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CANADA

DEPARTMENT OF MINES
AND TECHNICAL SURVEYS

PAPER 62-17

AGE DETERMINATIONS AND GEOLOGICAL STUDIES

(Including Isotopic Ages – Report 3)

(Report and 3 figures)

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H. W. Tipper, and R. K. Wanless

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CANADA

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PART I - AGE DETERMINATIONS BY THE GEOLOGICAL SURVEY OF CANADA

Isotopic Ages. Report 3
- compiled by J. A. Lowdon

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

PART II - GEOLOGICAL STUDIES

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

Topley Intrusions
- by H. W. Tipper

DEPARTMENT OF

MINES AND TECHNICAL SURVEYS

CANADA

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

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.
S. Abbey	Potassium determination.

CONTENTS

ABSTRACTS

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

The ages of twenty-three biotite-muscovite pairs were compared. Of these, fourteen pairs agree; the remaining nine show differences of up to 32 per cent.

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

Additional potassium-argon dates obtained during 1961 substantiate the subdivisions proposed a year ago (Stockwell, in Geol. Surv., Canada, Paper 61-17, compiled by Lowdon). The Shield is divided into six main structural provinces and several subprovinces. Three main Precambrian orogenic periods are clearly distinguished with peaks at about 2,500, 1,700, and 950 m.y. The three orogenies, when considered in conjunction with major unconformities, give a natural, fourfold time-classification of the sedimentary, volcanic, and intrusive rocks. The oldest time-unit, called 'the Archaean', came to a close with the 2,500 m.y. orogeny. This was followed by the Lower Proterozoic, culminating with the 1,700 m.y. orogeny, the Middle Proterozoic, culminating with the 950 m.y. orogeny, and the Upper Proterozoic, ending with the beginning of Cambrian time. A number of named formational and other stratigraphic units have been assigned to one or another of the main time-units.

Topley Intrusions—H.W. Tipper

Four K-Ar dates from two phases of the Topley Intrusions ranged from 63 m.y. to 178 m.y. This information coupled with stratigraphic evidence indicates that:

1. the Topley Intrusions are probably Lower Jurassic;
2. two phases of the intrusions were probably emplaced contemporaneously; and
3. variance in K-Ar dates is probably due to later events.

PART I

AGE DETERMINATIONS BY THE GEOLOGICAL SURVEY OF CANADA

INTRODUCTION

This publication is the third in a series of annual releases of potassium-argon ages determined in the laboratories of the Geological Survey of Canada. The first report (GSC Paper 60-17) contained 98 determinations carried out during 1959. The second report (GSC Paper 61-17) presented 152 determinations completed during 1960. This report presents an additional 204 ages measured during 1961.

Procedure

All samples are examined mineralogically and the concentrates are analyzed by X-ray diffraction to determine the degree of chloritization. The potassium content is determined by both flame photometric and X-ray fluorescence techniques. A 6KW high-frequency generator is used to fuse the samples in vacuo and standard isotope dilution techniques are used to determine the radiogenic argon content.

Accuracy of Determinations

The analytical error has not been quoted for each age 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 (see Table, p. 122).

The limits to be applied to the calculated values are:

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

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

Constants Employed in Age Calculations

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

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

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

Geological Time-scale

During 1961, Kulp presented a slightly revised time-scale for post-Precambrian time (Kulp, 1961). This scale, together with Holmes' (1959) scale, is shown in Figure 1. Details regarding the ages on which the various divisions were established may be found in the original papers.

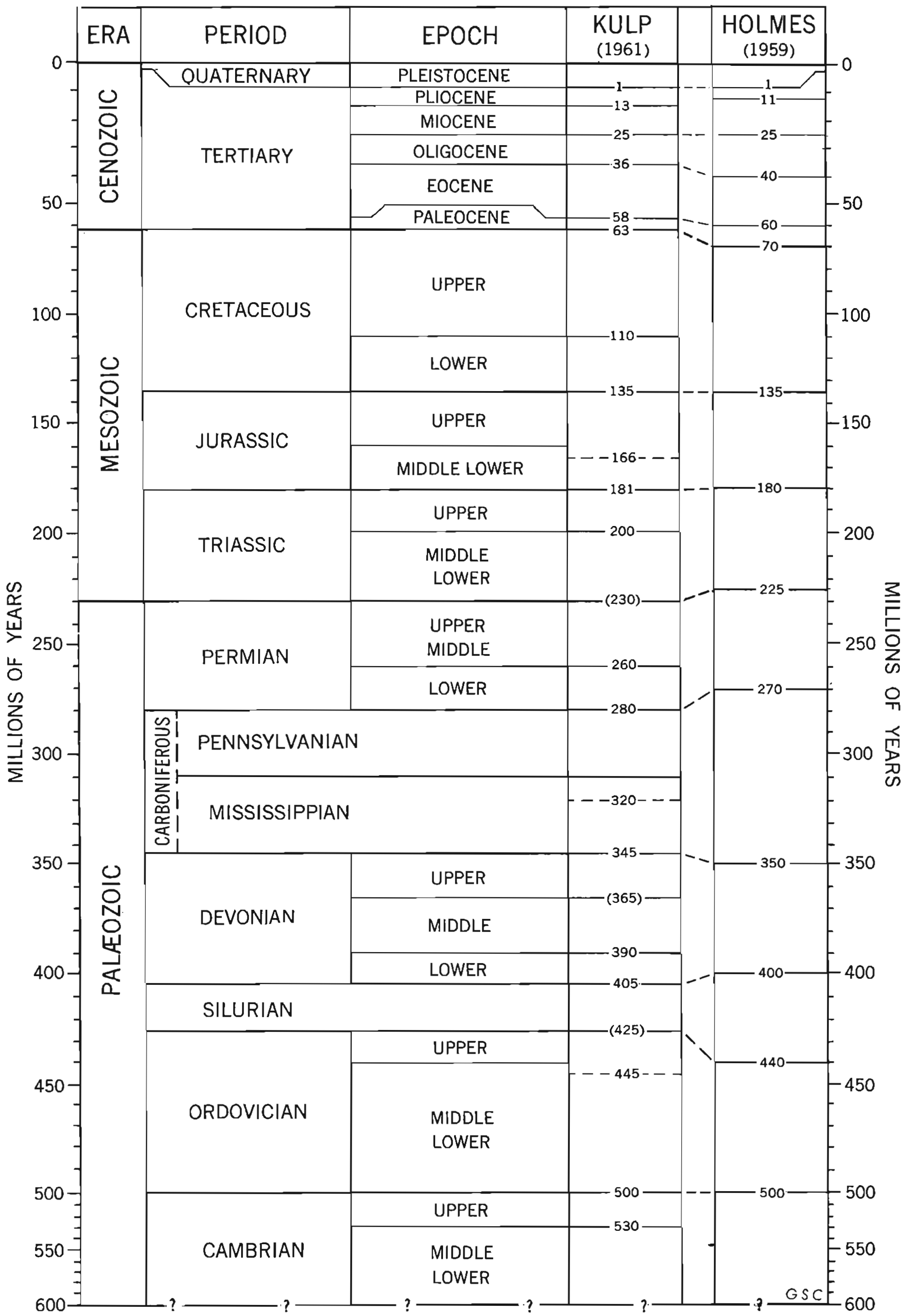

Figure 1. Geological time scale, after Kulp and Holmes

Errata

GSC Paper 61-17. Age determinations by the Geological Survey of Canada. Report 2—Isotopic Ages. Compiled by J. A. Lowdon.

Sample GSC 60-3:
Chlorite/biotite ratio should be 0.1.

Sample GSC 60-41:
Chlorite/biotite ratio should be approximately 3.0.

Sample GSC 60-105:
Correct N. T. S. number is 41 J.

Sample GSC 60-136:
Correct N. T. S. number is 21 G.

Samples GSC 60-141 and GSC 60-142:
Coordinates should read 54°29'40"N
65°46'50"W

ISOTOPIC AGES—REPORT 3

Compiled by J. A. Lowdon

British Columbia

GSC 61-1

Biotite, K-Ar age 140 m.y.

K 7.51%, Ar^{40}/K^{40} .00853; radiogenic argon 97%. Concentrate: contains about 50% pale green flakes with bleached patches; about 35% pale brown flakes; about 5% blue-green hornblende; about 10% impure grains consisting of fine-grained quartz-chlorite-hornblende and biotite-epidote-hornblende intergrowths. Chlorite/biotite 0.11.

From biotite-quartz-plagioclase gneiss.
(82 L)[1] 2.8 miles west of Squilax Bridge across South Thompson River, on the Trans-Canada Highway; 50°47'30"N, 119°40'W. Map-unit 3, GSC Map 1059A. Sample 643-RA-1. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 61-7).

GSC 61-2

Biotite, K-Ar age 135 m.y.

K 7.50% , Ar^{40}/K^{40}.00819; radiogenic argon 100%. Concentrate: flakes are light brown and have numerous inclusions of epidote and bleached greenish patches. Only a few flakes are entirely clean. A small amount of muscovite is present. Chlorite/biotite 0.15.

From biotite-muscovite schist.
(82 L) 5.3 miles west of Squilax Bridge across South Thompson River, on the Trans-Canada Highway; 50°48'N, 119°42'W. Map-unit 3, GSC Map 1059A. Sample 644-RA-1. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 61-7).

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

British Columbia

GSC 61-3

Muscovite, K-Ar age 140 m.y.

K 8.80%, Ar^{40}/K^{40} .00849; radiogenic argon 100%. Concentrate: about 50% of the flakes are clean and the rest have small attached specks of biotite, chloritized biotite, and quartz. Chlorite/muscovite 0.05.

From biotite-muscovite schist.
(82 L) 5.3 miles west of Squilax Bridge across South Thompson River, on the Trans-Canada Highway; 50°48'N, 119°42'W. Map-unit 3, GSC Map 1059A. Sample 644-RA-1. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 61-7.)

GSC 61-4

Biotite, K-Ar age 57 m.y.

K 7.31%, Ar^{40}/K^{40} .00336; radiogenic argon 100%. Concentrate: contains about 90% clean, reddish brown biotite and about 10% showing chloritization along fractures and edges of grains. A few flakes of chlorite are present. Chlorite/biotite 0.07.

From pegmatitic granite.
(82 L) East shore of Mabel Lake, 5.4 miles south of Tsuius Creek; 50°34'N, 118°43'W. Map-unit 1, GSC Map 1059A. Sample 637-RA-2. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 61-7.)

GSC 61-5

Biotite, K-Ar age 52 m.y.

K 7.81%, Ar^{40}/K^{40} .00309; radiogenic argon 100%. Concentrate: consists of 80-85% reddish brown, reasonably clean biotite flakes; 10-15% of biotite flakes contain long needles and are bleached along the edges. A few flakes of grey-green chlorite are present. Chlorite/biotite 0.09.

From sillimanite-garnet-biotite-quartz-plagioclase gneiss.
(82 L) East shore of Mabel Lake, 5.4 miles south of Tsuius Creek; 50°34'N, 118°43'W. Map-unit 1, GSC Map 1059A. Sample 637-RA-3. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 61-7.)

British Columbia

GSC 61-6 Biotite, K-Ar age 71 m.y.

K 7.72%, Ar^{40}/K^{40} .00423; radiogenic argon 100%. Concentrate: consists mainly of clean red-brown biotite. About 5 to 10% of the flakes have green chloritized edges. About 5% chlorite occurs as separate grains. Chlorite/biotite 0.09.

From pegmatitic granite.
(82 L) Road-cut on Three Valley Lake on the Trans-Canada Highway, approximately 12 miles west of Revelstoke; 50°56'N, 118°27'W. Map-unit 1, GSC Map 1059A. Sample 646-RA-2. Collected and interpreted by J. E. Reesor.

(For interpretation see determination GSC 61-7).

GSC 61-7 Biotite, K-Ar age 102 m.y.

K 7.94%, Ar^{40}/K^{40} .00612; radiogenic argon 58%. Concentrate: consists of reasonably pure red-brown biotite. Chlorite/biotite 0.04.

From paragneiss.
(82 L) Road-cut on Three Valley Lake on the Trans-Canada Highway, approximately 12 miles west of Revelstoke; 50°56'N, 118°27'W. Map-unit 1, GSC Map 1059A. Sample 646-RA-3. Collected and interpreted by J.E. Reesor.

The Shuswap terrane of southern British Columbia is an area of high regional grade of metamorphism and intense structural deformation. The Shuswap is divided into two major groups. The Mount Ida Group, on structural and metamorphic grounds, is considered to be younger than the Monashee Group (Jones, 1959).

Interpretation and evaluation of the age of a complex terrane such as this, based on so few determinations, is premature. Nevertheless, a certain pattern seems apparent.

Within the Monashee Group the four ages presented here range from 52 m.y. to 102 m.y. (GSC 61-5, GSC 61-4, GSC 61-6 and GSC 61-7; see also determination GSC 60-1 which gave a date from the Monashee Group of 62 m.y.). This group of rocks consists of high-grade metamorphic rocks of sillimanite-garnet subfacies, gneisses, and migmatites, and concordant as well as crosscutting pegmatites. In this high-grade metamorphic terrane, ages appear to be spread from 50 m.y. to 100 m.y. with a great disregard for geologically related or apparently 'later' pegmatites. Thus two 'late' pegmatites, clearly crosscutting the gneisses and migmatites, give an age of 57 m.y. (GSC 61-4) at Sugar Lake and 71 m.y. (GSC 61-6) at Three Valley Lake. The enclosing gneisses range from 52 m.y. (GSC 61-5) to 102 m.y. (GSC 61-7). On the other hand, the specimens from the Mount Ida Group, less migmatized and of somewhat lower grade of metamorphism, give remarkably consistent results from 135 m.y. (GSC 61-2) to 140 m.y. (GSC 61-3 and GSC 61-1). Thus the 'pattern' of ages appears to follow and be dependent upon the grade of metamorphism and the pattern of structural deformation rather than the postulated geological relationships.

The problem of the Shuswap might be divided into two distinct parts; the age or ages of the rocks involved and, the age or ages of the metamorphism and structural deformation. Pending further determinations that might show a complete overlap between the Mount Ida and Monashee Groups, it might be suggested that though the Mesozoic phase of the metamorphism (and structural deformation?) may have started at the same time in both groups, it continued longer in the Monashee Group and was, at least in its latest manifestations, erratically distributed, at least in its effect on biotite in both the gneisses and the pegmatite. This would explain, in part, not only the spread of ages in the Monashee Group, but also their younger average age.

In considering the validity of these results as 'absolute' ages of metamorphism of the Monashee Group it must be pointed out that rocks of known early Tertiary age unconformably overlie the group. K-Ar dates on clearly post-tectonic Tertiary rocks farther west (Rouse and Mathews, 1961) yield results ranging from 45 m.y. to 49 m.y. Thus the age of the major metamorphism and deformation of the Shuswap can under no circumstances be considered Tertiary, based on the above results. Much further structural, petrological and age-determination work is currently being continued in this terrane.

GSC 61-8 Muscovite, K-Ar age 81 m.y.

K 8.83%, Ar^{40}/K^{40} .00485; radiogenic argon 95%. Concentrate: contains about 95% clean muscovite. A few flakes contain minor inclusions of quartz and small prisms of apatite. Chlorite not detected.

From quartz-feldspar pegmatite.

(82 L) On the mountain range west of the headwaters of the upper north branch of Blanket Creek; 50°49'03"N, 118°15'48"W. Map-unit 1, GSC Map 1059A. Sample CO-61-87. Collected and interpreted by D. B. Craig.

British Columbia

The material for this age determination was taken from a coarse-grained, muscovite-bearing, quartz feldspar pegmatite which discordantly cuts biotite-quartz-feldspar gneiss of the Monashee Group.

From the observed geological relationships, the interpretations possible at present are twofold. Either the extensive, intense deformation these rocks have undergone was completed more than 81 million years ago, or basalt dykes, which cut the country rocks and pegmatite, are younger than 81 million years, for which there already is some evidence.

GSC 61-9 Biotite, K-Ar age 73 m.y.

K 7.61%, Ar^{40}/K^{40} .00436; radiogenic argon 94%. Concentrate: very pure. Most biotite flakes are olive-green and some have inclusions of apatite. A few flakes are brown and some brighter green flakes are also present. Chlorite/biotite 0.04.

(82 F) From biotite granodiorite. Near southern boundary of White Creek batholith; 49°48'33"N, 116°16'10"W. Map-unit 9, GSC Map 1053A. Sample W-58-RA-22. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 61-11.)

GSC 61-10 Biotite, K-Ar age 82 m.y.

K 7.50%, Ar^{40}/K^{40} .00489; radiogenic argon 100%. Concentrate: consists of clean red-brown to opaque biotite flakes with numerous inclusions of zircon surrounded by pleochroic haloes. A few flakes are intergrown with quartz and muscovite. About 30% of the flakes contain tiny specks and have bleached edges. Chlorite/biotite 0.08.

