounts of muscovite, indicate that the muscovite-bearing granites are slightly "older" rather than "younger" than the more common biotite granite. The presence of muscovite is probably no guide in this area to the relative age of granitic rocks.

GSC 62-165 Biotite, K-Ar age 384 m.y.

K 7.33%, Ar^{40}/K^{40} .02491; radiogenic argon 100%. Concentrate; biotite varies from buff to red-brown and the flakes contain numerous inclusions of zircon surrounded by dark brown pleochroic haloes. About 10% of the flakes are partly altered to chlorite and epidote. Chlorite content is about 8%.

From granite.

(21 A) Gold River Valley just downstream from a bridge on Highway 12; 44°43'30"N, 64°26'55"W. Map-unit 2, GSC Map 1981. Sample TA 61-T 44. Collected and interpreted by F. C. Taylor.

The sample is from a weakly porphyritic, grey, coarse-grained muscovite-biotite granite. The age of 384 m.y. agrees reasonably well with other ages from the main Nova Scotia batholith (Fairbairn et al, 1960) and tends to confirm that the emplacement of the main part of the granite intrusions of Nova Scotia occurred in the Upper to Middle Devonian according to Kulp's time scale (1961).

GSC 62-166 Muscovite, K-Ar age 396 m.y.

K 8.50%, Ar^{40}/K^{40} .02578; radiogenic argon 100%. Concentrate; consists of mostly clean muscovite. About 20% of the flakes contain a few small inclusions of quartz and 5% are stained yellow and contain specks of biotite. Chlorite not detected.

From granite.

(21 A) Along the coast, 1/2 mile west of Schnare Point; 44°38'30"N, 64°00'30"W. Map-unit 7, GSC Map 40-1961. Sample TA 61-T 114. Collected and interpreted by F. C. Taylor.

The sample is from a muscovite granite dyke that cuts biotite granite that is part of the main Nova Scotia batholith. The dyke contains inclusions of biotite granite.

The biotite granite has previously been dated by Fairbairn et al (1960) from two nearby locations (approximately 8 miles on either side of the present occurrence) with the following results:

Nova Scotia

		Rb/Sr Method	K-Ar Method
St. Margaret Bay			
	Biotite	368 m.y.	340 m.y.
	Muscovite	332 m.y.	--------
Shad Bay			
	Biotite	385 m.y.	--------
	Muscovite	373 m.y.	--------

The 396 m.y. age obtained on the present sample cannot be reconciled in view of the field relationships.

GSC 62-167 Biotite, K-Ar age 383 m.y.

K 6.04%, Ar^{40}/K^{40} .02484; radiogenic argon 100%. Concentrate; consists of buff to ginger brown biotite containing a few inclusions of quartz, zircon, and iron oxides. About 25% of the flakes are partly bleached and chloritized along grain edges and fractures. Chlorite content is about 17%.

From garnet-biotite schist.
(20 P) On the east side of Negro Harbour near the village of North West Harbour; 43°33'40"N, 65°24'50"W. Map-unit 2, GSC Map 44-1960. Sample TA 59-T 118. Collected and interpreted by F. C. Taylor.

This sample of biotite schist forms part of the Goldenville Formation. The determined age of 383 m.y. is significantly older than any previous ages in the southern part of Nova Scotia. These range from 245 m.y. to 335 m.y. for micas from granitic rocks and 340 m.y. on biotite from a schist, also from the Goldenville Formation, at Lockeport, 18 miles northeast of the present sample site (Fairbairn et al, 1960).

However, the 383 m.y. age compares favourably with ages on micas from granitic rocks to the north that form part of the main Nova Scotia granite batholith. This suggests that the metamorphism of the Goldenville Formation at this locality occurred prior to the emplacement of the granitic rocks in the southern part of the province but during the major period of granitic emplacement.

GSC 62-168 Biotite, K-Ar age 360 m.y.

K 7.58%, Ar^{40}/K^{40} .0232; radiogenic argon 95%. Concentrate; is clean, consisting of reddish brown biotite. About 20% of the flakes are slightly chloritized and contain epidote inclusions in bleached areas. Dark pleochroic haloes surround zircon inclusions. The estimated chlorite content is about 4%.

From biotite granite.
(11 F) 2,000 feet northwest of American Cove Village; 45°15'33"N, 61°19'51"W. Map-unit 4, GSC Map 3-1959. Sample SG-413-57. Collected and interpreted by I. M. Stevenson.

(For interpretation see determination GSC 62-169).

GSC 62-169 Muscovite, K-Ar age 383 m.y.

K 8.72%, Ar^{40}/K^{40} .0249; radiogenic argon 100%. Concentrate; clean concentrate of muscovite but about half of the flakes are partly coated with yellow crusts and contain small adhering fragments of biotite and quartz. Chlorite not detected.

From biotite granite.
(11 F) 2,000 feet northwest of American Cove Village; 45°15'33"N, 61°19'51"W. Map-unit 4, GSC Map 3-1959. Sample SG-413-57. Collected and interpreted by I. M. Stevenson.

The rock is a coarse-grained, massive, brown-grey, undeformed quartz monzonite composed mainly of quartz, perthite, plagioclase, biotite, and a small amount of muscovite. The quartz is slightly stained and the plagioclase is twinned and zoned. The biotite is pleochroic tan to reddish brown and chloritized along some cleavage planes. Accessory minerals are zircon, sphene and garnet.

The sample is from a small batholith that has intruded sediments of the Meguma Group of Cambro-Ordovician age. This particular granite body forms part of the main granite mass that was emplaced in Nova Scotia during the Devonian orogeny. An age determination carried out at M.I.T., using the Rb/Sr method on biotite and muscovite from a specimen of granite collected at Queensport some 6 miles to the northeast, yielded a concordant age of 370 m.y. (Fairbairn et al, 1960). At the same laboratory, a determination on biotite by the K-Ar method yielded 366 m.y. (Fairbairn et al, 1960).

The K-Ar ages of both the muscovite (GSC 62-169, 383 m.y.) and the biotite (GSC 62-168, 360 m.y.) compare very favourably with the age of the Queensport specimen, which was collected from the same granite body. The remarkable similarity between G. S. C. and M. I. T. dates is a tribute to the accuracy of the two methods of age determination, and supports the contention that no marked deformation or metamorphism has occurred in the granite since Devonian time.

Newfoundland

GSC 62-170 Biotite, K-Ar age 1,775 m.y.

K 7.58%, Ar^{40}/K^{40} .1728; radiogenic argon 100%. Concentrate; clean concentrate of biotite. Most of the flakes are brown and clean but some are greenish, slightly altered and contain acicular inclusions of epidote and a few grains of quartz. The total chlorite content is about 7.5%.

From lit-par-lit gneiss.
(24 P) East shore of Eclipse Channel, Labrador; 59°43'30"N, 64°09'00"W. Map-unit 4; GSC Map 52-22A. Sample SH-13-62. Collected and described by C.H. Stockwell.

The sample is a well banded rock in which layers rich in biotite are interleaved with layers of light grey granitic material. The rock is composed of oligoclase, quartz, and biotite with minor hornblende, apatite, and zircon. Many of the biotite crystals are bent and most are fresh but a few are interleaved with chlorite. Elsewhere on the outcrop the dark layers are rich in hornblende. The determined age is that of the orogeny and metamorphism.

GSC 62-171 Biotite, K-Ar age 2,255 m.y.

K 7.13%, Ar^{40}/K^{40} .2547; radiogenic argon 100%. Concentrate; consists of greenish brown biotite. About 30% of the biotite flakes are partly altered to chlorite and contain small acicular inclusions of rutile and epidote. The total chlorite content is about 20%.

From lit-par-lit gneiss.
(14 F) Southeast end of Mugford Harbour, Kraaken Inlet, Labrador; 57°46'30"N, 61°43'00"W. Map-unit 4, GSC Map 52-22A. Sample SH-18-62. Collected and interpreted by C.H. Stockwell.

The lit-par-lit gneiss shows dark greenish grey layers alternating with white granite. Minerals noted include oligoclase, quartz, biotite, and minor hornblende, titanite, and apatite. Most of the biotite and hornblende crystals are considerably altered to chlorite.

The gneiss is overlain unconformably by nearly flat-lying rocks of the Mugford Series and the determined age of 2,255 m.y. is a maximum for the Mugford.

Newfoundland

GSC 62-172 Biotite, K-Ar age 1,275 m.y.

K 7.16%, Ar^{40}/K^{40} .1069; radiogenic argon 100%. Concentrate; clean concentrate of dark brown biotite. A few flakes are slightly bleached. The total chlorite content is about 1%.

(14 E) From quartz monzonite. South shore of a lake just northwest of Umiakovik Lake, Labrador; 57°24'00"N, 62°56'00"W. Map-unit 4a, GSC Map 52-22A. Sample SH-19-62. Collected and described by C.H. Stockwell.