(82 F) From leuco-quartz monzonite. Approximate elevation 5,000 feet; 49°51'10"N, 116°16'40"W. Map-unit 12, GSC Map 1053A. Sample W-58-RA-20. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 61-11.)

British Columbia

GSC 61-11 Muscovite, K-Ar age 80 m.y.

K 8.80%, Ar^{40}/K^{40} .00478; radiogenic argon 100%. Concentrate: majority of flakes are clean. Some flakes have air trapped between (001) cleavage and a few inclusions of quartz and biotite. A few flakes have a yellowish stain along the edges. Chlorite not detected.

From leuco-quartz monzonite.
(82 F) Approximate elevation 5,000 feet; 49°51'10"N, 116°16'40"W. Map-unit 12, GSC Map 1053A. Sample W-58-RA-20. Collected and interpreted by J.E. Reesor.

Samples GSC 61-9, GSC 61-10, and GSC 61-11, were collected from White Creek batholith; GSC 61-9 from biotite granodiorite near the outer boundary of the intrusion, in the valley of White Creek, and GSC 61-10 and GSC 61-11 from the core of the batholith also in the valley of White Creek. Five earlier ages were determined for this intrusion and reported earlier (Lowdon, 1961, p. 8). A preliminary discussion of these earlier samples was presented on p. 87 of the above publication, in which it was pointed out that there was a gradation in age not only from the boundary of the intrusion to the interior, but also apparently from the mountain tops to the valley bottoms. The three dates presented here do not confirm this pattern, but show rather an average age of 78.5 m.y., if only the four highest ages are taken (range 73-82 m.y.) from both boundary and core of the intrusion. This result agrees better with the hypothesis presented in Reesor (1958), that the White Creek batholith was a single intrusion and that variations in lithology and structure were related to contamination during that intrusion. However, this still leaves unexplained the range of ages in quite fresh, massive granitic rock from 18 to 82 m.y., even though the age of the intrusion might be taken with some degree of confidence at 77 ±5 m.y.

GSC 61-12 Biotite, K-Ar age 53 m.y.

K 7.61%, Ar^{40}/K^{40} .00313; radiogenic argon 88%. Concentrate: reasonably clean with about 5-10% of green hornblende present as an impurity. A few flakes are slightly bleached. Chlorite/biotite 0.02.

From granite.
(82 F) Northeast edge of 8,000-foot peak, 1 mile northwest of the highest peak in the area; 49°49'15"N, 117°56'20"W. Map-unit 22, GSC Map 1090A. Sample D-310-RA-1. Collected by J.F. Donovan. Interpreted by J.E. Reesor.

(For interpretation see determination GSC 61-13.)

British Columbia

GSC 61-13 Biotite, K-Ar age 32 m.y.

K 7.67%, Ar^{40}/K^{40} .00188; radiogenic argon 45%. Concentrate: reasonably pure biotite with minute colourless inclusions. Chlorite not detected.

From pink hornblende-biotite granite.
(82 F) Altitude 7,500 feet, just below ridge top; 49°50'30"N, 117°56'40"W. Map-unit 22, GSC Map 1090A. Sample D-341-RA-1. Collected by J.F. Donovan. Interpreted by J.E. Reesor.

Samples GSC 61-12 and GSC 61-13 of Coryell Granite were collected in Valkyr Range near the south end of the small intrusion noted on GSC Map 1090A, map-unit 22.

The pink granite of Coryell type cuts the leucogranite and porphyritic hornblende granodiorite of the Valkyr and Valhalla Ranges. They are geologically younger, yet ages of the intruded rock—see samples GSC 61-14, GSC 61-15, and GSC 61-16 in this publication, and the discussion of the Valhalla Complex by Reesor (in Lowdon 1961, p. 92)—have about the same range as those of the younger granitic intrusions.

The age of Coryell Granites is generally considered, on geological grounds, to be Tertiary (Little, 1960), and this agrees with the ages determined. On the other hand, the ages of both the intruded granitic and gneissic rocks and the Coryell Granite do not appear to be appreciably different although they are very different in composition and structural relations.

GSC 61-14 Biotite, K-Ar age 66 m.y.

K 7.65%, Ar^{40}/K^{40} .00394; radiogenic argon 100%. Concentrate: reasonably clean. Impurities constitute less than 10% of the concentrate and include: greenish grey chlorite; biotite-quartz intergrowths; and a few fragments of blue-green hornblende. Chlorite/biotite 0.05.

From biotite granite.
(82 F) Ridge top, altitude 7,000 feet, due southeast from northwest corner of map-area (Passmore); 49°44'N, 117°58'W. Map-unit 20, GSC Map 1090A. Sample D-253-RA-1. Collected by J.F. Donovan. Interpreted by J.E. Reesor.

(For interpretation see determination GSC 61-16.)

British Columbia

GSC 61-15 Biotite, K-Ar age 59 m.y.

K 7.65%, Ar^{40}/K^{40} .00350; radiogenic argon 100%. Concentrate: consists of mostly clean brown biotite. About 10% of the flakes have chloritized edges and patches. Chlorite/biotite 0.09.

From biotite granite-gneiss.
(82 F) Altitude 4,800 feet on a hillside northeast of the junction of Watson and Koch Creeks; 49°42'25"N, 117°54'W. Map-unit 19a, GSC Map 1090A. Sample D-386-RA-1. Collected by J.F. Donovan. Interpreted by J.E. Reesor.

(For interpretation see determination GSC 61-16.)

GSC 61-16 Biotite, K-Ar age 58 m.y.

K 7.50%, Ar^{40}/K^{40} .00343; radiogenic argon 100%. Concentrate: the biotite flakes are reasonably clean and vary from brownish and greenish grey. Some flakes have bright green chloritized edges. A few fragments of quartz and hornblende are present as impurities. Chlorite/biotite 0.11.

From porphyritic hornblende granite.
(82 F) At south end of 8,000-foot mountain top; 49°48'N, 117°54'W. Map-unit 19a, GSC Map 1090A. Sample D-296-RA-1. Collected by J.F. Donovan. Interpreted by J.E. Reesor.

Samples GSC 61-14, GSC 61-15, and GSC 61-16 were collected from the massive granitic rocks that occur in the Valkyre Range just west of the Valhalla Complex. Sample GSC 61-14 was collected in an isolated area of biotite-granite schlieren in leucogranite. Sample GSC 61-15 was collected from a layer of strongly lineated coarse biotite-granite associated with leucogranite gneiss at the junction of Koch and Watson Creeks, in the western limit of Valhalla gneiss dome. Sample GSC 61-16 was collected in Valkyr Range in porphyritic hornblende granodiorite. Field relations show the biotite and leucogranitic rocks of the first two specimens to intrude the porphyritic hornblende granodiorite of the last specimen. The ages determined for the two types show no significant difference.

In considering these ages in conjunction with those of the geologically later Coryell granitic rocks it seems necessary to assume that a late period of metamorphism, sufficiently penetrative to have affected the biotite of all the rock types, has effectively oblitered any evidence from the K-Ar ratios that these rocks might be of even slightly different geological ages.

British Columbia

GSC 61-17 — Biotite, K-Ar age 131 m.y.

K 6.06%, Ar^{40}/K^{40} .00791; radiogenic argon 75%. Concentrate: consists of about 80% greenish biotite; about 15% chloritized biotite and free chlorite; and about 5% free grains of green hornblende. Chlorite/biotite 0.35.

From granodiorite.
(82 F) South of Mount Chipman at an altitude of 7,500 feet; 49°51'30"N, 117°2'48"W. Map-unit 19a, GSC Map 1090A. Sample N3-RA-1. Collected and interpreted by J.E. Reesor.

This sample was collected in the northeast corner of the Nelson batholith and is the oldest so far obtained for rocks of this complex. An early Lower Cretaceous age for at least a part of these rocks agrees precisely with that deduced on geological grounds by Little (1960).

GSC 61-18 — Biotite, K-Ar age 127 m.y.

K 7.86%, Ar^{40}/K^{40} .00770; radiogenic argon 100%. Concentrate: consists of fresh brown biotite containing prismatic inclusions of apatite and zircon. Some flakes are coated with very fine grained specks, possibly quartz. Chlorite not detected.

From granodiorite.
(82 K) At south end of glacier that caps the stock; 50°23'12"N, 116°47'49"W. Map-unit A, GSC Map 12-1957. Sample Gl RA-1. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 61-20.)

GSC 61-19 — Biotite, K-Ar age 205 m.y.

K 7.91%, Ar^{40}/K^{40} .0127; radiogenic argon 91%. Concentrate: contains about 85% clean brown biotite and 10% partly chloritized flakes. The biotite flakes contain a few inclusions of quartz and apatite; 2-3% green chlorite is present as an impurity. Chlorite/biotite 0.14.

British Columbia

From granite.

(82 K) South of the head of Howser River at an altitude of 8,200 feet; 50°38'6"N, 116°35'42"W. Map-unit 28, GSC Map 12-1957. Sample H I RA-1. Collected and interpreted by J.E. Reesor.

(For interpretation see determination GSC 61-20.)

GSC 61-20 Biotite, K-Ar age 100 m.y.

K 7.77%, Ar^{40}/K^{40} .00601; radiogenic argon 100%. Concentrate: consists of fresh green and brown biotite with minor quartz inclusions. Chlorite not detected.

From biotite granodiorite.

(82 K) On east side of glacier at head of first north fork of East Creek; 50°44'6"N, 116°55'30"W. Map-unit 28, GSC Map 12-1957. Sample B1 RA-1. Collected and interpreted by J.E. Reesor.

These three samples (GSC 61-19, GSC 61-20, and GSC 61-18) were collected from the Horsethief, Bugaboo, and Glacier Creek stocks respectively, in the central Purcell Mountains. The first two are post-tectonic, crosscutting plutons ranging in composition from granodiorite to granite. The Glacier Creek stock is a partly conformable granodiorite intrusion. All the stocks cut late Precambrian or early Palaeozoic rocks and all crosscut the structures of these folded sedimentary rocks. As this folding involves mid-Jurassic rocks in the Selkirk Mountains immediately to the west, the folding in the Purcell Mountains is generally accepted as at least post Middle Jurassic. Therefore a late Lower to early Upper Cretaceous age (100 m.y. to 127 m.y.) for the Glacier Creek and Bugaboo stocks appears to indicate folding in late Jurassic to early Cretaceous followed by intrusion in early Upper Cretaceous. This pattern seems entirely reasonable.

The date of 205 m.y. for the western part of the Horsethief stock presents some difficulties, and perhaps a single determination is not enough to warrant a revision of a consistent pattern of post-tectonic granitic intrusions of Upper Cretaceous age throughout the Purcell Mountains (though in this connection see GSC 61-23 on the Adamant Batholith). Therefore no specific conclusion on this determination will be presented until further measurements confirm this age. It is of course by no means impossible that a part of this mass may in fact date from the Upper Triassic, even though no presently available structural or geological evidence exists to confirm the possibility.

British Columbia

GSC 61-21 Biotite, K-Ar age 281 m.y.

K 8.08%, Ar^{40}/K^{40} .0177; radiogenic argon 89%. Concentrate: consists of clean biotite flakes varying from pale brown to olive-brown. A few hornblende fragments occur as impurities. Chlorite not detected.

From granodiorite.
(82 N) North side of Palmer Creek, elevation 7,000 feet; 51°42'40"N, 117°50'30"W. Map-unit B, GSC PS Map 4-1961. Sample FK-A-1. Collected and interpreted by P. E. Fox.

(For interpretation see determination GSC 61-23.)

GSC 61-22 Biotite, K-Ar age 131 m.y.

K 8.19%, Ar^{40}/K^{40} .00792; radiogenic argon 100%. Concentrate: consists of clean, mainly brown biotite. Chlorite not detected.

From pegmatite.
(82 N) North side of Palmer Creek, elevation 7,000 feet; 51°42'40"N, 117°50'30"W. Map-unit B, GSC PS Map 4-1961. Sample FK-A-2. Collected and interpreted by P. E. Fox.

(For interpretation see determination GSC 61-24.)

GSC 61-23 Biotite, K-Ar age 200 m.y.

K 7.45%, Ar^{40}/K^{40} .0123; radiogenic argon 48%. Concentrate: consists of about 75% clean biotite; 10% slightly altered biotite; 10% free chlorite; and 5% hornblende. Chlorite/biotite 0.15.

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 and interpreted by P. E. Fox.

Samples GSC 61-21 and GSC 61-23 were collected from the Adamant Range batholith near the headwaters of Palmer Creek and Swan Creek respectively. The Adamant Range batholith is in the northern Selkirk Mountains and is part of a series of granitic intrusions along the axis of the Selkirks. The batholith is roughly oval in shape, covering an area of about 60 square miles. The long axis of the batholith trends northeast across the regional structural trend of the country rocks. The Adamant Range batholith has intruded medium-grade metamorphic rocks probably belonging to the Proterozoic Horsethief Creek group. These late Precambrian country rocks, which normally trend northwest, have been shouldered aside near the intrusion into conformity with the margin of the batholith. Both samples are medium-grained, equigranular, biotite-hornblende granodiorite, containing about 5-10% biotite, 25-30% hornblende, 35% plagioclase, 15% quartz, and 15% orthoclase. The biotite occurs as anhedral flakes up to 0.5 mm in size and is commonly intergrown with hornblende. The granodiorite forms an outer envelope surrounding a pyroxene monzonite interior.

The K-Ar dates for these two samples differ by 81 m.y. There is no indication that there is a real difference in age between the two as both represent granodiorite about the same distance from the intrusive contact. Information regarding the age of metamorphism of the country rock is not yet available. Lacking this, and keeping in mind that the Adamant Range batholith is post-tectonic, there is no way of testing the agreement or disagreement of the age determinations of the Adamant Range batholith.

GSC 61-24 Biotite, K-Ar age 90 m.y.

K 8.14%, Ar^{40}/K^{40} .00538; radiogenic argon 87%. Concentrate: consists of very clean biotite. Chlorite not detected.

From quartz-rich vein in granodiorite.
(82 N) Rock bastion on north side of Granite Glacier; 51°45'40"N, 117°54'20"W. Map-unit B, GSC PS Map 4-1961. Sample FK-A-4. Collected and interpreted by P.E. Fox.

Samples GSC 61-22 and GSC 61-24 are coarse biotite crystals taken from a pegmatite dyke and a quartz-rich segregation respectively. Both dyke and vein occur in the Adamant Range granodiorite described under GSC 61-23. The pegmatite consists of 25% quartz, 25% microcline, 45% plagioclase, 3% biotite, and lesser amounts of epidote, sphene, apatite, zircon, tourmaline, and chalcopyrite. The quartz vein is mostly composed of quartz and coarse segregations of biotite, calcite, scapolite, and specularite.

There is a wide divergence in the ages determined for the granodiorite (GSC 61-21 and 61-23) and the pegmatite (GSC 61-22 and GSC 61-24). It is logical for the pegmatites to be younger than the granodiorite but it is remarkable that the crystallization of the pegmatite from the residual granodiorite magma required at least 70 million years.

GSC 61-25 Muscovite, K-Ar age 675 m.y.

K 8.44%, Ar^{40}/K^{40} .0474; radiogenic argon 90%. Concentrate: consists of very clean muscovite. A few flakes have tiny inclusions, probably of quartz. Chlorite not detected.

From pegmatitic granodiorite.
(82 F) Angus Creek, 0.9 mile above Hellroaring Creek; 49°34'03"N, 116°09'06"W. Map-unit 11, GSC Map 15-1957. Sample L525-5-2. Collected and interpreted by G.B. Leech.

This date is probably less than the age of the intrusion, because it was yielded by deformed mica. The intrusion cuts the lower division of the Aldridge Formation and a sill of the Moyie Intrusions. It is 1/3 mile east of the Hellroaring Creek stock whose Precambrian age was reported previously (GSC 60-2). See also determinations GSC 61-26 and GSC 61-27. For further discussion see Leech (1962).

GSC 61-26 Muscovite, K-Ar age 745 m.y.

K 8.74%, Ar^{40}/K^{40} .0529; radiogenic argon 100%. Concentrate: consists of very clean muscovite. Some flakes are fractured and contain minute quartz inclusions along fractures and edges. Chlorite not detected.

From pegmatitic leucocratic granodiorite.
(82 F) West of Matthew Creek and 5 3/4 miles southwest of Kimberley; 49°38'48"N, 116°05'40"W. Map-unit 11, GSC Map 15-1957. Sample LD-ML1. Collected and interpreted by G. B. Leech.

This small stock intrudes the lower division of the Aldridge Formation in the metamorphic area referred to under GSC 61-27. The muscovite and other minerals in the stock are deformed and therefore the age of 745 m.y. is regarded as minimal.

For further discussion see Leech (1962).

British Columbia

GSC 61-27 Muscovite, K-Ar age 790 m.y.

K 6.80%, Ar^{40}/K^{40} .0574; radiogenic argon 64%. Concentrate: consists of 80 to 85% aggregates of muscovite and sericite. About 15% of impurities are present, consisting of quartz and chlorite. The chlorite-biotite ratio was not determined.

From quartzite.

(82 F) West of Matthew Creek and 5 1/2 miles southwest of Kimberley; 49°38'48"N, 116°05'17"W. Map-unit 1, GSC Map 15-1957. Sample LD-ML3. Collected and interpreted by G. B. Leech.

This quartzite is part of a distinct area in which the metamorphism of the Aldridge Formation and Moyie Intrusions is of much higher grade than that characteristic of the surrounding region; specifically, the almandine-amphibolite metamorphic facies in contrast to the lower part of the greenschist facies.

The 790 m.y. K-Ar age of the metamorphic muscovite, and the Precambrian age of grandiorite (GSC 61-26) in the metamorphic area and at Hellroaring Creek (GSC 60-2 GSC 61-25), are evidence of a Precambrian orogeny.

For further discussion see Leech (1962).

GSC 61-28 Muscovite, K-Ar age 107 m.y.

K 7.96%, Ar^{40}/K^{40} .00644; radiogenic argon 100%. Concentrate is clean. Muscovite flakes contain minor inclusions of quartz. Chlorite not detected.

From pegmatite.

(82 N) 6.5 miles S84°W of the mouth of Swan Creek; 51°48'N, 117°57'W. Map-unit A, GSC Map 4-1961. Sample WB-120W-3-61. Collected and interpreted by J. O. Wheeler.

The pegmatite cuts gently across the foliation in the surrounding metamorphic rocks of the Horsethief Creek Group. No interpretation of this date can be made until the results are known from ages determined for the surrounding metamorphic rocks. At present a latest Lower Cretaceous age (Kulp, 1961) of 107 m.y. seems reasonable.

British Columbia

GSC 61-29 Biotite, K-Ar age 80 m.y.

K 6.97%, Ar^{40}/K^{40} .00479; radiogenic argon 93%. Concentrate: consists of clean, light to dark, red-brown biotite with a small amount of greenish brown flakes. Some flakes are zoned and many of the flakes contain small inclusions of quartz. Chlorite not detected.

(92 I) From argillized vitrophyric biotite-andesite lava. Between forks of Birkett Creek at almost 4,230 feet elevation; 50°12'N, 120°55'W. Map-unit 6, GSC Map 886A. Sample JMC 60-110. Collected and interpreted by J.M. Carr, B.C. Dept. Mines, Petroleum Resources.

This sample is from unmineralized volcanic strata that unconformably overlie mineralized Nicola rocks in which a low-grade metamorphic halo is formed around the Craigmont orebody. Orthoclase from veins in the orebody has been dated as not less than 108 m.y. (recent unpublished determination by the Dept. Geology, Univ. Alberta).

GSC 61-30 Biotite, K-Ar age 69 m.y.

K 7.93%, Ar^{40}/K^{40} .00413; radiogenic argon 100%. Concentrate: consists of clean biotite varying from light brown to deep chestnut and greenish brown. Chlorite not detected.

(93 O) From quartz-feldspar-biotite gneiss. Wolverine Range, north of Nation River; 55°33'N, 123°56'W. Map-unit A, GSC Map 11-1961. Sample H 31. Collected and interpreted by J.E. Muller.

(For interpretation see determination GSC 61-33.)

GSC 61-31 Muscovite, K-Ar age 75 m.y.

K 8.61%, Ar^{40}/K^{40} .00445; radiogenic argon 100%. Concentrate: consists mostly of clean muscovite but some flakes contain small inclusions of quartz and attached fragments of brown biotite. An orange-yellow stain is evident on some flakes. Chlorite not detected.

(93 O) From quartz-muscovite-biotite schist. Near Nation River; 55°23'30"N, 123°39'50"W. Map-unit A, GSC Map 11-1961. Sample IV. Collected and interpreted by J.E. Muller.

(For interpretation see determination GSC 61-33.)

British Columbia

GSC 61-32 Biotite, K-Ar age 77 m.y.

K 7.87%, Ar^{40}/K^{40} .00457; radiogenic argon 100%. Concentrate: consists of mostly clean red-brown biotite. Some flakes contain small inclusions of quartz. Chlorite not detected.

From quartz-muscovite-biotite schist.
(93 O) Near Nation River; 55°23'30"N, 123°39'50"W. Map-unit A, GSC Map 11-1961. Sample IV. Collected and interpreted by J.E. Muller.

(For interpretation see determination GSC 61-33.)

GSC 61-33 Muscovite, K-Ar age 71 m.y.

K 8.79%, Ar^{40}/K^{40} .00425; radiogenic argon 100%. Concentrate: most of the muscovite flakes are clean but a few contain minor inclusions of quartz and attached specks of brown biotite. Chlorite not detected.

From quartz-feldspar-muscovite gneiss.
(93 O) Wolverine Range, south of Nation River; 55°19'N, 123°30'W. Map-unit A, GSC Map 11-1961. Sample 118 I. Collected and interpreted by J.E. Muller.

These four samples of mica (GSC 61-31, GSC 61-32, GSC 61-30, and GSC 61-33) from quartz-mica schist and gneiss, ranging in age from 77 m.y. to 69 m.y., should be considered together with sample GSC 60-23 (granite pegmatite, 22 m.y.) and sample GSC 60-24 (biotite-diopside-feldspar marble, 29 m.y.). All were collected in the Pine Pass area and have been mapped as part of the metamorphic Wolverine Complex. In the notes on the 1960 determinations (Lowdon, 1961), it was suggested that the similar ages of pegmatite and metamorphic rock supported earlier conclusions that metamorphism, granitization, and intrusion of pegmatite were related. However, an older stage of metamorphism is now indicated by the four new analyses of quartz-mica schist, while metamorphism of the marble appears to be related to the pegmatite.

Determinations GSC 61-31 and GSC 61-32 were made on muscovite and biotite from the same sample. The dates of 75 m.y. and 77 m.y. are in remarkably close agreement and compare favourably with most muscovite-biotite pairs analyzed so far in the laboratories of the Geological Survey of Canada (Wanless and Lowdon, in Lowdon, 1961, p. 119). The two other analyses give additional support to this pair. GSC 61-30, from 16 miles to the northwest, is dated at 69 m.y., and GSC 61-33, 8 miles to the southeast, is dated at 71 m.y.

British Columbia

Metamorphism of these rocks was thus apparently concluded by the end of the Mesozoic. Similar K-Ar dates, mainly between 50 m.y. and 70 m.y., have already been found for some metamorphic rocks of the Yukon, Shuswap, and Valhalla Complexes (Lowdon, 1961).

The close grouping of the dates also gives a measure of confidence in K-Ar determinations. Of the four dates on the mica-schists of the metamorphic complex, the two extremes are from samples taken more than 20 miles apart, and the other two are from two minerals from the same sample. All are within 10% of the average age and this coincidence reduces to a minimum the possibility of argon loss after the close of metamorphism. If there had been appreciable loss of argon, it must have been in the same ratio for both micas in a single sample and for the two other samples from 8 and 16 miles away, which is most improbable. Furthermore, if the actual ages are in fact different and the apparent ages were brought into agreement by varying argon-loss the coincidence would be even more surprising and improbable. The loss of argon after the metamorphism at the end of Cretaceous time was therefore almost certainly small, if there was any.

Nonetheless, a granite-pegmatite of substantially lower K-Ar age intruded the two-mica schist only some 20 feet distant from where the sample was taken. The conclusion therefore seems unavoidable that this intrusion did not affect the K-Ar age of the schist by argon loss.

It must be borne in mind, however, that this is a special case and no conclusions on the general reliability of K-Ar dates may safely be drawn from it.

GSC 61-34 Biotite, K-Ar age 63 m.y.

K 8.05%, Ar^{40}/K^{40} .00375; radiogenic argon 100%. Concentrate: clean, consisting of brown biotite flakes with tiny specks along fractures and a few inclusions of red hematite and quartz. About 10% of the flakes are a greenish colour. Chlorite not detected.

From quartz diorite.
(93 F) East side of Nuki Hills; 53°42'N, 124°2'W. Map-unit 4A, 4B, GSC PS Map 54-11. Sample TD-6-61. Collected and interpreted by H.W. Tipper.

For interpretation by Tipper see Part II of this Paper.

British Columbia

GSC 61-35

Biotite, K-Ar age 178 m.y.

K 7.75%, Ar^{40}/K^{40} .01094; radiogenic argon 100%. Concentrate: consists mainly of clean brown biotite. A few flakes are greenish and chloritized, and some have tiny inclusions along fractures. Chlorite/biotite 0.02.

From diorite.

(93 K) South side of Camsell Lake, 1 mile from the east end; 54°31'N, 124°52'W. Map-unit 5C, GSC Map 907A. Sample TD-5-61. Collected and interpreted by H. W. Tipper.

For interpretation by Tipper see Part II of this Paper.

GSC 61-36

Biotite, K-Ar age 138 m.y.

K 6.80%, Ar^{40}/K^{40} .00835; radiogenic argon 91%. Concentrate: reasonably clean concentrate of partly altered biotite. The biotite flakes contain numerous inclusions of epidote and are chloritized along the fractures. The concentrate contains about 5% free chlorite. Chlorite/biotite 0.17.

From granite.

(93 K) 1 mile north of the village of Endako; 54°5'N, 125°2'W. Map-unit 5A, GSC Map 907A. Sample TD-3-61. Collected and interpreted by H. W. Tipper.

For interpretation by Tipper see Part II of this Paper.

GSC 61-37

Biotite, K-Ar age 154 m.y.

K 5.19%, Ar^{40}/K^{40} .00940; radiogenic argon 100%. Concentrate: reasonably clean but most of the biotite flakes are bleached along fractures and contain numerous inclusions in bleached areas. The high chlorite-to-biotite ratio is accounted for by the presence of about 15% free grains of green chlorite. Chlorite/biotite 0.5.

From granite.

(93 K) East end of Francois Lake; 54°2'N, 125°2'W. Map-unit 5A, GSC Map 907A. Sample TD-1-61. Collected and interpreted by H. W. Tipper.

For interpretation by Tipper see Part II of this Paper.

British Columbia

GSC 61-38 Biotite, K-Ar age 65 m.y.

K 7.23%, Ar^{40}/K^{40}.00386; radiogenic argon 40%. Concentrate: biotite flakes are small, irregular, and vary in colour from light to dark olive-brown. A few flakes have inclusions of zircon surrounded by faint pleochroic haloes and a few prisms of apatite. About 10% of the flakes are altered in varying degree to chlorite and contain epidote inclusions. Chlorite/biotite 0.10.

From biotite granodiorite.
(104 M) W.P. and Y.R. Railway, mile 36.2; 59°47'30"N, 135°00'30"W. Map-unit 6, GSC Map 19-1957. Sample CB-55-4-5. Collected and interpreted by R.L. Christie.

(For interpretation see determination GSC 61-39.)

GSC 61-39 Biotite, K-Ar age 54 m.y.

K 7.53%, Ar^{40}/K^{40}.00322; radiogenic argon 72%. Concentrate: contains about 70% clean olive-brown, brown, and nearly opaque, biotite flakes; 20-25% olive-brown flakes with ginger-brown and greenish patches; and 6% dark green chlorite mainly as free flakes with inclusions of opaque material, epidote, and fine needles. A few biotite flakes have apatite inclusions. Chlorite/biotite 0.08.

From biotite granodiorite.
(104 M) W.P. and Y.R. Railway, mile 29.5; 59°44'N, 134°59'W. Map-unit 6, GSC Map 19-1957. Sample CB-55-4-10. Collected and interpreted by R.L. Christie.

The granodiorite from which samples GSC 61-38 and GSC 61-39 were taken intrudes porphyritic granodiorite that is considered, from field and indirect evidence, to be intermediate in age for the granitic rocks of the Bennett area. Granitic bodies of the 'Intermediate' group are considered, from geological evidence, to be certainly post-Lower Jurassic, possibly in part post-Middle Cretaceous, and probably pre-Tertiary in age.

Sample GSC 61-38 was thought, in the field, to be closely related to, and possibly a younger phase of, the porphyritic granodiorite; sample GSC 61-39, on the other hand, is texturally distinct, and was thought to be a separate intrusion. A K-Ar age

(GSC 60-27) of 68 m.y. has been obtained from the porphyritic granodiorite some miles from the localities of GSC 61-38 and GSC 61-39.

The K-Ar dates of 65 m.y. and 54 m.y. possibly confirm the apparent field relationships. However they do not confirm the supposition that the 'intermediate' group is older than the 'brown granite' suite, for which K-Ar dates of 61 m.y. (GSC 60-26), 65 m.y. (GSC 61-46), and 70 m.y. (GSC 61-47) have been obtained in the Bennett area. The K-Ar dates of 68 m.y. (GSC 60-27), 65 m.y. (GSC 61-38), and 54 m.y. (GSC 61-39) (possibly latest Upper Cretaceous to early Tertiary according to recent time-scales) are younger than were expected, but the ages do not contradict any direct field evidence.

Yukon Territory

GSC 61-40 Muscovite, K-Ar age 175 m.y.

K 8.85%, Ar^{40}/K^{40} .0107; radiogenic argon 98%. Concentrate: consists of muscovite—about 70% colourless soft flakes, about 20% greenish, tough flakes, and about 10% flakes coated with thin films of fine-grained iron oxides. A few ginger-reddish plates of lepidocrocite, some ginger-brown stained patches, and a few quartz inclusions are present. Chlorite not detected.

From quartz-muscovite schist.
(116 C) Sixty-mile Road, 8 miles from the Alaska Boundary; 64°07'N, 140°48'W. Map-unit A2, GSC Map 1812. Sample XXI. Collected and interpreted by J.E. Muller.

The sample is from Klondike schist, part of the Yukon Group, until lately believed to be a Precambrian metamorphic complex.

The K-Ar date confirms, only in a general way, the 138-m.y. date obtained on Klondike schist from Ogilvie map-area (GSC 60-33). It places final metamorphism in Lower Jurassic time, whereas the metamorphic age of the other sample is Upper Jurassic. In the Kluane Lake area, a date of 176 m.y. was obtained previously for biotite-quartz monzonite within Yukon Group metamorphic rocks (GSC 59-12) while nearby biotite-garnet schist gave 140 m.y. (GSC 59-11).

These dates suggest a Jurassic period of metamorphism and intrusion in the Yukon Complex, possibly related to Jurassic intrusions known elsewhere in the western Cordillera.

GSC 61-41 Biotite, K-Ar age 147 m.y.

K 7.67%, Ar^{40}/K^{40} .00891; radiogenic argon 94%. Concentrate: consists of clean, reddish brown biotite. About 30% of the flakes contain very small inclusions of quartz and opaque minerals. A few dark grey pleochroic haloes are present. Chlorite/ biotite 0.08.

From quartz-biotite schist.
(115 H) On Aishihik Road, mile-post 30; 61°14'N, 136°57'W. Map-unit 1, W.E. Cockfield, GSC Sum. Rept. 1926, pt. A, pp. 1-13. Sample XIII. Collected and interpreted by J.E. Muller.

Yukon Territory

The K-Ar date of 147 m.y. falls within the same general range as 140 m.y., obtained for a sample of quartz-biotite schist taken in the Kluane Lake area 40 miles to the west (GSC 59-11), and of 138 m.y. found in quartz-muscovite schist (Klondike schist) of the Ogilvie map-area (GSC 60-33). Cockfield considered the Yukon Group, from which this sample was taken, to be Precambrian, but metamorphosed to a high degree by the Coast Range Intrusions, of Jurassic to Lower Cretaceous age.

The K-Ar age, indicating Upper Jurassic metamorphism, may be construed to agree with his opinion. However, granite, sampled 11 miles south of the gneiss, gave a date of 65 m.y. and suggests that the metamorphosed terrain was intruded again at the end of the Mesozoic.

GSC 61-42 — Muscovite, K-Ar age 222 m.y.

K 3.93%, Ar^{40}/K^{40} .0138; radiogenic argon 100%. Concentrate: consists of about 70% muscovite flakes containing very fine, black, unidentified inclusions some patches of brownish decomposed biotite, and about 30% of impurities, mainly quartz. Only a trace of chlorite is present.

From quartz-muscovite schist.

(105 C) Near Morley River bridge, Alaska Highway, mile 777.7; 60°00'30"N, 132°8'20"W. Map-unit 1, GSC PS Map 54-20. Sample XXVII. Collected by J.E. Muller. Interpreted by R. Mulligan.

The sample was designed to check the K-Ar date of 214 m.y. (GSC 59-9) obtained on similar mica schist in the Teslin area. The 222-m.y. date of the check sample is well within the 10% possible error.

The rocks concerned are from a regionally metamorphosed group that, in part at least, underlies Mississippian limestone, and are much more highly metamorphosed than Permian and Mesozoic rocks.