The quartz monzonite is a massive, coarse-grained rock composed of bluish grey quartz, white orthoclase and oligoclase and lesser amounts of hornblende and biotite. Minor constituents include magnetite, apatite, titanite, and zircon. The oligoclase is somewhat altered to sericite and the biotite, though unchloritized contains dark streaks along cleavage planes. As the rock is massive and apparently unmetamorphosed the biotite age of 1,275 m.y. probably indicates the age of primary crystallization.

GSC 62-173 Biotite, K-Ar age 1,615 m.y.

K 8.07%, Ar^{40}/K^{40} .1497; radiogenic argon 100%. Concentrate; clean concentrate of biotite. Biotite flakes vary from brown to greenish. A few flakes are slightly bleached and altered to chlorite. The total chlorite content is about 2%.

(23 H) From paragneiss. Peninsula on the south shore of Sangirt Lake at the inlet of the Atikonak River, Labrador; 53°51'30"N, 65°15'30"W. Map-unit A, GSC Map 17-1961. Sample SH-33-62. Collected and described by C.H. Stockwell.

(For description see determination GSC 62-174).

GSC 62-174 Muscovite, K-Ar age 1,645 m.y.

K 6.86%, Ar^{40}/K^{40} .1537; radiogenic argon 100%. Concentrate; consists of about 70% muscovite flakes which are reasonably clean but contain a few small inclusions of quartz. Impurities total about 30% and consist of feldspar, quartz, rutile, anatase, sphene, apatite, sulphides, zircon, minor intergrowths of muscovite, and chloritized biotite, and a few opaque grains, probably of carbon. The total feldspar content is 15%, quartz 2%, and chlorite 2%.

From paragneiss.

(23 H) Peninsula on the south shore of Sangirt Lake at the inlet of the Atikonak River, Labrador; 53°51'30"N, 65°15'30"W. Map-unit A, GSC Map 17-1961. Sample SH-33-62. Collected and described by C. H. Stockwell.

This and the previous concentrate form a biotite-muscovite pair from the same sample of rock and the two ages agree with one another. The sample of paragneiss shows dark grey biotite-rich layers permeated with lenses and stringers of white granitic material. The thin section shows, in addition to biotite, plentiful quartz and oligoclase and flakes of muscovite. Apatite and zircon are accessory. The plagioclase is somewhat clouded with sericite but the micas are fresh.

The sample was taken from a locality 3 miles east of the Labrador trough and the author of the map correlates the paragneiss with a formation that appears to be overlain unconformably by the Kaniapiskau Supergroup but both the Kaniapiskau and the basement rocks have been metamorphosed together. The K-Ar ages on the micas show the time of the overriding metamorphism and give a minimum for the Kaniapiskau.

GSC 62-175 Biotite, K-Ar age 2,210 m.y.

K 7.59%, Ar^{40}/K^{40} .2459; radiogenic argon 100%. Concentrate; a very clean concentrate of red-brown biotite with oriented inclusions of rutile (sagenite). About 10% of the flakes are slightly chloritized along the edges and contain inclusions of epidote. The total chlorite content is about 2%.

From diorite.

(23 H) Gabbro Lake, outcrop just north of the road to Grand Falls, Labrador; 53°45'30"N, 65°21'30"W. Map-unit 8, GSC Map 17-1961. Sample SH-34-62. Collected and interpreted by C.H. Stockwell.

This rock is a somewhat schistose, dark greenish diorite composed chiefly of plagioclase, antiperthite, hornblende, biotite, and altered pyroxene. The plagioclase is much altered to sericitic material and some carbonate. The biotite is dirty brown and is crossed by streaks of opaque material.

Newfoundland

The age of 2,210 m.y. is difficult to interpret. The sample of diorite was collected from an outcrop shown on the map as olivine gabbros which, nearby to the northeast, intrudes the Sims Formation. This formation lies unconformably on the Kaniapiskau Supergroup which has a minimum age of around 1,600 to 1,700 m.y. so that the olivine gabbro must be still younger. The diorite lies within an area surrounded by Kaniapiskau rocks and, judged by the date obtained, could be part of the pre-Kaniapiskau basement or, at best, a pre-Sims intrusion into the Kaniapiskau.

<u>GSC 62-176</u> Biotite, K-Ar age $\left.\begin{array}{l}\text{3,760 m.y.}\\\text{3,700 m.y.}\end{array}\right\}$ Average <u>3,730 m.y.</u>

K 8.02%, Ar^{40}/K^{40} $\begin{array}{l}.6993\\.6749\end{array}$; radiogenic argon $\begin{array}{l}100\%\\100\%\end{array}$.
Concentrate; clean concentrate of dark greenish brown biotite. Some flakes are slightly altered and contain inclusions of epidote, quartz and a few grains of magnetite. The total chlorite content is about 4%.

From granite.
(23 H) North side of cableway, 1/2 mile above Grand Falls, Labrador; 53°36'00"N, 64°19'00"W. Map-unit 2, GSC Map 52-9. Sample SH-8-61. Collected by A.P. Beavan. Interpreted by C.H. Stockwell.

The granite from which this biotite was separated is a medium-grained, massive, grey rock composed mainly of microcline, oligoclase, quartz, and biotite with lesser amounts of myrmekite, magnetite, titanite, and zircon. Recrystallized cataclastic texture is noticeable around the borders of feldspar grains. The biotite is fresh and occurs mainly in the recrystallized granulated parts of the rock.

The sample was collected from the Grenville province with the object of helping to map the position of the Grenville front, which may occur along a northeasterly trending fault some 4 miles to the west. The surprisingly old date of 3,730 m.y. is unrealistic and anomalous and is probably due to the addition of extraneous argon to the biotite. (For discussion see Part II of this report).

A rubidium-strontium age of 900 m.y. was obtained on the same biotite, an initial Sr^{87}/Sr^{86} ratio of .7065 being assumed. This age agrees with potassium-argon ages for the Grenville orogeny and no doubt correctly indicates the time of crystallization of the biotite.

Newfoundland

GSC 62-177 Biotite, K-Ar age 1,430 m.y.

K 7.76%, Ar^{40}/K^{40} .1253; radiogenic argon 100%. Concentrate; reasonably clean concentrate of biotite. Biotite flakes vary from brown to greenish and contain inclusions of epidote, apatite, and quartz. A few flakes are partly altered to chlorite. The total chlorite content is 4%.

From paragneiss.
(13 L) 1/2 mile north of Shipiskan Lake, Labrador; 54°39'45"N, 62°18'00"W. Map-unit A3, GSC Map 53-14. Sample SH-24-62. Collected and described by C.H. Stockwell.

The rock is a fine-grained, grey paragneiss with streaks and lenses of white feldspar. It consists of quartz, oligoclase, biotite, and accessory magnetite, apatite, titanite, and zircon. The biotite is fresh.

The sample is from a thin layer of sedimentary gneiss in pink, fine-grained granite-gneiss. The whole is overlain unconformably by rock of the Seal Group, those to the west being virtually flat-lying while those just south of the locality where the sample was collected are folded. The area of gneiss is partly surrounded by anorthosite which also lies unconformably beneath the Seal.

The age determination was made for the purpose of getting a maximum age on the Seal Group but it is uncertain whether the age of 1,430 m.y. on the biotite is a true indication of the time of the strong metamorphism because part of the argon may have been driven off when the Seal rocks were folded.

GSC 62-178 Biotite, K-Ar age 2,430 m.y.

K 7.45%, Ar^{40}/K^{40} .2895; radiogenic argon 100%. Concentrate; reasonably clean concentrate of brown biotite. About 40% of the biotite flakes contain inclusions of epidote and are slightly altered to chlorite. The concentrate also contains about 10% bright green chlorite flakes. The total chlorite content is about 15%.

From granitic gneiss.
(13 N) North shore of an unnamed lake, Labrador; 55°05'00"N, 60°27'00"W. Map-unit A, GSC Map 53-14. Sample SH-26-62. Collected and described by C.H. Stockwell.

Newfoundland

This is a medium-grained, grey granitic gneiss cut by stringers of white granite. It is probably a highly granitized paragneiss. The rock is composed of oligoclase, quartz, biotite and a little apatite and epidote. Some of the biotites are fresh but many are speckled with magnetite or are much altered to chlorite.

The sample is correlated with the Hopedale Gneiss of Kranck (Geol. Surv., Canada, Bull. 26). The 2,430 m.y. age on the biotite indicates that the Kenoran orogeny affected this region of Labrador far to the east of the Superior province which is the type locality.

GSC 62-179 Biotite, K-Ar age 1,645 m.y.

K 7.40%, Ar^{40}/K^{40} .1535; radiogenic argon 100%. Concentrate; reasonably clean concentrate of brown biotite. Some flakes are reddish brown and contain inclusions of quartz, apatite, small zircons surrounded by pleochroic haloes, and colloform red iron oxides. About 30% of the biotite flakes are partly bleached and contain epidote inclusions in altered areas. The total chlorite content is about 13%.

From granite.
(13 O) East shore Aillik Bay, 3,100 feet east of Buttress Point, Labrador; 55°13'13"N, 59°09'40"W. Cuts Map-unit 4, Figure 1, GSC Bull. 26. Sample SH-2-62. Collected by A. F. King. Described by C. H. Stockwell and A. F. King.

The granite is a medium-grained, light grey, massive rock consisting of oligoclase, microcline, quartz, a little biotite, and accessory magnetite. Most of the biotite crystals are fresh but some are partly or completely altered to chlorite. On the outcrop the granite is seen to hold inclusions of fine-grained diorite and to grade into granitized sediments. Regional relationships indicate that the granite is younger than the Aillik Series of sediments and is also younger than dykes of pegmatite, epidiorite, feldspar porphyry, pyroxenite, and diorite which cut this series.

The age obtained is a minimum for the Aillik Series and helps to define the position of the Grenville front which must lie somewhere farther south.

Newfoundland

GSC 62-180 Biotite, K-Ar age 535 m.y.

K 5.35%, Ar^{40}/K^{40} .0363; radiogenic argon 100%. Concentrate; consists of biotite from the groundmass (see GSC 62-182). It is an impure concentrate of pale brown biotite. About 25% of impurities consist of altered pyroxene and calcite. Chlorite not detected.

From lamprophyre.
(13 O) East shore Aillik Bay, 1,400 feet southeast of Buttress Point, Labrador; 55°11'55"N, 59°10'22"W. Map-unit 8, Figure 1, GSC Bull. 26. Sample SH-1-62. Collected by A.F. King. Described by C.H. Stockwell and A.F. King.

(For description see determination GSC 62-182).

GSC 62-181 Biotite, K-Ar age 585 m.y.

K 7.37%, Ar^{40}/K^{40} .0401; radiogenic argon 100%. Concentrate; reasonably clean concentrate of fine-grained biotite. The flakes vary from buff (70%) to dark brown (25%). About 5% of the brown flakes contain numerous inclusions of apatite and a few zircons. The major impurity (about 5%) is an altered feldspar. Chlorite not detected.

From lamprophyre.
(13 O) East shore of Aillik Bay, 1,400 feet southeast of Buttress Point, Labrador; 55°11'55"N, 59°10'22"W. Map-unit 8, Figure 1, GSC Bull. 26. Sample SH-1-62. Collected by A.F. King. Described by C.H. Stockwell and A.F. King.

(For description see determination GSC 62-182).

GSC 62-182 Biotite, K-Ar age 590 m.y.

K 7.87%, Ar^{40}/K^{40} .0403; radiogenic argon 100%. Concentrate; clean concentrate of coarse brown biotite. About 10% of the coarse biotite flakes (900 μ in diameter) contain flaky inclusions of fine-grained darker biotite (50 μ in diameter) along the fractures. Some flakes contain numerous inclusions of apatite. Chlorite not detected.

Newfoundland

From lamprophyre.
(13 O) East shore of Aillik Bay, 1,400 feet southeast of Buttress Point, Labrador; 55°11'55"N, 59°10'22"W. Map-unit 8, Figure 1, GSC Bull. 26. Sample SH-1-62. Collected by A. F. King. Described by C. H. Stockwell and A. F. King.

This and the two previous concentrates GSC 62-180 (535 m.y.) and GSC 62-181 (585 m.y.) are from the same sample. The first two are of fine-grained biotite of the groundmass and the present sample is of coarser biotite phenocrysts. The three ages agree reasonably well with one another and average 570 m.y. which, according to the time scale of Kulp and Holmes falls in the Cambrian.

The sample is a brown weathering, dark grey, massive lamprophyre dyke composed chiefly of biotite, pyroxene, and olivine which occur both as phenocrysts and as small crystals in a fine-grained groundmass containing abundant carbonate. The olivine is somewhat altered to serpentine but the biotite is fresh. Apatite and a dark opaque mineral are plentiful accessories.

The dyke is 4 feet wide, dips vertically and intrudes granitized rocks. Regional relationships indicate that it is the youngest rock of the area, being younger than the granite of GSC 62-179 and younger than dykes of felsite, diabase, and diorite porphyry which cut this granite.

GSC 62-183 Biotite, K-Ar age 1,035 m.y.

K 6.82%, Ar^{40}/K^{40} .0805; radiogenic argon 100%. Concentrate; consists of at least 90% clean biotite. Most of the flakes are deep green but some vary from green to brown. Minor amounts of yellow-stained muscovite and quartz are present as impurities. Chlorite/biotite 0.04.

From meta-greywacke.
(13 K) East end of a small lake, Labrador; 54°23'10"N, 60°45'00"W. Sample SH-20-61. Collected by K. E. Eade. Described by C. H. Stockwell.

(For description see determination GSC 62-184).

Newfoundland

GSC 62-184 Muscovite, K-Ar age 1,005 m.y.

K 6.90%, Ar^{40}/K^{40} .0778; radiogenic argon 100%. Concentrate; consists of about 75% muscovite. Most flakes are clean but some are stained yellow and have quartz inclusions. Impurities consist of 15% feldspar and 10% quartz with traces of epidote and zircon. Chlorite not detected.

From meta-greywacke.
(13 K) East end of a small lake, Labrador; 54°23'10"N, 60°45'00"W. Sample SH-20-61. Collected by K. E. Eade. Described by C.H. Stockwell.

The muscovite, 1,005 m.y., is from the same sample as the biotite of GSC 62-183, 1,035 m.y., and the agreement is good.

The sample is a fine-grained grey rock with a poor cleavage due to parallel flakes and shreds of metamorphic biotite and muscovite. The micas are fresh. Other constituents include quartz, plagioclase, and minor carbonate which is probably a primary constituent.

The meta-greywacke is possibly an eastward extension of the Croteau Group. The micas, which developed during the Grenville orogeny, give a minimum age for the group.

GSC 62-185 Muscovite, K-Ar age 975 m.y.

K 7.20%, Ar^{40}/K^{40} .0746; radiogenic argon 100%. Concentrate; consists of about 60% clean muscovite, 25% muscovite with numerous quartz inclusions, and 15% quartz and minor feldspar grains. Chlorite not detected.

From quartzite.
(13 K) South shore of small lake, 1 1/2 miles east of Naskaupi River, Labrador; 54°08'10"N, 61°23'20"W. Map-unit 8, GSC Map 1079A, Sample SH-14-61. Collected by K.E. Eade. Described by C.H. Stockwell.

This is a fine-grained, white, sericitic quartzite containing, in addition to abundant quartz, a few scattered grains of microcline and rare zircons. The sericite forms shreds and flakes lying parallel with one another.

Newfoundland

The sample is from a locality 3 miles south of the Grenville front and represents a metamorphosed equivalent of the Snare Group that was involved in the Grenville orogeny. The K-Ar age is a minimum for the Snare. A maximum for the Snare is given by an apparently Archaean age of 2,390 m.y. on biotite (GSC 61-196).

GSC 62-186 Chlorite, K-Ar age 451 m.y. (415-485 m.y.)

K 0.81%, Ar^{40}/K^{40} .0298; radiogenic argon 100%. Concentrate; consists mainly of greenish chlorite and lesser amounts of chloritized biotite. Biotite is present as a minor constituent. The total biotite content is about 5-10%.

From anorthosite.

(12 B) Flat Bay Brook, north side, 1 mile east of Hells Gulch; 48°22'N, 58°19'W. Map-unit 1, GSC Bull. 27, Fig. 7. Sample RG-61-A-2. Collected and interpreted by E.R. Rose.

The sample consists mainly of greenish dark chlorite and lesser amounts of chloritized biotite collected from sporadic clots and crystals of altered pyroxene in anorthosite from near the centre of the Flat Bay Brook anorthosite mass. Chloritization is believed to be related to late-stage magmatic reactions subsequent to consolidation of the bulk of the anorthosite body, which on geological grounds is believed to be of Precambrian age. The K-Ar age determination of 451 m.y., being on chlorite, is therefore suspect.

On the other hand, it is possible that chloritization is much younger than the host rock anorthosite, and that the K-Ar dating is accurate. It is also possible, but not probable, that both anorthosite and chloritization are of Palaeozoic age as indicated. Further work will be necessary to resolve this problem.

GSC 62-187 Biotite, K-Ar age 440 m.y.

K 7.24%, Ar^{40}/K^{40} .02906; radiogenic argon 100%. Concentrate; consists of mostly clean brown biotite containing rare inclusions of apatite. About 5% of the flakes are altered to chlorite and epidote along the edges. About 5% pale green hornblende is present as an impurity. Total chlorite content is about 5%.

Newfoundland

(2 E) From biotite granite.
Western head of Little Burnt Bay, Exploits Bay; 49°21'39"N, 55°5'26"W. Map-unit 17, GSC Paper 62-9. Sample WF-708. Collected and interpreted by H. Williams.

(For interpretation see determination GSC 62-188).

GSC 62-188 Biotite, K-Ar age 423 m.y.

K 7.30%, Ar^{40}/K^{40} .0277; radiogenic argon 100%. Concentrate; biotite varies from olive to reddish brown and contains numerous inclusions of quartz, acicular crystals and small, brown, roughly hexagonal plates, a few prisms of rutile and rare zircons. A few flakes are partly chloritized. Chlorite content is about 4%.