The age is one of the oldest so far found in Cordilleran metamorphic rocks. It is also remarkably close to that of GSC 59-11 (223 m.y.) on hornblende granodiorite from Whitehorse map-area.

The indicated age suggests a period of metamorphism at the end of the Palaeozoic, corresponding with a widespread hiatus in the early Triassic stratigraphic record. However, the main contrast in metamorphism in the area is between Permian and older rocks, not between Mesozoic and Permian.

Yukon Territory

This relationship also holds in the Tuya-Teslin and Dease Lake - Cry Lake areas farther southeast along the metamorphic belt (H. Gabrielse, personal communication).

Thus the indicated age fails to confirm the field evidence for a pre-late Permian interval of metamorphism, according to current geochronological estimates.

GSC 61-43 — Biotite, K-Ar age 100 m.y.

K 7.16%, Ar^{40}/K^{40} .00602; radiogenic argon 89%. Concentrate: clean fresh brown biotite with 1-2% hornblende present as an impurity. Some flakes are partly coated with small quartz fragments. Chlorite not detected.

From porphyritic dacite.
(105 J) 0.4 mile west of triangulation station 7003 (Sheldon Lake Topo. Map); 62°31'N, 131°51'W. Map-unit 14, GSC Map 12-1961. Sample GC 60-843b. Collected and interpreted by L.H. Green.

(For interpretation see determination GSC 61-44).

GSC 61-44 — Biotite, K-Ar age 117 m.y.

K 7.07%, Ar^{40}/K^{40} .00705; radiogenic argon 100%. Concentrate: consists of reasonably clean, fresh brown biotite. A small amount of brown hornblende is present as an impurity. Chlorite/biotite 0.01.

From porphyritic dacite.
(105 K) 8.0 miles northwest of the west end of Tay Lake; 62°27'N, 132°18'W. Map-unit 14, GSC Map 13-1961. Sample GC-60-839. Collected and interpreted by L.H. Green.

The dates obtained from the dacite (117 m.y., GSC 61-44, and 100 m.y., GSC 61-43) are close to those obtained from the Cassiar batholith and the Marker Lake batholith approximately 140 miles to the southeast. Preliminary field work suggests a gradation from granodiorite, through coarsely porphyritic rocks, to porphyritic dacite, may occur near the location of the dacite samples. The dates obtained appear to support this suggestion.

Yukon Territory

GSC 61-45 Biotite, K-Ar age 126 m.y.

K 7.75%, Ar^{40}/K^{40} .00759; radiogenic argon 96%. Concentrate: consists mainly of biotite varying in colour from brown to green. About 5% green chlorite containing long prismatic inclusions is present as an impurity. Chlorite/biotite 0.11.

From granodiorite.
(105 B) 3 miles north-northwest of north end of Marker Lake; 60°33'N, 130°57'W. Map-unit 15a, GSC Map 10-1960. Sample GC 59-218. Collected and interpreted by L. H. Green.

The age obtained (126 m.y.) from the Marker Lake batholith, a possible satellite of the Cassiar batholith, differs from that obtained from metamorphic rocks 7 miles to the northeast (GSC 60-30, 98 m.y.), and from the Cassiar batholith 18 miles to the southwest (GSC 60-28, 98 m.y.). The significance of this variation is unknown.

Alaska

GSC 61-46

Biotite, K-Ar age 65 m.y.

K 7.33%, Ar^{40}/K^{40} .00385; radiogenic argon 76%. Concentrate: consists of mainly brown biotite flakes with inclusions of prismatic apatite. About 20% of the flakes are a greenish olive colour. A few flakes of dark green chlorite are present. Chlorite/biotite 0.05.

From biotite leucogranite.
(104 M) W.P. and Y.R. Railway, mile 11.9; 59°34'N, 135°11'W. Sample CB-55-4-15/1. Collected and interpreted by R. L. Christie.

(For interpretation see determination GSC 61-47.)

GSC 61-47

Biotite, K-Ar age 70 m.y.

K 7.23%, Ar^{40}/K^{40} .00416; radiogenic argon 91%. Concentrate: consists of dark brown to nearly opaque biotite containing numerous inclusions of apatite. About 10% of flakes show greenish chloritization along the edges. Chlorite/biotite 0.06.

From biotite leucogranodiorite.
(104 M) W.P. and Y.R. Railway, mile 9, at east fork of Skagway River; 59°30'30"N, 135°13'30"W. Sample CB-55-4-15/3. Collected and interpreted by R.L. Christie.

Samples GSC 61-46 and GSC 61-47 are from massive leucogranodiorite bodies which intrude variable, foliated hornblende-biotite quartz diorite (these are respectively the "brown granite" and the foliated quartz diorite suites that were described more fully in GSC Paper 61-17, p. 15). The K-Ar dates of 65 m.y. and 70 m.y., which suggest a late Cretaceous or early Cenozoic time of intrusion, confirm the 61-m.y. date (GSC 60-26) obtained on a similar, nearby, and possibly connected body.

Latest Lower or earliest Upper Cretaceous and later ages have been presumed generally for the "brown granites" of north-western British Columbia and southwestern Yukon from intrusive relations and from the appearance of leucogranitic boulders for the first time in Upper Cretaceous conglomerates. The presumptions appear satisfactory in the light of the K-Ar dates, although the isotopic dates generally appear slightly younger than expected. The discrepancy may eventually be resolved, however, when the somewhat contentious dating of the end of Cretaceous time is fixed with greater assurance. Muller (GSC Paper 61-17, p. 104) discusses this problem, and notes that rocks dated between 60 m.y. and 70 m.y. should perhaps be considered Upper Cretaceous.

District of Franklin

GSC 61-48 Biotite, K-Ar age 360 m.y.

K 7.54%, Ar^{40}/K^{40} .0231; radiogenic argon 95%. Concentrate: consists mainly of clean ginger-brown biotite flakes with rare zircon inclusions surrounded by dark pleochroic haloes. About 10-15% of the flakes are partly bleached and contain minor inclusions of quartz, epidote, and chloritized patches. Chlorite/biotite 0.12.

From quartz diorite.
(560 D) At the foot of a ridge; 81°14'15"N, 94°20'W. Map-unit A, GSC PS map in preparation. Sample TM-47a. Collected and interpreted by H. P. Trettin.

The sample locality lies between Cape Thomas Hubbard and Rens Fiord, in the northernmost part of Axel Heiberg Island where a thick section of the Franklinian eugeosyncline is exposed. The eugeosynclinal strata there range in age from Lower Silurian or older to Lower Devonian or younger. The sample was taken from one of several small plutons of granodiorite and quartz diorite intruding the Lower Silurian and/or older Rens Fiord complex. This complex is the only rock unit in the area that shows appreciable regional metamorphism. The intrusions and their thermo-metamorphic aureoles are younger than the regional metamorphism. As the dioritic intrusions are confined to the oldest rocks these plutons were expected to be Silurian or older in age. However, the K-Ar date of 360 m.y. corresponds well with a postulated Middle to Upper Devonian orogeny. That orogeny was inferred, first, from an angular unconformity which in this area separates Lower Devonian or younger strata from late Lower Mississippian beds, and secondly, from lithology, thickness, and distribution of certain Upper Devonian sediments in the central parts of the Arctic Archipelago (Thorsteinsson and Tozer, 1960). This orogeny has produced severe structural deformation but no appreciable regional metamorphism. Therefore the age of 360 m.y. may indicate the time of intrusion. It is however possible that the emplacement of these plutons occurred in Silurian or earlier time and that the postulated Middle to Upper Devonian orogeny has affected the K:Ar ratio of the mica analyzed.

GSC 61-49 Biotite, K-Ar age 1,760 m.y.

K 8.23%, Ar^{40}/K^{40} .1699; radiogenic argon 99%. Concentrate: consists of clean ginger-brown biotite. A few dendritic and prismatic inclusions of opaque minerals are present and a few flakes are bleached. Impurities consist of a few fragments of feldspar. Chlorite/biotite 0.01.

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(39 B) From biotite-garnet-quartz-feldspar gneiss. About 1 mile north of north edge of terminus of large glacier northwest of Coburg Island; 76°20'N, 79°25'W. Sample CB-60-3-36/A. Collected and interpreted by R. L. Christie.

The specimen represents the host rock of a ptygmatic complex of fine- to medium-grained, biotitic, garnetiferous gneiss. The 'intrusive' structures vary in size and mineral content from simple transecting veins and dykes of quartz-feldspar rock with minor biotite to intimately mixed material containing appreciable amounts of garnet and biotite.

The K-Ar date of 1,760 m.y. suggests that southeastern Ellesmere Island is a northern extension of the Churchill province, where K-Ar dates fall chiefly within the range 1,550 to 1,850 m.y.

GSC 61-50 Biotite, K-Ar age 1,780 m.y.

K 7.84%, Ar^{40}/K^{40} .1732; radiogenic argon 100%. Concentrate: consists of clean, fresh, olive-brown to opaque biotite. A few grains are slightly altered and contain numerous inclusions. A few garnet fragments occur as impurity. Chlorite/biotite 0.03.

(27 C) From mica schist. North shore of Clyde River, Baffin Island; 69°48'N, 70°35'W. Sample SH-10-61. Collected by E. H. Kranck. Described by C. H. Stockwell.

The sample is a black, biotite schist permeated along cleavage planes by pink granitic material. The biotite concentrate was obtained, no doubt, almost entirely from the black schist. The rock consists chiefly of quartz, andesine, microcline, fresh biotite, and a little muscovite, myrmekite, sillimanite, apatite, carbonate, and chlorite.

The sample is from the metasedimentary Clyde Series which consists of mica schists, quartzite, and marbles containing diopside, hornblende, chondrodite, and phlogopite. The series represents a less-metamorphosed part of the predominant gneisses of the region (Kranck, 1955, pp. 236-237).

GSC 61-51 Muscovite, K-Ar age 1,805 m.y.

K 8.54%, Ar^{40}/K^{40} .1772; radiogenic argon 100%. Concentrate: clean concentrate of compact muscovite with slightly stained ginger-brown edges. Chlorite not detected.

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From pegmatite.
(27 C) 3 miles south of Generator Lake, Baffin Island; 69°30'N, 71°48'W. Sample SH-11-61. Collected by E. H. Kranck. Described by C. H. Stockwell.

The sample consists of books of muscovite 1 inch across associated with quartz and red garnets.

The pegmatite has been described in detail by Kranck (1955, p. 234). It is exposed on the north slope of Eskimo Hill for a length of 600 feet and across a width of 150 to 200 feet. It consists of feldspar, quartz, muscovite, tourmaline (as crystals up to 3 feet long), columbite, and a little magnetite, sphene, apatite, and allanite.

GSC 61-52 Biotite, K-Ar age 1,740 m.y.

K 7.23%, Ar^{40}/K^{40} .1675; radiogenic argon 99%. Concentrate: clean, consisting of dark red-brown biotite flakes containing very small opaque specks along fractures. Chlorite not detected.

From pegmatite.
(25 K) 3 1/2 miles north of Soper Lake on the east side of stream into Soper Lake; 62°58'N, 69°52'W. Map-unit 3, GSC Map 29-1958. Sample SL37A-51. Collected and interpreted by W. L. Davison.

The sample, collected primarily for its allanite content, is from a pegmatite that lies close to the nose of a north-northeast-trending fold. The geological setting, mineral assemblage, and internal structure of the pegmatite indicates that it was emplaced during a late stage of the latest orogeny that has affected the region.

Allanite crystals, with thin altered borders, have evidently grown, or expanded, so as to deform closely associated biotite and feldspar. It was therefore anticipated that the K-Ar age determination might give a younger age than those obtained from other micas of southern Baffin Island (GSC 59-36, GSC 59-37, and GSC 59-38). The age, however, although within the general range, is on the high side. The significance of this small deviation cannot be evaluated without further determinations on micas from southeast Baffin Island.

GSC 61-53 Muscovite, K-Ar age 2,405 m.y.

K 8.66%, Ar^{40}/K^{40}.2854; radiogenic argon 98%. Concentrate: consists of reasonably pure muscovite.

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About 10% of flakes contain inclusions of quartz. Free fragments of quartz and microcline constitute about 4% of the sample. Chlorite not detected.

From granodiorite.

(77 G) Point opposite islands in southwesternmost part of Hadley Bay, Victoria Island; 71°45'N, 108°10'W. Map-unit 2, GSC Map 20-1961. Sample CB-59-3-4/A. Collected and interpreted by R. L. Christie.

Coarse grey to pink granodiorite is exposed over an area about 1/2 mile by 3 miles. Relations with adjacent Precambrian sedimentary and metamorphic rocks are uncertain, but there is evidence for presuming that the granodiorite intrudes a formation of quartzites and both are overlain unconformably by unmetamorphosed basal beds of the Shaler Group. (The latter beds, named by Thorsteinsson and Tozer in GSC Paper 61-12, p. 2, are later Precambrian sedimentary beds similar to the Coppermine River Series.)

From the K-Ar date of 2,405 m.y. it seems apparent that the Hadley Bay granodiorite and quartzite terrane is related to, and perhaps is a distant inlier of the Slave (Yellowknife) structural province, where K-Ar dates range from about 2,000 m.y. to 2,500 m.y. The Hadley Bay terrane is the northernmost exposure known of the "most ancient" masses that are incorporated within the North American continental framework.

A relatively young age is indicated for the Shaler and Coppermine River terrane by K-Ar dates from the mainland (Lowdon, 1961), and the presumed geological relationships are thus confirmed.

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GSC 61-54 Glauconite, K-Ar age 470 m.y.

K 6.86%, Ar^{40}/K^{40} .0312; radiogenic argon 42%. Concentrate: consists of fine-grained granular aggregates. The glauconite grains range in size from less than 1 micron to 2 microns and are coarser along the outer parts of the granular aggregates. A few of the granules are intergrown with quartz.

From shale.
(96 P) Haldane River; 67°14'N, 120°41'W. Map-unit 21, GSC PS Map 18-1960. Sample GSC 41183. Submitted by J.C. Sproule and Associates Limited, Calgary. Interpreted by J.A. Fraser.

The sample is from greenish grey shale containing poorly preserved fossils that have been identified as Lower Palaeozoic, possibly Middle or Upper Cambrian. Lithologically similar shale in the same region overlies sandstone considered to be Cambrian. The sandstone is underlain unconformably by Proterozoic dolomite of the Hornby Bay Group.

The K-Ar age of the glauconite indicates it to be Ordovician, assuming an age for the Cambrian-Ordovician boundary of 500 m.y. If allowance is made, however, for the possibility that the K-Ar ages of Lower Palaeozoic glauconites may underestimate the true age, the result is not inconsistent with a Cambrian age.

GSC 61-55 Biotite, K-Ar age 1,785 m.y.

K 7.80%, Ar^{40}/K^{40} .1741; radiogenic argon 93%. Concentrate: flakes are mainly olive-brown with large brown pleochroic haloes surrounding small prisms of zircon. About 20% of the flakes are olive-green, slightly bleached, and have disseminated small inclusions. About 10% of the flakes are gradational from pale biotite to greenish chlorite. Chlorite/biotite 0.09.

From quartz monzonite.
(86 G) Station F66, Camsell River; 65°18'N, 114°29'W. Map-unit 3d, GSC PS Map 18-1960. Sample FD-46-59. Collected and interpreted by J.A. Fraser.

The biotite is from granodiorite containing large inclusions of calc-silicate hornfels. The hornfels has probably been derived from dolomite of the Epworth Formation or from dolomite of the Snare Group. The date of 1,785 m.y. would thus represent a lower limit for one or both of these groups. Age relationships between the two groups have not yet been worked out from field evidence but both groups are known to overlie granite unconformably and are generally considered to be Proterozoic.

GSC 61-56 Sericite, K-Ar age 1,855 m.y.

K 5.27%, Ar^{40}/K^{40} .1848; radiogenic argon 88%. Concentrate: consists of 50% fine-grained sericite (less than 40 microns in diameter), 25% quartz, 15% feldspar, and 10% chlorite.

From sillimanite-biotite schist.
(86 C) West shore of Grant Lake; 64°50'40"N, 116°37'00"W. Map-unit B, GSC Map 697A. Sample SH-54-59. Collected by C.H. Stockwell. Interpreted by J.Y.H. Rimsaite.

The sericite is an alteration product of feldspar. It also occurs in fractures in garnet and is associated with chlorite that replaces biotite.

The sericite has been dated to allow comparison with the ages obtained on two biotite concentrates prepared from the same rock: GSC 60-40 which contained 60% reasonably fresh biotite and 40% biotite partly altered to chlorite, and GSC 60-41 which contained 20% reasonably fresh biotite and 80% partly to completely chloritized biotite.

The chloritized biotite apparently served as a diluent and both concentrates gave the same age of 1,720 m.y. (GSC Paper 61-17, pp. 23, 24).