(2 E) From biotite gneiss.
9,000 feet south from mouth of Jumper Brook; 49°0'30"N, 55°24'20"W. Map-units 16 and 17, GSC Paper 62-9. Sample WF-689. Collected and interpreted by H. Williams.

The biotite used for the age determination (GSC 62-188) was collected from medium-grained thermally metamorphosed sedimentary rocks of the Botwood Group. The date of 423 m.y. indicates the time of intrusion and accompanying thermal metamorphism of the Botwood sedimentary rocks. Recent fossil evidence and field mapping indicates that the Botwood Group is of Silurian age. The fact that the rocks were intruded and thermally metamorphosed in generally Middle Silurian time (423 m.y.) combines to eliminate the earlier Devonian age assignment. Intrusive rocks in this part of Newfoundland were considered to have been emplaced during Acadian orogeny (Devonian). The present age indicates that at least some of the intrusions are dated within the Silurian.

A similar age of 440 m.y. (GSC 62-187) was obtained on biotite collected from a nearby granodiorite intrusion which cuts Middle Ordovician rocks (Exploits Group). Geological interpretation suggests that the granodiorite is also younger than Silurian rocks of the Botwood Group. The similarity in age of the granodiorite (440 m.y.) and of intrusive rocks that definitely cut the Silurian Botwood Group (423 m.y.) suggests a single period of intrusion in Silurian time. The date of 440 m.y. falls within the Silurian if the limit of analytical error (± 30 m.y.) is subtracted.

Newfoundland

GSC 62-189 Biotite, K-Ar age 382 m.y.

K 6.80%, Ar^{40}/K^{40} .0248; radiogenic argon 100%. Concentrate; consists mainly of brown biotite with about 5-10% greenish chloritized flakes. About 30% of the flakes have platy inclusions of red hematite and rare prisms of apatite and zircon. Chlorite/biotite 0.05.

From granite.
(1 M) 1 mile south of Long Island, Placentia Bay; 47°34'30"N, 54°43'W. Map-unit 4, GSC Map 1043A. Sample AA 14-64-1. Collected and interpreted by F.D. Anderson.

The sample was taken from an outcrop on Iron Island about 1 mile south of Long Island in Placentia Bay. About 6 miles to the southwest, on Red Island, this granite intruded, and thermally metamorphosed, Middle Cambrian sediments. The K-Ar date suggests that the granite is Devonian in age, and thus represents the most easterly Devonian age date in the Appalachian region. The age also strengthens the hypothesis that the Precambrian strata of the Avalon Peninsula were deformed during the Acadian orogeny.

GSC 62-190 Biotite, K-Ar age 392 m.y.

K 7.50%, Ar^{40}/K^{40} .0255; radiogenic argon 100%. Concentrate; the biotite varies from brown to greenish. Some flakes contain inclusions along fractures and around edges. About 30% of the flakes contain red, platy, partly colloform inclusions of iron oxide or hydroxide. The chlorite content is less than 2%.

From granite.
(1 M) 1 mile northeast of the Dunns Brook - Burin Road Bridge; 47°45'N, 54°33'W. Map-unit 4, GSC Map 1043A. Sample AA 6-135-1. Collected and interpreted by F.D. Anderson.

The sample is from the southeastern margin of the Ackley Granite. The date of 392 m.y. agrees reasonably well with the date of 368 m.y. (GSC 60-150) obtained from the northwestern margin of the batholith.

K-AR AGE MEASUREMENTS ON BIOTITE-MUSCOVITE PAIRS

By R. K. Wanless and J. A. Lowdon

Age measurements have been carried out, wherever possible, on mineral pairs separated from the same rock specimen. (For previously reported results see Lowdon, 1961, and Lowdon et al., 1963.)

The results obtained for an additional twenty-six biotite-muscovite pairs are summarized in the accompanying table. Details for each sample and a discussion of the results are given in the foregoing section or earlier reports.

The calculated ages for the first sixteen pairs are in agreement within the limits of experimental error. For the remaining ten pairs, however, the difference between the ages varies from 11.5 per cent to 38 per cent. In nine of these (pairs 17 to 25) the biotite age is less than the muscovite age and in one (pair 26) it is greater.

So far, fifty-nine biotite-muscovite pairs have been studied. Thirty-five of them yielded concordant ages for the two minerals; in seventeen, biotite gave the lesser age; and in seven, biotite gave the greater.

This work is expected to continue.

Sample Pair	Sample Number*	Mineral	% K	% Chlorite	Age (m.y.)	% Difference
1	GSC 62-44	Biotite	7.82	9	70	+7.7
	GSC 62-45	Muscovite	8.64	0	65	
2	GSC 62-49	Biotite	7.17	2	73	+1.4
	GSC 62-50	Muscovite	7.68	Less than 1.0	72	
3	GSC 62-11	Biotite	8.01	0	86	-5.5
	GSC 62-10	Muscovite	8.03	1	91	
4	GSC 62-20	Biotite	7.36	7	92	+1.1
	GSC 62-21	Muscovite	8.30	0	91	
5	GSC 62-51	Biotite	7.50	Less than 1.0	119	-4.0
	GSC 62-52	Muscovite	8.74	0	124	
6	GSC 62-17	Biotite	8.10	5	132	-4.3
	GSC 62-18	Muscovite	8.83	Less than 1.0	138	
7	GSC 62-65	Biotite	7.05	Less than 2.0	143	+5.1
	GSC 62-66	Muscovite	8.51	0	136	
8	GSC 62-168	Biotite	7.58	4	360	-6.0
	GSC 62-169	Muscovite	8.72	0	383	
9	GSC 62-164	Biotite	7.34	0	400	-2.4
	GSC 62-163	Muscovite	8.30	0	410	
10	GSC 61-188	Biotite	7.73	0	411	-1.4
	GSC 62-155	Muscovite	6.20	3	417	
11	GSC 62-140	Biotite	8.54	0	920	-2.6
	GSC 62-141	Muscovite	9.15	Less than 1.0	945	
12	GSC 62-151	Biotite	7.91	0	950	-3.1
	GSC 62-152	Muscovite	5.96	3	980	
13	GSC 62-183	Biotite	6.82	4	1,035	+3.0
	GSC 62-184	Muscovite	6.90	0	1,005	
14	GSC 62-148	Biotite	7.82	6	1,050	+4.0
	GSC 62-149	Muscovite	9.17	0	1,010	
15	GSC 62-173	Biotite	8.07	2	1,615	-1.8
	GSC 62-174	Muscovite	6.86	2	1,645	
16	GSC 60-42	Biotite	7.02	18	1,725	-6.3
	GSC 62-89	Muscovite	8.14	0	1,840	

Sample Pair	Sample Number*	Mineral	% K	% Chlorite	Age (m.y.)	% Difference
17	GSC 62-33	Biotite	7.60	7	66	-27
	GSC 62-34	Muscovite	8.99	0	90	
18	GSC 62-69	Biotite	7.96	0	123	-11.5
	GSC 62-68	Muscovite	8.72	0	139	
19	GSC 62-72	Biotite	7.68	7	124	-36
	GSC 62-73	Muscovite	8.21	0	194	
20	GSC 62-53	Biotite	7.13	10	146	-29
	GSC 62-54	Muscovite	6.02	10	205	
21	GSC 62-40	Biotite	7.37	3	221	-19
	GSC 62-42	Muscovite	8.27	1	398	
22	GSC 60-77	Biotite	7.86	3	1,650	-38
	GSC 62-99	Muscovite	8.69	1	2,670	
23	GSC 62-153	Biotite	7.75	4	1,815	-22
	GSC 62-154	Muscovite	8.04	0	2,340	
24	GSC 62-90	Biotite	6.68	15	1,800	-27
	GSC 60-47	Muscovite	8.87	0	2,460	
25	GSC 60-46	Biotite	6.68	13	1,900	-21
	GSC 62-91	Muscovite	7.10	2	2,400	
26	GSC 62-146	Biotite	7.64	5	1,315	+24
	GSC 62-147	Muscovite	8.46	0	1,060	

*"GSC 60-.." numbers are from Lowdon (1961).
"GSC 61-.." numbers are from Lowdon et al. (1963).
"GSC 62-.." numbers are from this report.

PART II

GEOLOGICAL STUDIES

THIRD REPORT ON STRUCTURAL PROVINCES, OROGENIES, AND TIME-CLASSIFICATION OF ROCKS OF THE CANADIAN PRECAMBRIAN SHIELD

by C. H. Stockwell

The first and second reports (Stockwell, 1961, 1963) covered results up to the end of 1961 when about 310 potassium-argon age determinations on micas from the Canadian Shield had been completed in the laboratories of the Geological Survey of Canada. This report adds the results of an additional 65 determinations made since that time. The new dates help to fill in large gaps in the Shield and have contributed toward the solution of special problems which came to light during the reconnaissance study; the Grenville front has now been extended eastward to the Atlantic Ocean, a new structural province has been added in Labrador, and several additional stratigraphic units have been placed in the time-stratigraphic classification.