The age of the impure sericite (1,855 m.y.) is a mixed age of sericite and of feldspar which constituted approximately 15% of the concentrate. As the sericite is an alteration product of the feldspar, it is paragenetically younger than the feldspar. How this date is affected by the presence of feldspar is not known. As altered feldspar may lose argon more readily than mica, the age of the pure sericite may be older than 1,855 m.y. On the other hand, the feldspar may have been much older than the sericite (even detrital) and in such a case, pure sericite might give a lower age than 1,855 m.y.

The complex assemblage of minerals and the texture suggest that this rock was affected by more than one stage of metamorphism. This, coupled with the impure nature of the mica concentrates, precludes any reasonable interpretation of the age pattern.

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GSC 61-57 Biotite, K-Ar age 1,810 m.y.

K 6.17%, Ar^{40}/K^{40} .1774; radiogenic argon 99%. Concentrate: consists of fine-grained brown biotite with attached impurities including quartz, muscovite, hornblende, apatite, and opaque minerals. Hornblende, muscovite and quartz are also present as separate grains. The estimated biotite content is 75%. Hornblende is the main impurity. Chlorite not detected.

From biotite-amphibole schist.
(85 N) North shore of Saddle Lake; 63°55'10"N, 116°27'50"W. Map-unit 4, GSC Map 690A. Sample SH-56-59. Collected and described by C.H. Stockwell.

This is a fine-grained, black, schistose rock showing tiny, glistening flakes of biotite on cleavage faces. In addition to biotite, which is fresh, the rock contains pale green hornblende, quartz, labradorite, and accessory magnetite.

The sample is from a knotted, quartz-mica schist that is a member of the Snare Group. It was taken from a locality just south of a contact with a large body of post-Snare granite and, on the outcrop, is cut by small dykes of white, biotite granite which apparently are offshoots from the large body. The K-Ar age is a minimum for the Snare Group and probably approximates the age of the granite.

GSC 61-58 Biotite, K-Ar age 1,765 m.y.

K 5.79%, Ar^{40}/K^{40} .1709; radiogenic argon 100%. Concentrate: contains about 65% reasonably clean, dark brown biotite; about 20% chloritized biotite and some free chlorite; and about 15% hornblende. Chlorite/biotite 0.40.

From intrusive porphyry.
(86 C) Shore of a small lake, 10.5 miles west of the south-east end of Little Crapeau Lake; 64°46'30"N, 116°12"W. Map-unit 9, GSC Map 697A. Sample MC-A-10. Collected and interpreted by J.C. McGlynn.

This biotite is from an intrusive porphyry that cuts rocks which, on the basis of similar distinctive mineral assemblages, have been correlated with the Echo-Cameron Bay Group of volcanic and sedimentary rocks at Great Bear Lake. If the correlation is correct, the date, then, gives a minimum age for the Echo-Cameron Bay Group.

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GSC 61-59 Muscovite, K-Ar age 1,815 m.y.

K 8.93%, Ar^{40}/K^{40} .1788; radiogenic argon 100%. Concentrate: contains about 70% clean muscovite flakes, and about 30% of flakes coated with small grains of quartz and flakes with yellowish films and stained patches. A few flakes contain long acicular inclusions. Chlorite not detected.

From altered quartzite.
(85 N) Southwest of Basler Lake; 63°50'30"N, 116°11'W. Map-unit B, GSC Map 690A. Sample MC-A-3. Collected and interpreted by J. C. McGlynn.

This sample is from a metamorphosed quartzite inclusion in a granodiorite body. The quartzite is lithologically similar to sediments of the Snare Group and this age determination indicates that the enclosing granitic rock is post-Snare. However, biotite in sample GSC 60-47, located about 4 miles to the southwest from what was thought to be the same granitic mass, dated at 2,460 m.y. More field work will have to be done before these dates can be properly interpreted.

GSC 61-60 Biotite, K-Ar age 1,905 m.y.

K 7.85%, Ar^{40}/K^{40} .1927; radiogenic argon 98%. Concentrate: consists of clean, pale to dark brown biotite. Minor impurities include a few fragments of quartz and muscovite, and some biotite coated with dark brown to opaque fine-grained iron oxides. Chlorite not detected.

From granodiorite.
(85 O) Shore of central part of Basler Lake; 63°55'N, 115°56'W. Map-unit B, GSC Map 690A. Sample MC-A-4. Collected and interpreted by J. C. McGlynn.

(For interpretation see determination GSC 61-63.)

GSC 61-61 Muscovite, K-Ar age 2,155 m.y.

K 8.47%, Ar^{40}/K^{40}.2357; radiogenic argon 96%. Concentrate: consists of about 80% clean muscovite flakes, and 20% muscovite intergrown with fine-grained quartz in varying amounts. Chlorite content not determined.

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From granodiorite.
(85 O) Shore of central part of Basler Lake; 63°55'N, 115°56'W. Map-unit B, GSC Map 690A. Sample MC-A-4. Collected and interpreted by J. C. McGlynn.

(For interpretation see determination GSC 61-63.)

GSC 61-62 Muscovite, K-Ar age 2,415 m.y.

K 8.50%, Ar^{40}/K^{40} .2869, radiogenic argon 99%. Concentrate: consists of about 65% colourless and 25% buff-coloured muscovite. The buff colour is probably due to iron staining. Feldspar and quartz impurities probably total less than 10%. Chlorite not detected.

From granodiorite.
(85 O) On shore of central part of Kwejinne Lake; 63°46'30"N, 115°56'W. Map-unit B, GSC Map 690A. Sample MC-B-60. Collected and interpreted by J. C. McGlynn.

(For interpretation see determination GSC 61-63.)

GSC 61-63 Biotite, K-Ar age 1,755 m.y.

K 6.61%, Ar^{40}/K^{40} .1697; radiogenic argon 100%. Concentrate: reasonably clean but the biotite is considerably altered and varies in colour. Concentrate consists of: (1) about 50% olive-green to brown biotite flakes with large brown pleochroic haloes and irregular brown patches, some grading into green chlorite; (2) about 20% almost opaque biotite coated with fine-grained iron oxides; (3) about 15% intergrowths of muscovite and chloritized biotite; (4) about 10% bright green chloritized biotite; (5) about 3% muscovite; and (6) about 2% fresh red-brown biotite with black unidentified inclusions. Chlorite/biotite 0.33.

From granodiorite.
(85 O) On shore of central part of Kwejinne Lake; 63°46'30"N, 115°56'W. Map-unit B, GSC Map 690A. Sample MC-B-60. Collected and interpreted by J. C. McGlynn.

The biotite of GSC 61-63 and muscovite of GSC 61-62 are from one sample of a granodiorite that cuts rocks of the Yellowknife

Group. Sediments of the Snare Group overlie rocks of the Yellowknife Group unconformably and were deposited on the granodiorite. The granodiorite is therefore known to be older than the Snare sediments from field evidence. In the general area, mica from granitic rocks that cut the Yellowknife Group and are older than Snare sediments give dates of about 2,300 m.y. Mica from granite rocks that cut the Snare Group give ages of between 1,700 and 1,800 m.y. Therefore, from what is known of the field relations of the granodiorite and the regional distribution of dates, the muscovite (GSC 61-62) gives the expected age of the granodiorite. Biotite (GSC 61-63) gives an age equivalent to that of post-Snare granitic rocks and metamorphism. Study of thin sections shows that the muscovite is unaltered, whereas biotite is extensively altered to chlorite. Also locally there is evidence of crushing of the granodiorite. Preliminary study of the metamorphism of the sediments of the Yellowknife Group cut by this granodiorite indicates that they were metamorphosed at about the time of intrusion of the granodiorite and remetamorphosed—possibly at the same time as the Snare sediments were metamorphosed. The biotite date (GSC 61-63) is probably the result of this second metamorphism which affected the Snare and Yellowknife Groups.

Biotite (GSC 61-60) and muscovite (GSC 61-61) are from a different place in the same granodiorite mass. There both dates are less than the expected age of the granodiorite but older than the age of Snare intrusions. In thin section the muscovite appears unaltered and the biotite is slightly altered mainly to chlorite. In this case it is suggested that both micas were affected by the second metamorphism so that some argon was lost, resulting in dates less than the expected age of the granodiorite.

GSC 61-64 Biotite, K-Ar 2,490 m.y.

K 7.03%, Ar^{40}/K^{40} .3027; radiogenic argon 100%. Concentrate: consists of about 20% dark brown to opaque biotite flakes containing rare zircon inclusions surrounded by black pleochroic haloes; about 30% lighter brown clean flakes; about 30% greenish brown flakes; and about 20% partly chloritized greenish flakes with branching inclusions along the edges. Chlorite/biotite 0.1.

From granite.

(85 J) Road-cut, 28.5 miles west of Yellowknife airport along the highway toward Rae; 62°34'N, 115°09'W. Map-unit 13, GSC Map 1055A. Sample SH-46-59. Collected and described by C.H. Stockwell.

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The granite is a massive, pink, coarse-grained rock with feldspar crystals mostly about 1/2 inch long. Constituent minerals include quartz, microcline, oligoclase, biotite, hornblende, epidote, and accessory titanite, apatite, and magnetite. The oligoclase is clouded with sericite and the epidote is closely associated with biotite.

The rock is massive and is not cut by dykes of aplite and granite such as cut gneissic granites farther east, and may, therefore, be the youngest granite of the area. The biotite is thought to date the time of crystallization of the granite.

GSC 61-65 Biotite, K-Ar age 2,365 m.y.

K 7.12%, Ar^{40}/K^{40} .2767; radiogenic argon 99%. Concentrate: consists of biotite flakes that vary from medium reddish brown to bleached creamy-buff. Some zircon inclusions surrounded by pleochroic haloes occur. Concentrate consists of about 60% clean flakes and 40% flakes with fine inclusions of quartz and epidote. Chlorite/biotite 0.18.

From paragneiss.
(85 O) West shore of bay in east part of Germaine Lake; 63°17'45"N, 114°33'50"W. Map-unit 3, GSC Map 49-14. Sample SH-48-59. Collected and described by C.H. Stockwell.

The sample is a medium-grained, dark grey paragneiss with a fairly good foliation, and is composed of quartz, oligoclase, cordierite, biotite, and a little muscovite, zircon, apatite, and pyrite. The cordierite, is almost completely altered to sericite and chlorite and the biotite is mostly fresh but some is interleaved with chlorite.

On the outcrop the paragneiss is seen to be cut lit-par-lit by bodies of white and pink granite. The paragneiss is no doubt a metamorphosed equivalent of the Yellowknife Group and the determined age of metamorphism is, of course, a minimum for the group.

GSC 61-66 Biotite, K-Ar age 2,615 m.y.

K 7.49%, Ar^{40}/K^{40} .3308; radiogenic argon 99%. Concentrate: consists of dark brown biotite flakes with pleochroic haloes. Some have bleached edges and contain numerous fine inclusions. Some free chlorite is present. Chlorite/biotite 0.10.

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(85 J) From granodiorite.
End of peninsula near north end of Mason Lake; 62°24'25"N, 114°03'55"W. Map-unit 7a, GSC Map 709A. Sample SH-81-59. Collected and described by C. H. Stockwell.

The sample is a massive, equigranular, medium-grained granodiorite composed of quartz, oligoclase, biotite, and minor muscovite, chlorite, and apatite. The oligoclase is slightly altered to sericite. The biotite is fresh and clear except for a few inclusions of zircon with pleochroic haloes. The chlorite forms separate flakes distinct from those of the unaltered biotite. It may have crystallized earlier, for, if later, one would expect to see various stages of chloritization of biotite.

The granodiorite invades rocks of the Yellowknife Group and the biotite age is a minimum for this group. According to A. W. Jolliffe, the author of the map, the granodiorite is older than the Prosperous Granite (dated 2,540 m.y., GSC 60-49, as compared with 2,615 m.y. for the granodiorite) but the potassium-argon method does not distinguish the two. Two possible explanations present themselves: either the two rocks belong to the same general period of igneous activity and the potassium-argon method is not accurate enough to distinguish them or, less likely, the granodiorite is much older and the biotite was recrystallized when the Prosperous Granite was introduced, which would explain the biotite-chlorite relationship described above.

GSC 61-67 Muscovite, K-Ar age 2,495 m.y.

K 8.70%, Ar^{40}/K^{40} .3041; radiogenic argon 100%.
Concentrate: consists of clean muscovite flakes containing very fine grained inclusions of quartz. Chlorite not detected.

From granite pegmatite.
(85 I) About 3,650 feet east-northeast of Peg Tantalum pier on Ross Lake and beside the road to Peg Tantalum workings; 62°44'30"N, 113°07'W. Map-unit 4, GSC Paper 47-16. Sample BLO-30. Collected and interpreted by W. R. A. Baragar.

The sample is from a beryl pegmatite (pegmatite No. 190, GSC Bull. 34) which is one of a swarm of pegmatites that intrudes a granodiorite-gneiss-amphibolite assemblage between Upper Ross Lake and Redout Lake in the Beaulieu River area. A younger granite lies about 2 1/4 miles to the east. The date is in close agreement with a date previously determined for the Prosperous Lake granite (2,540 m.y., GSC 60-49) which is a typical representative of the younger granites of the region. A close spatial relationship coupled with the similarity in dates is strong evidence that the rare-element pegmatites of the Yellowknife-Beaulieu River area are genetically linked with the younger granites of the region.

GSC 61-68 Muscovite, K-Ar age 2,555 m.y.

K 8.30%, Ar^{40}/K^{40} .3168; radiogenic argon 100%. Concentrate: consists of about 60% clean muscovite; about 20% muscovite with micrographic intergrowths of quartz along the edges; about 20% muscovite flakes partly coated with iron oxides; and a few separate grains of quartz and feldspar. Chlorite/muscovite 0.01.

From quartz monzonite.
(85 I) Peninsula, east side of Redout Lake; 62°45'36"N, 113°02'08"W. Map-unit 6, GSC Map 645A. Sample SH-61-59. Collected and described by C.H. Stockwell.

The quartz monzonite is a massive, medium-grained, pink rock composed of quartz, oligoclase, microcline, myrmekite, biotite, muscovite, and minor apatite and epidote.

It is mapped as the younger of two batholithic bodies of the area on the evidence that gabbro dykes cut the older and are cut by the younger. The K-Ar age is thought to indicate the approximate time of primary crystallization of the younger body.

GSC 61-69 Muscovite, K-Ar age 2,465 m.y.

K 7.48%, Ar^{40}/K^{40} .2976; radiogenic argon 100%. Concentrate: consists of 80-90% reasonably clean muscovite flakes containing minor quartz and sillimanite inclusions, and 10-20% impurities, which include sillimanite, sillimanite-quartz, and feldspar-sillimanite-quartz-muscovite intergrowths, and muscovite with attached specks of biotite. Only a trace of chlorite is present.

From biotite paragneiss.
(75 L) Mouth of Barnston River, Great Slave Lake; 62°56'20"N, 110°10'40"W. Map-unit 2C, GSC Map 51-25A. Sample SH-64-59. Collected and described by C.H. Stockwell.

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This muscovite is from the same sample that yielded the biotite which, as previously reported under GSC 60-51, gave an age of 2, 370 m.y. The two determinations are in reasonably good agreement with one another.

The ages are minima for the Yellowknife Group and maxima for the Great Slave Group. (For description of sample see determination GSC 60-51.)

GSC 61-70 Muscovite, K-Ar age 2,410 m.y.

K 8.72%, Ar^{40}/K^{40} .2855; radiogenic argon 100%. Concentrate is reasonably clean. Total impurities, such as quartz and minor feldspar, are estimated at about 5%. Chlorite not detected.

From migmatite.
(75 N) East shore of an unnamed lake west of Walmsley Lake; 63°24'40"N, 108°45'30"W. Map-unit 6B, GSC Map 1013A. Sample SH-70-59. Collected and described by C.H. Stockwell.

(For description see determination GSC 61-71.)

GSC 61-71 Biotite, K-Ar age 2,465 m.y.

K 7.34%, Ar^{40}/K^{40} .2973; radiogenic argon 99%. Concentrate: consists of somewhat altered biotite varying from dark red-brown to dull grey. Many flakes are partly bleached along fractures and contain minute needles and inclusions. Some flakes contain inclusions of zircon surrounded by pleochroic haloes. Chlorite/biotite 0.21.

From migmatite.
(75 N) East shore of unnamed lake west of Walmsley Lake, 63°24'40"N, 108°45'30"W; Map-unit 6B, GSC Map 1013A. Sample SH-70-59. Collected and described by C.H. Stockwell.

The sample is a mixed rock composed of white, pegmatitic, muscovite granite with interleaved streaks of less highly granitized material rich in biotite. In addition to the two micas the rock contains quartz, oligoclase, microcline, and orthoclase. The oligoclase is slightly sericitized; the muscovite is fresh although some crystals are bent and broken; the biotite encloses crystals of zircon with pleochroic haloes and is speckled with opaque material, but is generally unchloritized.

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Two concentrates were made from the same sample: one of muscovite (GSC 61-70) giving an age of 2,410 m.y., and the other of biotite (GSC 61-71) giving, in good agreement, an age of 2,465 m.y.