In a short paper entitled "A Tectonic Map of the Canadian Shield" (Stockwell, 1962), accompanied by a much generalized sketch map, rocks were mapped according to the age of the orogeny in which they were involved and virtually undeformed rocks were distinguished from those that are folded. A much more detailed tectonic map of Canada is being prepared for publication on the scale of 1:5,000,000.

Structural Provinces

No major changes have been made in the boundaries of the structural provinces shown in Figure 2 of the previous report (Stockwell, 1963) but the boundary of the western extension of the Superior province in basement rocks beneath the Palaeozoic cover of the Interior Plains can now be approximately shown (Figure 2, this report). This boundary is based largely on the work of Burwash, Baadsgaard and Peterman (1962) who obtained potassium-argon dates on core samples from deep drilling. The writer has extended the boundary easterly to join with the south boundary of the Superior province in Minnesota. This suggests that, in the basement beneath the plains, the Churchill province joins with the Southern province, both of which have been effected by the Hudsonian orogeny. As only the ages determined by the Geological Survey of Canada are shown in Figure 2, the reader is referred to Burwash, Baadsgaard and Peterman (1962) for dates beneath the plains and to Goldich et al. (1961) for those in Minnesota.

A new structural province has been roughly outlined in the Labrador part of Newfoundland and the adjacent part of Quebec. This is called the "Nain structural province", after a settlement of that name on the coast of Labrador. The Nain province is bounded on the west by the Churchill province and on the south by the Grenville province. The boundary between the Nain and the Churchill can be shown only rather roughly because large parts have not been geologically mapped. There appears, however, to be a distinct difference between the two regions not only geologically and structurally but also in their potassium-argon ages. The Churchill between the Nain and the Labrador trough, appears to be largely underlain by a rather monotonous assemblage of sedimentary and igneous gneisses with bodies of granite. The Nain province is more complex. Although it likewise contains much gneiss and granite, many of the rocks are charnokitic and are associated with large and small bodies of anorthosite, gabbro, syenite and alkaline intrusions. The geological history of the area seems to be complex and this is reflected in the variability of potassium-argon ages which range from 1,175 m.y. to 2,430 m.y. without any apparent overall systematic pattern. By contrast the dates in the adjacent part of the Churchill province are much more consistent, ranging only from 1,575 m.y. to 1,775 m.y. Structures within the Nain province probably trend mainly north as does its western boundary which forms an acute angle with the strike of the Labrador trough. Two small areas within the Nain province comprise gently to moderately dipping unmetamorphosed sedimentary and volcanic rocks of the Ramah and Mugford Formations which lie with marked angular unconformity on the gneisses and granitic rocks. (For detailed description see Christie, 1952.)

The north boundary of the Grenville province trends northeast from Lake Huron to the Atlantic Ocean, a distance of 1,160 miles, crosscutting on its way the easterly trending structures of the Southern and Superior provinces, the southeast trend of the Churchill province and the southerly trending structure of the Nain province. Three subprovinces of the Grenville are shown in Figure 2—the Melville, the Normanville, and the Naskaupi. The Melville, as stated in previous reports, consists of a cratonic cover of flat-lying sediments unconformably overlying gneisses. The Normanville fold belt is the continuation of the Labrador trough into the Grenville province. The name is derived from Normanville township in which the iron ores of Mount Wright lie. Structures in this subprovince are exceedingly complex due to folds formed during the Grenville orogeny having been superimposed over those formed during the Hudsonian. The Naskaupi fold belt is named after the river of that name and comprises the Seal and Croteau Groups of sedimentary and volcanic rocks intruded by sills of gabbro (for details see GSC Map 1079A). These groups lie unconformably on gneisses, granite, and anorthosite of the Nain province and are mostly folded along easterly trending axes, but the rocks in the northwest part of the subprovince form a gentle south-dipping homocline. As a rule the rocks are only slightly metamorphosed, but toward the south, as the main part of the Grenville province is approached, they were converted to schists during the Grenville orogeny. The Grenville front is taken to lie along the south boundary of the subprovince where the schists are followed by gneisses and granitic rocks. Farther east the boundary between the Nain province and the Grenville province is drawn along the contact between the Hopedale Gneiss to the north and the Domino Gneiss to the south, which have been described and mapped by Kranck (1953).

Orogenies

In last year's report (Stockwell, 1963, p. 125) it was pointed out that large parts of the Churchill province may have been involved in two orogenies—the Kenoran, followed by the Hudsonian. Also it was pointed out that certain areas of the province appear to have escaped complete reworking so that some older dates, from 1,900 to 2,460 m.y., have survived. This concept has since received confirmation in the finding of two additional Kenoran dates, both on muscovite; one at 2,420 m.y. (Burwash and Baadsgaard, 1962) and the other at 2,670 m.y. (GSC 62-99). In both of these examples an overriding, moderate effect of the Hudsonian is indicated by dates of 1,800 m.y. on biotite and sericite in the one case and 1,650 m.y. on biotite in the other. Similarly, Beall (1961) found a whole rock rubidium-strontium age of 2,510 m.y. in rocks of the Churchill province east of the Labrador trough where biotites nearby gave Hudsonian dates of 1,590 to 1,720 m.y. (Beall, Sauve, and staff, 1960). The Churchill province, of course, also contains Lower Proterozoic rocks and some of these, such as the Nonacho, seem to pass into gneisses that are difficult to distinguish from the Archaean gneisses of the province.

The orogenic history of the Nain province is too complex to be determined on the available meagre data. As shown in the histogram of Figure 3, most of the dates are spread through the early and middle parts of Middle Proterozoic time, suggesting the presence of an orogeny not definitely recognized elsewhere in the Canadian Shield; it is not yet well enough defined to be given a distinctive name or to be correlated with other orogenies of about the same age elsewhere. Some ages as old as the Kenoran have also been found in the Nain province as if certain parts of the region had escaped the effects of the younger metamorphism and intrusions. The Kenoran dates suggest that much of the terrain between the Labrador trough and the Atlantic may be Archaean that has been largely overridden by the Hudsonian near the trough and by a still younger orogeny in the Nain province. The presence of Archaean dates as far east as the Atlantic coast argues against continental growth in this area.

The Grenville province, like the Churchill, is known to contain rocks of widely different ages and orogenic history; all are overridden by the Grenville orogeny. As a rule it is difficult to trace the rocks from the Southern, Superior, Churchill, and Nain provinces into the Grenville because of their common transformation into gneisses. One quite well established example, however, is the Normanville subprovince. These rocks are the stratigraphic equivalent of the Lower Proterozoic rocks of the Labrador trough and have been traced into the Grenville province for a distance of about 230 miles. They have been largely converted into gneisses and the structure is very complex due to the superposition of Grenville structures over those of the Hudsonian.

In the southwestern part of the Grenville province of Quebec, Osborne and Morin (1962) have recognized that metamorphosed equivalents of Archaean sediments of the Superior province extend for many miles into the Grenville province, and they conclude that the Grenville Series is probably Archaean. These authors are the first geologists to attempt a large-scale subdivision of the Grenville province. They have divided the southwestern part into two main tectonic-lithologic units, with the dividing line extending south-southeasterly from the Mistassini subprovince to the Quebec border some miles northwest of Ottawa. In their subprovince west of the dividing line the gneisses were involved in superimposed periods of folding, the last trending northeast. In the other subprovince the structures, at least in the southwestern part, trend north, many of the intrusive rocks are charnokitic and the terrain contains numerous bodies of anorthosite. The similarity between this association and that of the Nain province is rather striking and one has only to glance at the geological map of Canada (GSC Map 1045A) to see that the belt of anorthosites extends through both provinces. Accordingly there is as yet no good evidence to show that an extensive period of sedimentation immediately preceded the Grenville orogeny but, rather, that much of the province is made up of rocks that had previously been involved in older periods of mountain building.

Stratigraphic Classification

Potassium-argon age determinations on micas have made it possible to place two additional formations in the Archaean (the Seine and the Sickle), one in the Lower Proterozoic (the Nonacho), and one in the Middle Proterozoic (the Athabasca) (see Figure 3). By means of bracketing formations between maximum and minimum limits, many of the more important stratigraphic units of the Canadian Shield have now been reasonably well placed within one or the other of the four main divisions of the time-stratigraphic scale. The potassium-argon method, however, has not been successful in dating subdivisions of the Archaean, but it is hoped that the rubidium-strontium method, which is now being used by the Geological Survey, will be helpful in penetrating deeper into Archaean history. This method may also prove useful in solving difficult stratigraphic problems in the Churchill, Nain, and Grenville provinces where the rocks have gone through two or even three periods of deformation.

Problems of Interpretation of Potassium-Argon Ages

Further study has been given to the previously stated hypothesis that, under certain conditions of metamorphism or heating, muscovite gives a more reliable age than biotite; biotite dates may be either younger or older than virtually coeval muscovite and it was suggested that the discrepancy was due to loss of argon from biotite in the one case and addition of argon to biotite in the other, the muscovite in both cases retaining an age that is geologically more reasonable.

The loss of argon from biotite and its retention by muscovite is illustrated by new determinations on two biotite-muscovite pairs from the Slave province, close to the boundary of the Bear province. In one of these pairs, biotite gave 1,900 m.y. (GSC 60-46) and muscovite 2,400 m.y. (GSC 62-91); in the other, biotite gave 1,800 m.y. (GSC 62-90) and muscovite 2,460 m.y. (GSC 60-47). That is to say, muscovite retained the Kenoran age under conditions where mild effects of the Hudsonian orogeny showed in the biotite. Another pair, well within the Bear province, gave the expected agreement between biotite at 1,725 m.y. (GSC 60-42) and muscovite at 1,840 m.y. (GSC 62-89).

At another locality, this one in the Churchill province, the retention of argon is illustrated by an Archaean age of 2,420 m.y. on muscovite from a pegmatite boulder in Nonacho conglomerate, while the overriding metamorphism gave the usual Hudsonian age of around 1,800 m.y. on biotite (Burwash and Baadsgaard, 1962). In another example, also in the Churchill province, muscovite from a metamorphosed equivalent of the Sickle Group gave the Kenoran age of 2,670 m.y. (GSC 62-99) while biotite from the same sample gave the overprint of the Hudsonian at 1,650 m.y. (GSC 60-77).

New examples in which the potassium-argon date obtained on biotite is older than that on muscovite are given below. The discrepancies are probably due to the additions of argon to biotite, the muscovite in each case being unaffected and giving, on geological evidence, the age that is more nearly correct. In this connection, a few additional dates have now been obtained at the Chibougamau highway locality across the Grenville front and these, together with those reported previously, may be summarized as follows. Muscovites on the Grenville side of the front gave close to the expected ages for the Grenville orogeny (1,060, 1,010, and 960 m.y.) but the biotite dates are too old (1,315, 1,050, 1,270, and 1,105). In passing over to the Superior side of the front the reverse relationship is found where muscovite gives the expected old age (2,340 m.y.) but the biotite dates are too young (1,815 and 1,840 m.y.). The old biotite dates on the Grenville side are evidently related to local conditions close to the front because, in the Grenville province generally, the biotite dates are normally some 30 to 40 m.y. younger than those on muscovite.

Any explanation offered to account for the abnormally old biotite dates has to take into account the well-established fact that argon can be lost from biotite under rather moderate conditions of metamorphism or heating but, on the Grenville side, has not been driven off even though the rocks have been highly metamorphosed. The explanation offered is that argon, which was lost from old biotite on the Superior side of the front (due to heat from the Grenville orogeny), migrated down the concentration gradient and was added to the younger biotite on the Grenville side. The distance through which the argon travelled was in the order of 5 to 10 miles and the time available for the migration to take place may have been in the order of 30 to 40 m.y. (For further details of this locality see discussion under GSC 62-147.) Similar results were reported previously from elsewhere along the Grenville front (Stockwell 1963, pp. 132-133).

The conclusion that argon can be added to biotite receives support from a most surprisingly old date of 3,730 m.y. obtained on biotite from another locality in the Grenville province close to the Grenville front (GSC 62-176). On the same sample of biotite a rubidium-strontium determination gave 900 m.y., which is the age of the Grenville orogeny, as expected. It is therefore difficult to believe that the very old date represents the time of crystallization of the biotite and it seems necessary to appeal to the addition of argon for a satisfactory explanation.

Addition of argon is also offered as a plausible explanation for the anomalously old date of 241 m.y. obtained on a whole rock sample of diabase cutting Lower Cretaceous strata (GSC 62-87); the age should have been younger than 110 m.y. according to Kulp's time scale reproduced in this paper. It appears that heat from the diabase magma drove off argon from the country rock and the released argon entered into the diabase.

The biotite-muscovite pairs dated by the Geological Survey have been plotted in Figure 4 for the purpose of giving a comprehensive picture of the normal and discrepant relationships previously discussed. It is apparent that, with four exceptions, the muscovite ages consistently fall into three groups corresponding with the three main orogenies. The muscovites of the Kenoran are all from the Superior and Slave provinces, except one which is from the Churchill; those of the Hudsonian are all from the Churchill and Bear provinces, except one which is from the Superior; those of the Grenville orogeny are all from the Grenville province. Not agreeing with the general pattern is a group of three pairs intermediate between the Kenoran and Hudsonian. These are from the central and northern parts of the Slave province where ages in general are rather erratic, suggesting two possibilities— either that they represent another orogeny, or that they are Kenoran reworked by the Hudsonian to such severity that even the muscovite lost part of its argon.

The biotite dates of the pairs of Figure 4 are more erratic than those on muscovite. Many, however, are in essential agreement with the associated muscovite and if a more representative sampling of the Shield had been made a much larger proportion would undoubtedly be in agreement. As it is, the sampling was concentrated in problem areas and the diagram therefore shows a disproportionately large number of discrepant pairs. Confining our attention to those pairs showing marked discrepancies well beyond the analytical error, it is noticeable that the five biotites associated with Kenoran muscovites all give much younger dates; they fall in the Hudsonian and, as previously stated, are thought to indicate a weak overprint on the Kenoran, not strong enough to affect the muscovite. In the Grenville the markedly discrepant biotite dates are all older than the muscovites. This relationship, as previously explained, may be due to addition of argon to biotite, the argon having been derived from nearby rocks of the Kenoran.

Relationships on both sides of contacts between the Kenoran and Hudsonian and between the Hudsonian and Grenville require further study. If the present indications are further substantiated it might be a general rule that biotite dates in such contact zones will tend toward a common level due to argon transfer from older to younger biotites. If this is a general rule it could account for the essential agreement in potassium-argon dates over huge areas of the Shield where rocks obviously differ, at least somewhat, in age. The rule would be difficult to test in these regions, however, for the differences in actual age, if small, would be masked by the analytical error.

The study of biotite-muscovite pairs is being continued as it has proven useful both in throwing light on the interpretation of potassium-argon ages and also in revealing mild metamorphic conditions not evident in the field.

AGES OF REGIONAL METAMORPHISM OF THE ALDRIDGE FORMATION NEAR KIMBERLEY, B.C. (PRELIMINARY REPORT)

by G. B. Leech

Regional metamorphism in this district was long ascribed mainly to Mesozoic orogeny, to which all granitic intrusions were attributed, and the unconformities beneath formations of Middle or Upper Devonian age and Windermere (Precambrian) age in the Purcell Mountains were thought to reflect disturbances that contributed relatively little to the present state of regional metamorphism. K-Ar age determinations have corroborated the Mesozoic age of major intrusions (see GSC 61-11 and Reesor in Part I of this paper) but they have also proven the existence of Precambrian granitic intrusions (see Figure 5) and locally intense metamorphism of probably pre-Windermere age, and have indicated the importance of Precambrian tectonism (Leech, 1962).

The K-Ar determinations to be discussed now are on micas from rocks typical of the state of regional metamorphism of the Aldridge Formation of the Purcell sedimentary sequence, which is unconformably beneath the Windermere sequence. These K-Ar ages are considered to be hybrid and to reflect more than one geological episode. They are interpreted to mean that Precambrian regional metamorphism is an important contributor to the metamorphic grade of the Purcell sequence and that Mesozoic metamorphism is correspondingly less important than has commonly been supposed.

The analyzed micas (GSC 62-42, GSC 62-40, and GSC 62-41) are from quartzite and argillite (see Figure 5) collected 13 miles southwest of Kimberley, B. C. They are from a part of the Aldridge Formation (Map-unit 2 of GSC Map 15-1957) consisting dominantly of fine-grained quartzite, but with argillite as interbeds and in the tops of some of the quartzite beds. The strata are only mildly deformed into open folds. The argillites show more deformation than the quartzites because interbed slip was concentrated in them and there is more cleavage, though it is by no means intense. Regional metamorphism of the greenschist facies has obscured details of the original sedimentary texture but has preserved the original sedimentary structures. The detrital shapes of the quartz grains were destroyed by recrystallization and new growth and the clay minerals have given way to micas and albitic feldspar. The original laminae of sand and mud are however distinctly represented by relatively quartz-rich and mica-rich layers.