The sample represents a highly granitized phase of the Yellowknife Group, and the determined ages give the time of granitization and metamorphism and, of course, are minima for the time of deposition of the Yellowknife.

GSC 61-72 Biotite, K-Ar age 1,945 m.y.

K 7.53%, Ar^{40}/K^{40}.1994; radiogenic argon 100%. Concentrate: fresh biotite. Chlorite not detected.

From quartz-feldspar-biotite gneiss.
(85 P) Small island in narrows in Beniah Lake; 63°23'15"N, 112°20'20"W. Map-unit 6, GSC PS Map 51-8. Sample SH-63-59. Collected and described by C. H. Stockwell.

The gneiss is a dark grey, medium-grained, weakly foliated rock composed of a mosaic of quartz, oligoclase, and abundant brown, clear, unchloritized biotite; apatite is accessory. The sample contains many small lenses of white granite and, on the outcrop, the gneiss is cut by sills of pink and white granite. The age obtained for the biotite dates the approximate time of metamorphism and granitic intrusion.

GSC 61-73 Biotite, K-Ar age 2,100 m.y.

K 7.60%, Ar^{40}/K^{40}.2259; radiogenic argon 100%. Concentrate: consists of about 70% brown biotite flakes with sagenitic inclusions and about 30% biotite flakes with slightly chloritized edges and green patches containing small, roughly hexagonal plates along fractures, and patches of fine-grained anatase. About 10% of the flakes are almost opaque. Chlorite/biotite 0.07.

From granite.
(85 O) East shore of bay extending south from Ghost Lake; 63°47'50"N, 115°15'05"W. Map-unit 8, GSC Map 1021A. Sample SH-49-59. Collected and discussed by C. H. Stockwell.

District of Mackenzie

The sample is a massive, coarse-grained, pink granite in which feldspar crystals are mostly 1/2 to 1 inch long. As seen in thin section the rock is composed of microcline and lesser amounts of plagioclase, quartz, myrmekite, biotite, apatite, and zircon. The plagioclase is much altered to sericite and zoisite. The biotite apparently occurs in two generations, the older forming scattered flakes almost completely altered to chlorite, and the younger, which is fresh, forming bunches of crystals lying in the interstices between large feldspar crystals.

The granite cuts rocks of the Yellowknife Group and is mapped as the youngest granitic intrusion of the Ghost Lake area, but as no sample of the other granitic rocks of the area was collected, the geological relationships cannot be checked. In any case it is not at all certain that the K-Ar age of 2, 100 m.y. may not reflect a period of metamorphism, as suggested by the two generations of biotite and by the variable character of the biotite concentrate. The determined age is much younger than the prevalent ages of 2, 335 to 2, 615 m.y. found to the southeast but falls within a group of younger ages varying from 1, 790 to 2, 115 m.y. found in the Fort Enterprise area to the northeast and which apparently indicate an effect of the Hudsonian orogeny in this part of the Slave province.

GSC 61-74 — Muscovite, K-Ar age 2, 100 m.y.

K 8.79%, Ar^{40}/K^{40} .2258; radiogenic argon 100%. Concentrate: reasonably clean, consisting of about 70% clean muscovite; about 20% muscovite flakes with adhering specks of biotite and ginger-brown surface stains; and about 20% muscovite flakes with micrographic intergrowths of quartz and feldspar along the edges. Chlorite not detected.

From quartz monzonite.
(76 K) West of Bathurst Inlet; 66°58'N, 109°54'W. Unmapped area. Sample FD-604-61. Collected and interpreted by J.A. Fraser.

(For interpretation see determination GSC 61-75.)

GSC 61-75 — Biotite, K-Ar age 1, 890 m.y.

K 7.24%, Ar^{40}/K^{40} .1901; radiogenic argon 75%. Concentrate: flakes vary in colour from brown (60%) to greenish (40%). Some flakes contain small zircon inclusions surrounded by pleochroic haloes. Chloritized biotite and free chlorite constitute about 10% of the sample. Chlorite/biotite 0.15.

District of Mackenzie

From quartz monzonite.
(76 K) West of Bathurst Inlet; 66°58'N, 109°54'W. Unmapped area. Sample FD-604-61. Collected and interpreted by J. A. Fraser.

From aerial reconnaissance, the area appears to be underlain chiefly by granitic rocks. The quartz monzonite is a medium- to coarse-grained, massive, pink rock, comprising quartz, microcline, orthoclase, oligoclase, myrmekite, biotite, and muscovite. It is cut by dykes of very coarse grained pegmatite, up to 30 cm wide. The ages of the biotite (GSC 61-75) and muscovite (GSC 61-74) fall within the range of published ages (GSC Paper 61-17, Fig. 2) of samples from the Slave province.

GSC 61-76 Muscovite, K-Ar age 2,575 m.y.

K 8.87%, Ar^{40}/K^{40} .3216; radiogenic argon 100%. Concentrate: consists of good, clean muscovite. A few flakes contain small inclusions of quartz, and a few fragments of quartz and feldspar are present as impurities. Chlorite not detected.

From quartz monzonite.
(75 E) East end of Union Island, Great Slave Lake; 61°59'20"N, 111°48'00"W. Map-unit 5, GSC Map 377A. Sample SH-45-59. Collected and described by C. H. Stockwell.

The quartz monzonite is a massive, medium-grained, salmon-pink rock composed of oligoclase, microcline, orthoclase, quartz, muscovite, and chlorite. The oligoclase is slightly clouded with sericite and carbonate and the chlorite is thought to have formed by alteration of biotite.

The quartz monzonite is overlain unconformably by sediments of the Union Island Group (for description of the unconformity see Geol. Surv., Canada, Sum. Report 1932, pt. C, p. 58c). The muscovite is primary and the age obtained gives the time of crystallization of the quartz monzonite. It is a maximum for the Union Island.

GSC 61-77 Biotite, K-Ar age 2,555 m.y.

K 7.39%, Ar^{40}/K^{40} .3172; radiogenic argon 100%. Concentrate: consists of clean ginger-brown biotite. About half of the flakes are slightly altered, contain numerous inclusions along fractures, and have bleached edges. A few flakes of greenish grey chlorite are present. Chlorite/biotite 0.15.

District of Mackenzie

From paragneiss.
(85 H) Simpson Islands, Great Slave Lake; 61°41'20"N, 112°53'00"W. Map-unit 4, GSC Map 377A. Sample SH-82-59. Collected and described by C.H. Stockwell.

The sample is a medium-grained, dark grey paragneiss that is partly granitized, with the development of crystals and streaks of light grey feldspar. As seen in thin section, the rock is composed of plentiful quartz, oligoclase, and biotite, and minor amounts of microcline, garnet, and pyrite. The biotite is mostly clear and fresh but some flakes are considerably altered to chlorite.

The paragneiss is overlain unconformably by the Sosan Formation which is the basal member of the Great Slave Group. The determined age dates the time of granitization and metamorphism and is a maximum for the Great Slave Group.

GSC 61-78 Biotite, K-Ar age 1,845 m.y.

K 7.21%, Ar^{40}/K^{40} .1831; radiogenic argon 94%. Concentrate: contains about 60% fresh, olive-brown to almost opaque biotite, and 35% slightly bleached flakes with small inclusions along the margins. About 5% hornblende is present as an impurity. Chlorite/biotite 0.07.

From biotite-hornblende granite.
(75 K) 0.6 mile east-southeast of north end of Wilson Lake, east arm of Great Slave Lake; 62°29'45"N, 109°52'W. Map-unit 13, GSC Map 378A. Sample BLO-31. Collected and interpreted by W.R.A. Baragar.

The sample is from a hornblende granodiorite (with locally significant amounts of biotite) that intrudes members of the Great Slave Group in the east arm of Great Slave Lake. C.H. Stockwell assigns it an age post-dating the Great Slave Group and pre-dating the Et-Then Series. Hence, 1,845 m.y. represents a minimum for the Great Slave Group and a maximum for the Et-Then Series.

GSC 61-79 Biotite, K-Ar age 1,780 m.y.

K 5.27%, Ar^{40}/K^{40} .1730; radiogenic argon 97%. Concentrate: consists mainly of brown biotite flakes with bleached patches, and peppered with very small colourless inclusions. Minor attached impurities include chlorite, muscovite, and quartz. The X-ray pattern shows unresolved biotite (003) and chlorite (004) peaks, making the measurement of the chlorite/ biotite ratio difficult. The approximate value is 0.5.

From mica schist.

(75 E) Small island near the west shore of an unnamed lake, just west of Rutledge Lake, 61°33'40"N, 110°42'30"W. Map-unit 2, GSC Map 525A. Sample SH-42-59. Collected and described by C.H. Stockwell.

(For discussion see determination GSC 61-80.)

GSC 61-80 Muscovite, K-Ar age 1,840 m.y.

K 6.39%, Ar^{40}/K^{40} .1822; radiogenic argon 100%. Concentrate: impure, consisting of about 60% clean muscovite; about 20% muscovite with attached specks of quartz and chloritized biotite; and about 20% impurities, mainly quartz and minor feldspar. Only a trace of chlorite is present.

From mica schist.

(75 E) Small island near the west shore of an unnamed lake, just west of Rutledge Lake; 61°33'40"N, 110°52'30"W. Map-unit 2, GSC Map 525A. Sample SH-42-59. Collected and described by C.H. Stockwell.

The biotite of GSC 61-79 (1,780 m.y.) and the muscovite of GSC 61-80 (1,840 m.y.) are from the same sample. The agreement is good and is within the limits of analytical error. However, the slightly older age for the muscovite may be significant as it is confirmed by the petrographic evidence as explained below.

The rock is a fine-grained, mottled, grey, sedimentary schist with a poor cleavage and is composed of abundant quartz and lesser amounts of biotite, muscovite, garnet, and chlorite. The biotite, which is fresh, probably formed later than chlorite and is also later than garnet for it fills cracks in that mineral. Most of the biotite forms matted aggregates of crystals with random orientation, whereas the muscovite flakes are roughly parallel with one another as if having crystallized earlier.

The sample is from a belt of schist about a mile wide enclosed in an area of granitic rocks.

District of Mackenzie

GSC 61-81 Biotite, K-Ar age 1,810 m.y.

K 7.40%, Ar^{40}/K^{40}. 1779; radiogenic argon 100%. Concentrate: the biotite flakes are mainly brown but some are olive-green. The concentrate contains about 75% fresh biotite, 20% slightly chloritized biotite, and 5% free chlorite. Chlorite/biotite 0.18.

From augen gneiss.
(75 F) South shore of Nonacho Lake, 2 miles west of the mouth of Taltson River; 61°48'50"N, 108°58'20"W. Map-unit 5, GSC Map 526A. Sample SH-71-59. Collected and described by C.H. Stockwell.

Augen of pink microcline and orthoclase lie in a fine-grained, grey, granitic gneiss composed of quartz, orthoclase, microcline, oligoclase, biotite, and accessory magnetite, apatite, titanite, and zircon.

As seen on the outcrop the augen gneiss is cut along and across the strike by stringers of pegmatite. According to J.F. Henderson, the author of the map, the gneiss intrudes rocks of the Nonacho Group. The determined age is, accordingly, a minimum for the Nonacho.

GSC 61-82 Biotite, K-Ar age 2,460 m.y.

K 7.67%, Ar^{40}/K^{40}. 2967; radiogenic argon 100%. Concentrate: consists of mainly fresh reddish brown biotite. Some flakes have slightly bleached patches containing small specks of an unidentified mineral. Chlorite/biotite 0.08.

From paragneiss.
(75 K) West shore of Nelson Lake; 62°11'40"N, 108°05'50"W. Map-unit 3, GSC Map 51-26A. Sample SH-72-59. Collected and interpreted by C.H. Stockwell.

The paragneiss is a medium-grained, dark grey, well-foliated rock with stringers of granitic material along cleavage planes. Numerous nearly parallel flakes of biotite and lesser amounts of hornblende lie in a mosaic of quartz and andesine. Accessories include epidote, apatite, and titanite. The biotite is unaltered. As seen on the outcrop the paragneiss is cut by bodies of pink granite up to 30 feet across. The determinated age indicates the time of metamorphism.

District of Mackenzie

The sample was taken from a local area in the Churchill province where several previously reported ages were older than the Hudsonian orogeny which normally affected that province. The ages (2,000-2,070 m.y.) appeared to be survival values from an older orogeny that had not been completely reworked by the Hudsonian. The age of 2,460 m.y. for the present sample amply confirms this contention and indicates, moreover, that the older orogeny was the Kenoran. The sediments of this local area were deposited in Archaean time, were metamorphosed during the Kenoran orogeny, and escaped the Hudsonian deformation.

GSC 61-83 Biotite, K-Ar age 1,830 m.y.

K 7.06%, Ar^{40}/K^{40} .1812; radiogenic argon 98%. Concentrate: contains about 80% clean biotite flakes; 10-15% of biotite flakes with tiny inclusions and bleached edges; and about 5% green prismatic fragments of hornblende.

From granitic gneiss.
(65 D) North shore of large island in Wholdaia Lake; 60°35'40"N, 103°50'00"W. Map-unit 4, GSC Map 7-1956. Sample SH-94-59. Collected and described by C.H. Stockwell.

This is a medium-grained, grey, granitic gneiss in which mafic minerals are segregated into streaks and clots, and augen of feldspar up to 1/2 inch long are scattered here and there. Minerals present include quartz, oligoclase, microcline, myrmekite, hornblende, biotite, and a little garnet, apatite, and magnetite. Post-crystallization cataclastic structure is noticeable, especially around large feldspar grains where many of the minerals, including the biotite, are bent and broken.

The sample is from a large area mapped as gneisses derived from sedimentary rocks. It is uncertain whether the determined age dates the main period of metamorphism or gives the later time of cataclastic deformation.

GSC 61-84 Biotite, K-Ar age 1,680 m.y.

K 7.44%, Ar^{40}/K^{40} .1584; radiogenic argon 94%. Concentrate: brown biotite. Flakes contain numerous opaque inclusions. Chlorite/biotite 0.02.

From paragneiss.
(75 O) East shore of unnamed lake, 1 mile west of Ford

Lake; 63°07'40"N, 107°32'20"W. Map-unit 6, GSC Map 17-1956. Sample SH-66-59. Collected and described by C. H. Stockwell.

The paragneiss is a dark grey, medium-grained rock with a poorly developed layered structure and is composed chiefly of grains of quartz and oligoclase whose interspaces are partly filled with randomly oriented crystals of biotite. A few garnets are present. The biotite is unchloritized but is somewhat bent and is partly altered to specks of opaque material. Sericite forms felted masses here and there in association with chlorite, fills cracks in broken garnets, penetrates into biotite crystals, and is evidently of later origin than these two minerals.

The rock lies within the Churchill province close to the boundary with the Slave province and the determined age indicates a period of metamorphism.

GSC 61-85 Biotite, K-Ar age 1,830 m.y.

K 7.48%, Ar^{40}/K^{40} .1811; radiogenic argon 100%. Concentrate: consists of about 90% clean brown biotite; about 5% chloritized biotite and free chlorite; and about 5% green hornblende. Chlorite/biotite 0.06.

From migmatite.
(76 I) East of Bathurst Inlet; 66°52'N, 104°58'W. Unmapped area. Sample FD-605-61. Collected and interpreted by J.A. Fraser.

Gneiss from which the sample was obtained is exposed over a wide area in the region east of Bathurst Inlet. It is composed chiefly of dark grey andesine and hornblende, with minor quartz, biotite, and pyroxene. Foliation in the gneiss is defined by segregations of biotite and hornblende, and by medium-grained amphibolite in layers a few centimetres thick. Comparable ages are reported for similar rocks from the area north of Garry Lake, about 100 miles east of the sample locality (W. W. Heywood, GSC PS Map 28-1961.)

GSC 61-86 Biotite, K-Ar age 1,880 m.y.

K 7.15%, Ar^{40}/K^{40} .1889; radiogenic argon 100%. Concentrate: consists of about 80% reasonably clean brown biotite. The remainder consists of green hornblende, free chlorite, and biotite-quartz-chlorite-epidote intergrowths. A few of the biotite flakes are chloritized along the edges. Chlorite/biotite 0.1.

District of Mackenzie

From fine-grained porphyritic granodiorite.
(66 E) Eastern District of Mackenzie; 65°13'N, 102°28'W. Map-unit 8, GSC Map 17-1956. Sample HF-246-60. Collected by W. W. Heywood. Interpreted by G. M. Wright.

The sample was taken within a large area lacking age determinations. The date agrees reasonably well with dates obtained elsewhere within the Churchill geological province.

District of Keewatin

GSC 61-87 Biotite, K-Ar age 1,880 m.y.

K 7.86%, Ar^{40}/K^{40} .1884; radiogenic argon 100%. Concentrate: consists mainly of clean reddish brown biotite. A few inclusions of quartz and opaque specks are present in some flakes. Chlorite not detected.

From garnet-biotite rock.
(66 N) Ogden Bay area; 67°45'N, 101°12'W. Map-unit 2, GSC Map 28-1961. Sample AC-266-60. Collected by J.D. Aitken. Described by W.W. Heywood.

This sample is representative of an area characterized by the presence of calc-silicate gneisses, amphibolites, and granitoid gneisses.

GSC 61-88 Biotite, K-Ar age 1,640 m.y.

K 8.05%, Ar^{40}/K^{40} .1529; radiogenic argon 96%. Concentrate: reasonably clean rusty-brown to olive-green biotite containing about 15% of impurities, including chloritized biotite, free chlorite, and hornblende. Chlorite/biotite 0.13.

From biotite gneiss.
(66 N) Ogden Bay area; 67°09'N, 100°31'W. Map-unit 2, GSC Map 28-1961. Sample AC-293-c-60. Collected by J.D. Aitken. Interpreted by W.W. Heywood.

This sample is from an area of granitized paragneiss. In part the rock is massive with only remnants of the more basic gneisses remaining. Some chlorite is present and the feldspars have been partly sericitized. Fine-grained biotite has been developed in late fractures. The date may be low due to alteration and recrystallization.

GSC 61-89 Biotite, K-Ar age 1,720 m.y.

K 8.11%, Ar^{40}/K^{40} .1642; radiogenic argon 98%. Concentrate: biotite varies in colour from dull brown to green. About 50% of the flakes contain scattered tiny inclusions. About 1-2% quartz is present as impurity. Chlorite/biotite 0.05.

From biotite hornblende gneiss.
(66 J) Ogden Bay area; 66°37'N, 98°31'W. Map-unit 5, GSC Map 28-1961. Sample HF-266-60. Collected and described by W.W. Heywood.

The biotite from this sample is fresh and unaltered and the age should be that of the metamorphism.

District of Keewatin

GSC 61-90 Biotite, K-Ar age 1,750 m.y.

K 6.33%, Ar^{40}/K^{40} .1688; radiogenic argon 100%. Concentrate: contains about 50% clean dark brown biotite; 25% of biotite intergrown with relatively coarse quartz; and 20% partly chloritized and intergrown with epidote. About 5% free chlorite is present as an impurity. Chlorite/biotite 0.26.

From cataclastic quartz monzonite.
(66 J) Ogden Bay area; 66°06'N, 98°04'W. Map-unit 6, GSC Map 28-1961. Sample HF-256-60. Collected and described by W.W. Heywood.

This sample is from a zone of crushed and mylonitized granitoid rocks. The biotite is recrystallized and therefore the age is probably low.

GSC 61-91 Muscovite, K-Ar age 1,680 m.y.

K 9.07%, Ar^{40}/K^{40} .1586; radiogenic argon 100%. Concentrate: mostly clean muscovite. Some flakes have a few fine inclusions. Impurities consist of a few flakes of greenish biotite. Chlorite not detected.

From pegmatite sill.
(56 M) District of Keewatin; 67°28'N, 95°03'W. Map-unit 6, GSC Map 28-1961. Sample AC-160-60. Collected by J.D. Aitken. Interpreted by W.W. Heywood.

The pegmatite is intrusive into folded and metamorphosed sedimentary rocks of the Chantrey Group. The pegmatites are post-deformational and are of about the same age as the granitic and gneissic rocks to the south and east. Much of the contact between the metasedimentary rocks and the adjacent granite and gneiss is a fault. However, in part is appears to be an unconformity, and locally, near the eastern end of the folded belt, the sedimentary rocks appear to grade into higher-grade schists and gneisses.

GSC 61-92 Biotite, K-Ar age 1,685 m.y.

K 8.04%, Ar^{40}/K^{40} .1595; radiogenic argon 100%. Concentrate: most flakes are clean and vary from pale to dark brown. Some flakes have slightly bleached edges. About 30% contain small inclusions of quartz along fractures and cleavage planes. A few flakes contain zircon inclusions surrounded by dark pleochroic haloes. Chlorite/biotite 0.02.

District of Keewatin

From biotite granite-gneiss.
(56 K) Chantrey Inlet area; 66°57'N, 92°56'W. Map-unit 5, GSC Map 28-1961. Sample TJ-44-60. Collected by M. Tremblay. Described by W.W. Heywood.

This sample was selected to represent a large area of granite gneisses southeast of Chantrey Inlet. (See determination GSC 61-94.)

GSC 61-93 Biotite, K-Ar age 1,680 m.y.

K 7.93%, Ar^{40}/K^{40} .1584; radiogenic argon 100%. Concentrate: clean biotite varying from brownish to greenish grey. About 10% of flakes contain long needles of epidote and green chloritized patches. A few inclusions of apatite and dark grey pleochroic haloes are present. Chlorite/biotite 0.09.

From granodiorite.
(56 J) Chantrey Inlet area; 66°33'N, 90°34'W. Map-unit 5, GSC Map 28-1961. Sample HF-57-60. Collected and described by W. W. Heywood.

This specimen of granodiorite was collected from an area predominantly of granite-gneisses. (See determination GSC 61-94.)

GSC 61-94 Biotite, K-Ar age 1,700 m.y.

K 8.20%, Ar^{40}/K^{40} .1611; radiogenic argon 100%. Concentrate: most of the biotite flakes are clean and brownish grey in colour. A few are intergrown with quartz and some are slightly bleached. A few flakes contain zircon inclusions surrounded by ginger-brown pleochroic haloes. Impurities are limited to a few fragments of quartz and hornblende. Chlorite not detected.

From biotite-hornblende schist.
(56 J) Chantrey Inlet area; 66°49'N, 91°48'W. Map-unit 1a, GSC Map 28-1961. Sample AC-115-60. Collected by J. D. Aitken. Interpreted by W. W. Heywood.

The biotite-hornblende schist is probably derived from an intermediate to basic volcanic rock. It is associated with basic gneiss derived from metasediments; this gneiss locally grades into massive granite. The age is probably that of the metamorphism. The close correspondence with the ages of GSC 61-92 and GSC 61-93 suggests that all were formed at or about the same time.

District of Keewatin

GSC 61-95 Biotite, K-Ar age 1,715 m.y.

K 7.93%, Ar^{40}/K^{40} .1633; radiogenic argon 100%. Concentrate: very pure concentrate of mainly clean brown biotite. About 30% of the flakes contain minute inclusions along slightly bleached edges. Chlorite/biotite 0.02.

From biotite gneiss.
(57 C) Rae Strait area; 69°05'N, 92°48'W. Map-unit 5, GSC Map 28-1961. Sample HF-217a-60. Collected and described by W.W. Heywood.

The gneisses and granitoid gneisses of Boothia Peninsula southeast of Spence Bay are represented by this sample.

GSC 61-96 Biotite, K-Ar age 1,645 m.y.

K 8.08%, Ar^{40}/K^{40} .1540; radiogenic argon 98%. Concentrate: consists of 80% light greenish brown biotite; 15% biotite with minor inclusions of epidote; and 5% of brighter green chloritized flakes containing needle-like inclusions. Chlorite/biotite 0.03.

From biotite gneiss.
(57 A) Rae Strait area; 68°22'N, 90°58'W. Map-unit 5, GSC Map 28-1961. Sample HF-195-60. Collected and described by W.W. Heywood.

(For description see determination GSC 61-97.)

GSC 61-97 Biotite, K-Ar age 1,710 m.y.

K 7.68%, Ar^{40}/K^{40} .1630; radiogenic argon 100%. Concentrate: reasonably clean brown biotite. About 10% of the flakes are greenish brown and partly chloritized. Dark brown pleochroic haloes are present in a few flakes. About 3% free green chlorite occurs as an impurity. Chlorite/biotite 0.10.

From biotite gneiss.
(56 O) Rae Strait area; 67°59'N, 90°02'W. Map-unit 5, GSC Map 28-1961. Sample HF-165-60. Collected and described by W.W. Heywood.

District of Keewatin

These two determinations (GSC 61-96 and GSC 61-97) were made to obtain information on the age of gneissic to almost massive rocks in the area west of Pelly Bay. GSC 61-96 is a layered gneiss and GSC 61-97 is a more massive variety. It is probable that both samples are from rocks derived from sedimentary material, as impure quartzite is interlayered with, and grades into the gneiss.

GSC 61-98 — Biotite, K-Ar age 1,220 m.y.

K 7.23%, Ar^{40}/K^{40} .1003; radiogenic argon 100%. Concentrate: two types of biotite are evident in thin section—

1. coarse, light ginger-brown phenocrysts (GSC 61-98).
2. very fine grained subhedral to anhedral darker brown flakes in the matrix (GSC 61-99).

This concentrate is dominantly type 1 biotite; about 20% of the flakes have scattered quartz inclusions and about 10% show some bleaching. Chlorite/biotite 0.08.

From augite-biotite lamprophyre.
(66 A) Whitehills Lake; 64°38'N, 96°05'W. Map-unit A, GSC Paper 55-17. Sample DA-260-60. Collected by W.L. Davison. Interpreted by G.M. Wright and W.W. Heywood.

(For interpretation see determination GSC 61-99).

GSC 61-99 — Biotite, K-Ar age 1,665 m.y.

K 7.76%, Ar^{40}/K^{40} .1565; radiogenic argon 99%. Concentrate: consists mainly of type 2 biotite (see GSC 61-98). The flakes are darker brown than type 1 and contain numerous inclusions of quartz. Chlorite not detected.

From augite-biotite lamprophyre.
(66 A) Whitehills Lake; 64°38'N, 96°05'W. Map-unit A, GSC Paper 55-17. Sample DA-260-60. Collected by W.L. Davison. Interpreted by G.M. Wright and W.W. Heywood.

The rock from which this sample was obtained occurs on two islands in Whitehills Lake. It is probably intrusive into the Hurwitz sedimentary rocks that outcrop on adjacent islands and on the north and west sides of the lake. The lamprophyre was considered as a possible intrusive equivalent of the pyroxene-biotite porphyry of the Dubawnt Group, which gave an age of 1,515 m.y. (GSC 59-35).

Biotite phenocrysts (GSC 61-98) and biotite of the matrix (GSC 61-99) were separated and K-Ar ratios determined on each. The age determined for the phenocrysts was 1,220 m.y. and for the matrix biotite 1,665 m.y. Further work is required before any geological conclusions can be drawn.

GSC 61-100 — Biotite, K-Ar age 1,770 m.y.

K 7.11%, Ar^{40}/K^{40} .1719; radiogenic argon 100%. Concentrate: reasonably clean concentrate of pale buff biotite. Some flakes are zoned with darker rims. Concentrate contains about 15% impurities consisting mainly of altered pyroxene, hornblende, and feldspar. Some biotite flakes contain inclusions of iron oxides. Chlorite/biotite 0.07.

From feldspar-pyroxene porphyry.
(65 O) North end of Tulemalu Lake; 63°10'N, 99°23'W. Map-unit 9, GSC PS Map 55-17. Sample FD 603-61. Collected and interpreted by J.A. Fraser.

The sample is from purplish grey, Dubawnt porphyry, the only rock type exposed at this locality. Phenocrysts of feldspar, pyroxene, and biotite up to 1 mm across constitute about one third of the porphyry; the matrix is aphanitic and is composed mainly of feldspar and biotite. Ages of Dubawnt porphyry previously published are: 1,515 m.y. (GSC 59-35) and 1,720 m.y. (GSC 60-60).

GSC 61-101 — Biotite, K-Ar age 2,240 m.y.

K 6.41%, Ar^{40}/K^{40} .2513; radiogenic argon 98%. Concentrate: consists of coarse irregular flakes of olive-green biotite containing numerous inclusions of hydrated iron oxides. Flakes are bleached along fractures and edges. Chlorite/biotite 0.17.

From dacite.
(65 K) East shore near north end of small lake 4 miles east of Dubawnt Lake; 62°50'00"N, 100°55'20"W. Map-unit 9, GSC Map 55-17. Sample SH-100-59. Collected and interpreted by C.H. Stockwell.

District of Keewatin

The sample is a massive, medium-grained, dark purple rock composed of quartz, andesine, biotite, altered pyroxene (?) and a little orthoclase, myrmekite, and apatite. The biotite flakes are somewhat broken and the cracks are filled with magnetite and red iron oxide.

The sample is from an area mapped as Dubawnt porphyry which, on the outcrop from which the sample was collected, varies from massive to amygdaloidal and agglomeratic. The sample was taken from what appeared to be either a massive flow or an intrusive equivalent of the Dubawnt, but the disturbingly old age of 2,240 m.y. is difficult to interpret. One possibility is that the sample is not Dubawnt but is from the basement that lies unconformably beneath the flows. Another possibility is that the sample is really Dubawnt, that the ages formerly obtained (1,515 m.y. on GSC 59-35 and 1,770 m.y. on GSC 61-100) are about right, and that argon, driven from the basement rocks when they were heated by the overlying flows, has been added to the biotite to give the anomalously old age.

GSC 61-102 Biotite, K-Ar age 1,810 m.y.

K 7.03%, Ar^{40}/K^{40} .1776; radiogenic argon 97%. Concentrate: consists of orange to chestnut-brown biotite. Mostly fresh but some flakes have inclusions of opaque material, needles, and chloritic alteration. Chlorite/biotite 0.09.

From garnetiferous biotite schist.
(55 M) East end of small lake 4 miles southeast of outlet of Baker Lake; 63°57'40"N, 94°12'40"W. Map-unit 5, GSC Map 55-17. Sample SH-109-59. Collected and described by C.H. Stockwell.

The sample is a medium-grained, dark grey schist, composed of quartz, slightly sericitized oligoclase, garnet, abundant biotite, and minor apatite, green tourmaline, and pyrite.

The schist is typical of areas of metasedimentary rocks of the region that are surrounded by prevalent granitic terrain and are overlain unconformably by rocks of the Dubawnt Group.

The biotite gives the time of metamorphism of the schist and a maximum age for the Dubawnt.

District of Keewatin

GSC 61-103 Biotite, K-Ar age 1,695 m.y.

K 7.59%, Ar^{40}/K^{40} .1607; radiogenic argon 100%. Concentrate: consists mainly of clean biotite flakes. A few are slightly chloritized and have quartz inclusions. Chlorite/biotite 0.08.

From paragneiss.
(55 N) 6 miles northeast of McManaman Lake; 63°23'40"N, 92°01'00"W. Map-unit 6, GSC Map 55-17. Sample SH-107-59. Collected and described by C.H. Stockwell.

The sample is a medium-grained, grey paragneiss, composed of andesine, quartz, hornblende, fresh brown biotite, and minor epidote, titanite, apatite, and magnetite.

On the outcrop it is seen to be a well-layered rock interbanded with hornblende-rich gneiss, and the whole is cut by dykes of pink pegmatite. The biotite gives the age of metamorphism.

GSC 61-104 Biotite, K-Ar age 2,375 m.y.

K 6.95%, Ar^{40}/K^{40} .2783; radiogenic argon 98%. Concentrate: consists of about 90% fresh brown biotite and 10% or less of biotite flakes with attached chlorite and free grains of chlorite. Chlorite/biotite 0.07.

From granitic gneiss.
(65 J) West shore Yathkyed Lake, in bay just south of Windy Point; 62°31'30"N, 98°04'00"W. Map-unit 6, GSC Map 55-17. Sample SH-103-59. Collected and described by C.H. Stockwell.

The sample is a medium-grained, grey, granitic gneiss with a good foliation and is composed of a mosaic of oligoclase and quartz with lesser amounts of orthoclase, microcline, biotite, hornblende, and a little muscovite, apatite, and magnetite. The flakes of biotite, which lie about parallel with one another, are mostly fresh but a few are altered to chlorite. On the outcrop from which the sample was collected the granitic gneiss is cut by stringers of pink granite.

The determined age of 2,375 m.y. indicates the time of metamorphism. The rock lies within the Churchill structural province but the age is much older than the prevalent age of 1,700 ± 150 m.y. for that province, and suggests that the sample represents a remnant of Archaean rock that escaped much of the effect of the later Hudsonian orogeny in which most of the rocks of the Churchill province were involved.

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GSC 61-105 Biotite, K-Ar age 1,795 m.y.

K 7.73%, Ar^{40}/K^{40} .1758; radiogenic argon 100%. Concentrate: clean concentrate of biotite containing aligned rutile needles and some epidote. About 10% of the flakes are chloritized and free from rutile. Chlorite/biotite 0.09.

(55 K) From quartz monzonite. Southeast end of Gill Lake; 62°24'40"N, 93°01'30"W. Map-unit 6, GSC Map 55-17. Sample SH-105-59. Collected and described by C.H. Stockwell.

The quartz monzonite is a massive, medium-grained, greenish grey rock with scattered flakes of biotite, large eyes of quartz aggregates, and good-sized phenocrysts of pink, perthitic orthoclase. Oligoclase is a constituent of the groundmass and is much altered to sericite. Much of the biotite is partly gone to dark opaque material and some flakes are interleaved with chlorite or enclose needles of rutile. Carbonate is rather plentiful and minor constituents include muscovite, microcline, titanite, and epidote.