In cleaved argillite most of the larger mica crystals are parallel or subparallel with cleavage. The attitudes of the smaller grains are more varied but, in rock from the limbs of a fold, more of the fine-grained mica is subparallel with cleavage or bedding than with other directions. Specimens from crests of folds have not been examined. Muscovite is in general more nearly euhedral than biotite,

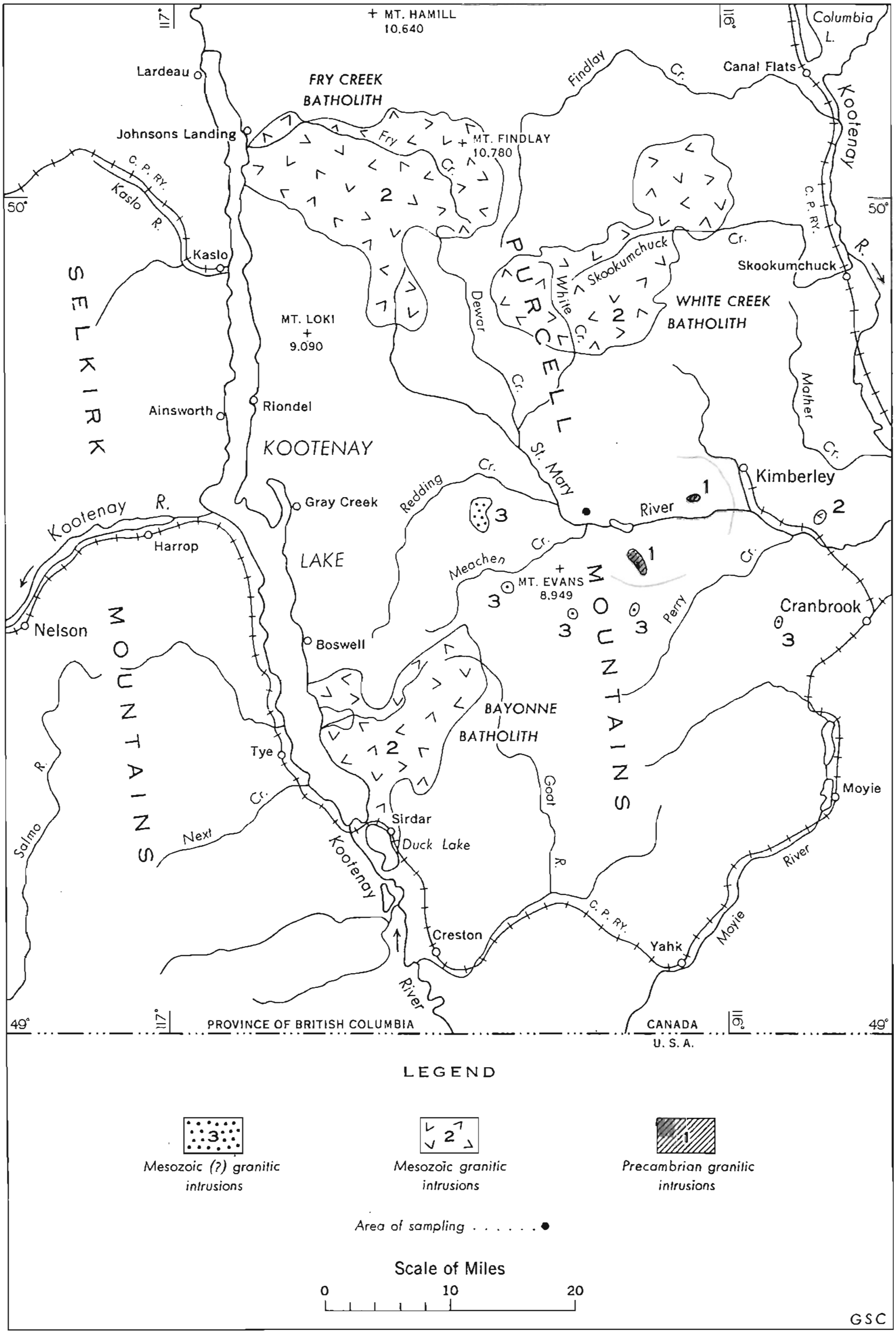

Figure 5. Relation of locality sampled to Mesozoic and Precambrian intrusions

and boundaries of the latter appear commonly to be governed by those of muscovite and quartz. Two kinds of biotite are present in argillite: the major kind occurs throughout the rock and by variations in its amount helps to delineate the primary sedimentary lamination; the minor type is red-brown, forms large irregular poikiloblastic flakes or aggregates, and is more commonly parallel to cleavage. In uncleaved quartzite the micas lack an obvious preferred orientation and the interstitial position of biotite is particularly evident.

Analyses GSC 62-42 (398 m.y.) and GSC 62-40 (221 m.y.) represent muscovite and biotite respectively from the same sample of quartzite, and GSC 62-41 (555 m.y.) represents muscovite from argillite[1] interbedded with this quartzite. The samples are typical of the regional metamorphic state of the strata where there is no evidence of local granitic intrusions. The K-Ar ages span the Palaeozoic era but, though there is abundant regional evidence for Mesozoic orogeny and increasing evidence for Precambrian orogeny, the present data suggest that Palaeozoic tectonism, probably chiefly middle or late Palaeozoic, was milder here. The K-Ar ages are therefore interpreted as hybrid, reflecting Mesozoic and older events and indicating that Mesozoic orogeny was not intense enough to reconstitute earlier micas completely or to produce enough new micas to swamp them.

Further interpretation depends upon assessing the contributions from the three most likely sources: detrital mica, mica formed during Precambrian metamorphism, and mica formed during Mesozoic metamorphism. Detrital mica would probably be from a Shield terrane and be a relatively more potent contributor to a hybrid age than autochthonous Precambrian metamorphic mica, whose most likely age is only 700-1,000 m.y.; the St. Mary Lake granitic intrusions and their metamorphic aureoles in this region yielded minimal muscovite ages of about 700-800 m.y. (Leech, 1962). A gabbroic sill 25 miles to the south yielded amphibole with a K-Ar age of 1,580 m.y. (K content 0.25 per cent) but biotite K-Ar ages of only 844 and 835 m.y. (Hunt, 1962) which Hunt ascribed to regional metamorphism at the time of intrusion of the St. Mary Lake granite.

The importance of detrital mica is difficult to assess, because the shapes of detrital and metamorphic flakes can be similar and both can lie parallel with bedding. Good evidence for the metamorphic origin of many grains can be found, e.g. orientation in cleavage planes and irregular 'interstitial' grain outlines, but, in the absence of comparable distinctive criteria, negative evidence for detrital origin is inconclusive, especially in a rock whose original texture is masked by metamorphism. Parallelism with bedding is not by itself a safe criterion for detrital origin of mica.

Detrital muscovite might have been stable enough to survive the greenschist metamorphic regime with only enough

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[1]A K-Ar age of 209 m.y. on biotite from this argillite was received after this manuscript was submitted.

modification to mask its origin, perhaps surviving as nuclei for the growth of metamorphic muscovite. Detrital biotite, on the other hand, is less likely to have survived metamorphism and is less likely to have been present in the first place because it is relatively unstable under the probable conditions of erosion and deposition responsible for the Aldridge Formation. Detrital mica would probably have come to rest in relatively greater amounts in muddy beds than in sandy beds, so that, if any detrital mica survived to yield a component to a K-Ar age, the effect would be chiefly on the age of muscovite from argillite.

In the absence of recognized positive evidence for detrital mica and in consideration of regional evidence of a Precambrian orogeny that involved the Aldridge Formation, the writer concludes that detrital mica is probably the lesser of the Precambrian contributors to the K-Ar ages and that its main effect is on the age of muscovite from argillite. The oldest K-Ar age, 555 m.y. (GSC 62-41), is in fact on muscovite from argillite.

The biotite in quartzite provides evidence of the relative importance of Precambrian and Mesozoic metamorphisms. The contribution by detrital biotite to the K-Ar age of 221 m.y. (GSC 62-40) is judged to be insignificant, because biotite was probably at best a minor component of the original sand, certainly far less than the biotite content of the present quartzite, and because the texture of the biotite is distinctly metamorphic, with anhedral grains. The 221 m.y. age (Palaeozoic-Mesozoic boundary) must therefore almost entirely reflect periods of metamorphism. It is interpreted as essentially a hybrid of Precambrian and Mesozoic regional metamorphisms[*] because evidence for a comparable Palaeozoic orogeny in the region has not yet been recognized. Precambrian metamorphic biotite must have existed in amounts that Mesozoic metamorphism could not overwhelm or obliterate.

The 398 m.y. K-Ar age of muscovite from quartzite (GSC 62-42) is contrastingly greater than the 221 m.y. age of biotite from the same sample. The greater K-Ar age of muscovite is probably due to a combination of the following factors: the greater stability of Precambrian metamorphic muscovite during Mesozoic metamorphism; the relatively lesser production of new muscovite, as compared to biotite, during Mesozoic metamorphism; and, possibly, the presence of detrital muscovite. This again leads to the inference that the intensity of Precambrian metamorphism may have been comparable to that of Mesozoic metamorphism.

REFERENCES

Alcock, F. J.
1948: Campobello, New Brunswick; Geol. Surv., Canada, Map 964A.

Baadsgaard, H., Folinsbee, R. E., and Lipson, J.
1959: Potassium-Argon Age of Biotites from Cordilleran Granites of Central British Columbia; Bull. Geol. Soc. Amer., vol. 70, p. 1564.

1961: Potassium-Argon Dates of Biotites from Cordilleran Granites; Bull. Geol. Soc. Amer., vol. 72, No. 5, pp. 689-702.

Beall, G.H., and staff
1961: Age Investigations in Ungava, New Quebec; N.Y.O. 3942, Ninth Ann. Prog. Rept. for 1961, Dept. Geol. Geophys., Mass. Inst. Technol., pp. 193-199.

Beall, G.H., Sauve, P., and staff
1960: Age Investigations in New Quebec and Labrador; N.Y.O. 3941, Eighth Ann. Prog. Rept. for 1960, Dept. Geol. Geophys., Mass. Inst. Technol., pp. 245-253.

Burwash, R.A., and Baadsgaard, H.
1962: "Yellowknife-Nonacho Age and Structural Relations" in The Tectonics of the Canadian Shield; Roy. Soc. Canada, Spec. Pub. No. 4, pp. 22-29.

Burwash, R.A., Baadsgaard, H., and Peterman, Z.E.
1962: Precambrian K-Ar Dates from the Western Canada Sedimentary Basin; J. Geophys. Research., vol. 67, No. 4, pp. 1617-1625.

Camsell, C.
1913: Geology and Mineral Deposits of the Tulameen District, British Columbia; Geol. Surv., Canada, Mem. 26.

Christie, A.M.
1952: Geology of the Northern Coast of Labrador, from Grenfell Sound to Port Manvers, Newfoundland; Geol. Surv., Canada, Paper 52-22.

Cooke, H.C.
1950: Geology of a Southwestern Part of the Eastern Townships of Quebec; Geol. Surv., Canada, Mem. 257, pp. 100-102.

Crosby, Percy
1960: Structure and Petrology of the Central Kootenay Lake Area, B.C.; Harvard Univ., unpub. Ph.D. thesis.

Dresser, J.A., and Denis, T.C.
1944: Geology of Quebec, vol. 2, Descriptive Geology; Que. Dept. Mines, Geol. Rept. 20, pp. 428-429.

Fairbairn, H.W., Hurley, P.M., and Pinson, W.H.
1960: Mineral and Rock Ages at Sudbury-Blind River, Ontario; N.Y.O. 3941, Eighth Ann. Prog. Rept. for 1960, Dept. Geol. Geophys., Mass. Inst. Technol., pp. 7-42.

Fairbairn, H.W., Hurley, P.M., Pinson, W.H., and Cormier, R.F.
1960: Age of the Granitic Rocks of Nova Scotia; Bull. Geol. Soc. Amer., vol. 71, April, pp. 399-414.

Faribault, E.R., Armstrong, P., and Wilson, J.T.
1939: Sherbrooke Lake, Nova Scotia; Geol. Surv., Canada, Map 531A.

Goldich, S.S., Nier, A.O., Baadsgaard, H., Hoffman, J.H., and Krueger, H.W.
1961: The Precambrian Geology and Geochronology of Minnesota; Univ. Minnesota, Minnesota Geol. Surv., Bull. 41.

Green, L.H., and Roddick, J.A.
1962: Dawson, Larsen Creek, and Nash Creek Map-areas, Yukon Territory; Geol. Surv., Canada, Paper 62-7.

Holmes, A.
1959: A Revised Geological Time-Scale; Trans. Edinburgh Geol. Soc., vol. 17, pt. 3, pp. 183-216.

Hunt, G.
1962: Time of Purcell Eruption in Southeastern British Columbia and Southwestern Alberta; J. Alta. Soc. Petrol. Geol., vol. 10, pp. 438-442.

Hurley, P.M.
1960: Summary of Potassium-Argon Ages from the Monteregian Hills, Quebec; N.Y.O. 3941, Eighth Ann. Prog. Rept. for 1960, Dept. Geol. Geophys., Mass. Inst. Technol., p. 283.

Hurley, P.M. et al.
1958: N.Y.O. 3939, Sixth Ann. Rept. for 1958, Dept. Geol. Geophys., Mass. Inst. Technol., p. 129.

Jones, A.G.
1959: Vernon Map-area, British Columbia; Geol. Surv., Canada, Mem. 296.

Kranck, E.H.
1953: Bedrock Geology of the Seaboard of Labrador between Domino Run and Hopedale, Newfoundland; Geol. Surv., Canada, Bull. 26.

Kulp, L.J.
1961: Geologic Time Scale; Science, vol. 133, No. 3459, pp. 1105-1114.

Lawson, A.C.
1913: The Archaean Geology of Rainy Lake Re-Studied; Geol. Surv., Canada, Mem. 40.

Leech, G.B.
1962: Metamorphism and Granitic Intrusions of Precambrian Age in Southeastern British Columbia; Geol. Surv., Canada, Paper 62-13.

Little, H.W
1960: Nelson Map-area, West Half, British Columbia; Geol. Surv., Canada, Mem. 308.

Lord, C.S.
1942: Snare River and Ingray Lake Map-areas, Northwest Territories; Geol. Surv., Canada, Mem. 235.

Lowdon, J.A. (comp.)
1960: Age Determinations by the Geological Survey of Canada, Report I—Isotopic Ages; Geol. Surv., Canada, Paper 60-17.

1961: Age Determinations by the Geological Survey of Canada, Report 2—Isotopic Ages; Geol. Surv., Canada, Paper 61-17.

Lowdon, J.A., Stockwell, C.H., Tipper, H.W., and Wanless, R.K.
1963: Age Determinations and Geological Studies (Including Isotopic Ages—Report 3); Geol. Surv., Canada, Paper 62-17.

Neale, E.R.W., Beland, J., Potter, R.R., and Poole, W.H.
1961: A Preliminary Tectonic Map of the Canadian Appalachian Region Based on Age of Folding; Bull. Can. Inst. Mining Met., vol. 54, No. 593, pp. 687-694.

Osborne, F.F., and Morin, M.
1962: "Tectonics of Part of the Grenville Subprovince in Quebec" in The Tectonics of the Canadian Shield; Roy. Soc. Canada, Spec. Pub. No. 4, pp. 118-143.

Quirke, T.T., and Collins, W.H.
1930: The Disappearance of the Huronian; Geol. Surv., Canada, Mem. 160.

Reesor, J.E.
1957: Lardeau Map-area, British Columbia; Geol. Surv., Canada, Prel. Map 12-1956.

1958: Dewar Creek Map-area, with Special Emphasis on the White Creek Batholith, British Columbia; Geol. Surv., Canada, Mem. 292.

Rice, H.M.A.
1941: Nelson Map-area, East-Half, British Columbia; Geol. Surv., Canada, Mem. 228.

1947: Geology and Mineral Deposits of the Princeton Map-area, British Columbia; Geol. Surv., Canada, Mem. 243.

Riordon, P.H.
1954: Thetford Mines-Black Lake Area, Frontenac, Megantic, and Wolfe Counties; Que. Dept. Mines, Prel. Rept. 295.

1962: Geology of the Asbestos Belt in Southeastern Quebec; Bull. Can. Inst. Mining Met., vol. 55, pp. 311-313, 500.

Roots, E.F.
1954: Geology and Mineral Deposits of Aiken Lake Map-area, British Columbia; Geol. Surv., Canada, Mem. 274.

Smitheringale, W.G.
1960: Geology of Nictaux-Torbrook Map-area, Nova Scotia; Geol. Surv., Canada, Paper 60-13.

Stockwell, C.H.
1961: "Structural Provinces, Orogenies, and Time-Classification of Rocks of the Canadian Precambrian Shield" in Age Determinations by the Geological Survey of Canada; Geol. Surv., Canada, Paper 61-17, pp. 108-118.

1962: "A Tectonic Map of the Canadian Shield" in The Tectonics of the Canadian Shield; Roy. Soc., Canada, Spec. Pub. No. 4, pp. 6-15.

Stockwell, C.H. (cont.)
1963: "Second Report on Structural Provinces, Orogenies, and Time-Classification of Rocks of the Canadian Precambrian Shield" in Age Determinations and Geological Studies; Geol. Surv., Canada, Paper 62-17, pp. 123-133.

Taylor, F.C.
1961: Shelburne Map-area; Geol. Surv., Canada, Map 44-1960.

Tupper, W.M., and Hart, S.R.
1961: Minimum Age of the Middle Silurian in New Brunswick Based on the K-Ar Method; Bull. Geol. Soc. Amer., vol. 72, pp. 1285-1288.

Walker, J.F.
1926: Geology and Mineral Deposits of Windermere Map-area, British Columbia; Geol. Surv., Canada, Mem. 148.

Watson, K. de P., and Mathews, W.H.
1944: The Tuya-Teslin Area, Northern British Columbia; B.C. Dept. Mines, Bull. 19.

Wheeler, J.O.
1961: Whitehorse Map-area, Yukon Territory; Geol. Surv., Canada, Mem. 312.

White, W.H., Thompson, R.M., and McTaggart, K.C.
1957: The Geology and Mineral Deposits of Highland Valley, British Columbia; Trans. Can. Inst. Mining Met., vol. 60, pp. 273-289.

ROGER DUHAMEL, F. R. S. C.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1963

Price 75 cents Cat. No. M44-63/17