The sample is from a pluton 16 miles long and 8 miles wide that intrudes volcanic rocks, that are overlain by sediments of the Hurwitz Group. The relationship between the quartz monzonite and the Hurwitz is uncertain but, as judged by the rather low metamorphic grade of the sediments, the quartz monzonite may be older. Unfortunately, the K-Ar age does not solve the problem for, as the rock is somewhat altered, the age may reflect the mild, post-Hurwitz metamorphism. It was hoped that an age on the muscovite would help but this mineral could not be satisfactorily concentrated.

GSC 61-106 Muscovite, K-Ar age 1,735 m.y.

K 8.13%, Ar^{40}/K^{40} .1664; radiogenic argon 100%. Concentrate: impure, consisting of—about 30% clean muscovite; about 40% muscovite with minor quartz inclusions; about 20% intergrowths of muscovite-quartz-feldspar-chlorite-biotite; and about 10% free grains of quartz and feldspar. Chlorite/muscovite 0.05.

(65 G) From gneissic granite. South shore of small unnamed lake; 61°46'30"N, 98°17'00"W. Map-unit 2, GSC Map 53-22. Sample SH-98-59. Collected and described by C.H. Stockwell.

District of Keewatin

The gneissic granite is a rather fine grained, light grey rock, with scattered, small phenocrysts of white feldspar. The rock is composed of quartz, microcline, oligoclase, biotite, muscovite, and small amounts of epidote, carbonate, magnetite, apatite, and zircon. The muscovite and much of the biotite is fresh but some biotite flakes are completely altered to chlorite.

The gneissic granite intrudes metavolcanic rocks and is cut by dykelets of coarser-grained granite. As the rock is gneissic it is uncertain whether the determined age indicates the time of primary crystallization or of metamorphism.

Alberta

GSC 61-107 Biotite, K-Ar age 1,825 m.y.

K 7.44%, Ar^{40}/K^{40} .1799; radiogenic argon 100%. Concentrate: clean, but the biotite flakes vary from brown to olive-green and contain numerous inclusions of quartz, rutile needles, and roughly hexagonal dark brown plates resembling secondary, higher iron biotite. About 10% of the flakes grade into olive-grey chlorite. Chlorite/biotite 0.09.

From gneiss.

(74 E) North shore of Clay Lake, southwest of Richardson River, Lake Athabasca region; 57°54'N, 110°48'W. GSC Map 16-1961. Sample TG-92-60. Collected and interpreted by L.P. Tremblay.

The sample is a coarse-grained, grey gneiss made up of about 60% oligoclase, some interstitial quartz, and 10% reddish brown biotite. A minor amount of chlorite occurs on the biotite and along seams and cracks in feldspar and quartz. A few grains of K-feldspar were noted. Apatite, sphene and pyrite were recognized.

The sample is from an area where the rock is granitoid and encloses diffuse patches of an older rock rich in coarse biotite flakes. This is interpreted as an area of granitized rocks, probably metasediments. These rocks are overlain unconformably to the northeast by the almost-flat-lying Athabaska Formation, and to the west by Devonian rocks. They are cut by dykes of pegmatites and, to the south, by dykes of basalt.

The biotite age dates the period of metamorphism. The date is equivalent to dates on biotites north of Lake Athabasca.

Saskatchewan

GSC 61-108 Biotite, K-Ar age, 1,795 m.y.

K 6.69%, Ar^{40}/K^{40}.1755; radiogenic argon 100%. Concentrate: a heterogeneous concentrate of mainly reddish brown biotite, speckled in appearance, which disintegrates readily on grinding. About 30% of the flakes are partly bleached and 10% are chloritized and greenish. A small amount of hornblende is present as an impurity. Chlorite/biotite 0.4.

From granitoid quartz-feldspar gneiss.
(74 N) East shore of Mickey Lake, about 300 feet inland, Beaverlodge area; 59°35'35"N, 108°26'40"W. GSC Map 25-1957. Sample TG-90-60. Collected and interpreted by L.P. Tremblay.

This biotite is from the Donaldson Lake gneiss, a coarse-grained grey rock with the composition of a quartz monzonite, and probably a metasediment. This rock unit is part of the Tazin Group and is overlain unconformably by the Martin Formation. Much of the biotite is altered to chlorite. This alteration probably represents a retrogressive metamorphism due to either dynamic or hydrothermal activities. These activities are regarded as late phases in the orogenic events responsible for the regional metamorphism and the development of biotite in the Beaverlodge area.

It was hoped that this age would date the regional metamorphism but, because of the alteration, it may be a little low. It is, however, of the right order of magnitude, if compared with the muscovite age of 1,815 m.y. (GSC 60-65) obtained on a pegmatite dyke cutting the ore zone at Gunner Mine.

GSC 61-109 Biotite, K-Ar age, 1,830 m.y.

K 6.22%, Ar^{40}/K^{40}.1811; radiogenic argon 100%. Concentrate: clean, but flakes vary from reddish brown (30%) to pale buff (40%). About 30% of the flakes grade into grey-green chlorite containing long colourless inclusions. The chlorite and biotite peaks are not resolved in the X-ray pattern. Chlorite/biotite 0.4, but this may be inaccurate owing to the poor peak resolution.

From quartz monzonite.
(74 P) East shore Dramnitzke Bay, Charlebois Lake; 59°23'00"N, 104°55'28"W. Map-unit 8, Sask. Dept. Mineral Resources Map 24A. Sample SH-88-59. Collected and described by C.H. Stockwell.

(For description see determination GSC 61-110.)

Saskatchewan

GSC 61-110 Muscovite, K-Ar age 1,780 m.y.

K 8.03%, Ar^{40}/K^{40} .1735; radiogenic argon 100%. Concentrate: a small impure concentrate of muscovite containing an estimated 11% feldspar, 10% quartz, and 7% chlorite as impurities. The muscovite flakes are reasonably clean.

From quartz monzonite.
(74 P) East shore of Dramnitzke Bay, Charlebois Lake; 59°23'00"N, 104°55'28"W. Map-unit 8, Sask. Dept. Mineral Resources Map 24A. Sample SH-88-59. Collected and described by C.H. Stockwell.

The biotite of GSC 61-109, giving an age of 1,830 m.y., and the muscovite of GSC 61-110, giving an age of 1,780 m.y., were separated from the same sample and the agreement in the determined ages is good.

The sample is a light grey, massive, fine-grained quartz monzonite composed of quartz, microcline, albite, biotite, muscovite, and accessory apatite and zircon. The muscovite and most of the biotite crystals are fresh but some of the biotites are partly or completely altered to chlorite.

As seen on the outcrop the fine-grained quartz monzonite is interlayered with white pegmatitic granite holding inclusions of biotite paragneiss in all stages of granitization, and it seems probable that the pegmatite and quartz monzonite are the end stages of the granitization process, the age of which is indicated by the K-Ar determination.

Radioactive deposits on Charlebois Lake have been explored by prospect pits and diamond-drilling. Ages on uraninite and pitchblende from the deposits and a K-Ar age on feldspar range from 1,780 to 1,800 m.y. (Cumming et al., 1955; Collins et al., 1954). These ages agree remarkably well with our K-Ar determinations on biotite and muscovite from the quartz monzonite.

GSC 61-111 Biotite, K-Ar age 1,780 m.y.

K 7.82%, Ar^{40}/K^{40} .1729; radiogenic argon 100%. Concentrate: consists of brown biotite flakes that contain numerous tiny transparent inclusions and some opaque specks. Pleochroic haloes are common. Chlorite not detected

Saskatchewan

From paragneiss.
(74 A) Small island near south shore of Copp Lake; 56°24'10"N, 104°01'20"W. Map-unit 10, GSC Map 433A. Sample SH-35-59. Collected and described by C. H. Stockwell.

The paragneiss is a medium-grained to fine-grained, banded rock consisting of a mosaic of quartz, microcline, and oligoclase through which are plentiful, nearly parallel flakes of brown biotite and a little muscovite. Apatite and pyrite are minor constituents. The biotite is fresh and clear except for a few inclusions of zircon surrounded by pleochroic haloes.

The outcrop consists of an intimate mixture of schist, gneiss, granite, and pegmatite, and the sample was taken from an inclusion of gneiss in the pegmatite. The determined age gives the approximate time of metamorphism of the gneiss and of the intrusion of the pegmatite.

GSC 61-112 Biotite, K-Ar age 1,705 m.y.

K 7.37%, Ar^{40}/K^{40} .1618; radiogenic argon 100%. Concentrate: the biotite varies in colour from brown to green. Some chloritized flakes and free chlorite are present. Inclusions and attached impurities are numerous. Chlorite/biotite 0.10.

From quartz monzonite.
(63 K) Small island at southeast end of Reynard Lake; 54°41'20"N, 101°59'50"W. Map-unit 8, GSC Map 633A. Sample SH-134-59. Collected and described by C. H. Stockwell.

The quartz monzonite is a medium-grained, massive, red rock composed of quartz, oligoclase, orthoclase, microcline, myrmekite, biotite, and accessory magnetite and apatite. The oligoclase is much saussuritized, and the biotite, which is generally bent and broken, is mostly interleaved with chlorite and speckled with opaque material.

The quartz monzonite invades volcanic rocks of the Amisk Group. The determined age may indicate the time of deformation and alteration of the biotite rather than the time of crystallization of the quartz monzonite magma but, in any case, it gives a minimum for the Amisk.

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GSC 61-113 Biotite, K-Ar age 1,735 m.y.

K 7.48%, Ar^{40}/K^{40} .1665; radiogenic argon 98%. Concentrate: consists of clean dark brown to olive-brown biotite and lesser amounts of pale olive-brown flakes. A few inclusions of quartz, apatite, and zircon occur. Some pleochroic haloes are present. Chlorite not detected.

From fluorite-granite.
(64 N) Northwest of Kasmere Lake; 59°44'N, 101°58'W. Map-unit 7b, GSC PS Map, Kasmere Lake (in press). Sample FD-128-61. Collected and interpreted by J.A. Fraser.

The sample is from a stock of coarse-grained, massive, pale pink to grey granite which truncates a folded belt of metasediments, tentatively correlated with strata of the Hurwitz Group in the southern part of the District of Keewatin. The granite consists of quartz, microcline microperthite, oligoclase, hornblende, and biotite, with accessory sphene, apatite, zircon, and magnetite, and infrequent grains of purple fluorite. Assuming the correlation to be correct, 1,735 m.y. would be a minimum age for the Hurwitz Group.

GSC 61-114 Biotite, K-Ar age 1,610 m.y.

K 7.76%, Ar^{40}/K^{40} .1489; radiogenic argon 98%. Concentrate: consists of about 90% clean, ginger-brown biotite. About 5% of the flakes are intergrown with pale green chlorite along edges and fractures. A few inclusions of zircon surrounded by pleochroic haloes are present. Chlorite/biotite 0.07.

From granite.
(64 P) 4 miles east of Round Sand Lake; 59°46'00"N, 96°28'30"W. Map-unit 3, Manitoba Dept. Mines Map 52-2. Sample SH-113-59. Collected and described by C.H. Stockwell.

The sample is a medium-grained, massive, olive-green granite, composed of quartz, orthoclase, oligoclase, myrmekite, and fresh brown biotite. Minor constituents include pyroxene (?), apatite, magnetite, and zircon.

The greenish granite is mapped as being the older ot two granites, the younger being pink. There is no apparent reason for supposing that the date obtained for the biotite does not indicate the time of primary crystallization of the older granite.

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GSC 61-115 Biotite, K-Ar age 1,730 m.y.

K 7.45%, Ar^{40}/K^{40} .1656; radiogenic argon 99%. Concentrate: clean biotite that varies from brown to green. The greenish biotite is slightly chloritized. Chlorite/biotite 0.07.

From quartz syenite.

(64 G) East shore of island in Big Sand Lake; 57°56'30"N, 99°32'30"W. Map-unit 6, GSC Map 45-1959. Sample SH-119-59. Collected and described by C.H. Stockwell.

This is a massive, red, coarse-grained rock with feldspar crystals up to 3/4 inch across. Perthite is the chief constituent and oligoclase, myrmekite, quartz, biotite, and muscovite occur in minor amounts together with accessory apatite, titanite, and magnetite. The biotite is primary and is mostly fresh but some flakes are slightly altered to chlorite.

The massive quartz syenite occurs in an otherwise generally gneissic terrain, is apparently post-tectonic, and the determined age is thought to give the approximate time of crystallization from a magma.

GSC 61-116 Biotite, K-Ar age 1,720 m.y.

K 8.10%, Ar^{40}/K^{40} .1642; radiogenic argon 100%. Concentrate: consists of olive-green biotite. Some flakes have inclusions and attached impurities. A few zircon inclusions are surrounded by pleochroic haloes. Chlorite/biotite 0.02.

From granitoid paragneiss.

(64 C) East end of McGavock Lake; 56°30'25"N, 101°18'15"W. Map-unit 23, Manitoba Dept. Mines 57-1, Map 5. Sample SH-126-59. Collected and described by C.H. Stockwell.

(For description see determination GSC 61-117.)

GSC 61-117 Muscovite, K-Ar age 1,745 m.y.

K 7.51%, Ar^{40}/K^{40} .1679; radiogenic argon 99%. Concentrate: consists of 50% clean muscovite flakes, 30% muscovite flakes intergrown with quartz along

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the edges, 20% muscovite with attached small specks of biotite, and a few free grains of quartz. The estimated quartz content is 8%. Chlorite not detected.

From granitoid paragneiss.
(64 C) East end of McGavock Lake; 56°30'25"N, 101°18'15"W. Map-unit 23, Manitoba Dept. Mines 57-1, Map 5. Sample SH-126-59. Collected and described by C. H. Stockwell.

The biotite (GSC 61-116, 1,720 m.y.) and the muscovite (GSC 61-117, 1,745 m.y.) are from the same sample and the agreement is good.

The sample is a medium-grained, grey paragneiss composed of microcline, oligoclase, quartz, biotite, muscovite, and accessory magnetite, apatite, and zircon. The micas, which are unaltered, lie about parallel with one another as if having crystallized at about the same time.

On the outcrop the granitoid paragneiss of the sample is associated with sillimanite gneiss and both are cut by dykes of pink granite. The gneisses are mapped as part of the Kisseynew Gneiss which, at this locality, is a metamorphosed equivalent of the Sickle Series. The micas, being metamorphic, give a minimum age for the Sickle.

GSC 61-118 Muscovite, K-Ar age 1,775 m.y.

K 8.52%, Ar^{40}/K^{40} .1722; radiogenic argon 100%. Concentrate: clean, but muscovite flakes contain numerous inclusions of relatively coarse feldspar and quartz, and small specks of biotite. The total feldspar and quartz impurities are estimated at 7% and 5%, respectively, by X-ray diffraction. Chlorite not detected.

From muscovite-biotite granite.
(63 K) East end of Reed Lake; 54°39'05"N, 100°15'40"W. Map-unit 9, GSC Map 906A. Sample SH-139-59. Collected and described by C.H. Stockwell.

The muscovite concentrate, giving an age of 1,775 m.y., was separated from the same sample that yielded the biotite concentrate of GSC 60-74 (1,745 m.y.) and the determined ages of the two coeval minerals are in good agreement. The sample is from a dyke cutting metamorphosed volcanic rocks of the Amisk Group. (For petrographic description and field relations see GSC 60-74.)

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GSC 61-119 Biotite, K-Ar age 1,770 m.y.

K 7.23%, Ar^{40}/K^{40} .1716; radiogenic argon 100%. Concentrate: consists of mainly pale brown biotite. Some flakes have minor amounts of quartz inclusions and a few zircons surrounded by pleochroic haloes. About 20% of the flakes are chloritized. Chlorite/biotite 0.1.

From impure quartzite.
(63 J) South shore of Hat Lake; 54°46'25"N, 99°32'10"W. Map-unit B, GSC Map 987A. Sample SH-142-59. Collected and described by C.H. Stockwell.

(For description see determination GSC 61-120.)

GSC 61-120 Muscovite, K-Ar age 1,620 m.y.

K 7.44%, Ar^{40}/K^{40} .1500; radiogenic argon 100%. Concentrate: consists of (1) 60-70% clean muscovite; (2) 20% muscovite flakes with inclusions; and (3) 10-20% impurities, mainly quartz but with minor feldspar, calcite, epidote, and tremolite. Only a trace of chlorite is present.

From impure quartzite.
(63 J) South shore of Hat Lake; 54°46'25"N, 99°32'10"W. Map-unit B, GSC Map 987A. Sample SH-142-59. Collected and described by C.H. Stockwell.

The biotite of GSC 61-119 (1,770 m.y.) and the muscovite GSC 61-120 (1,620 m.y.) were separated from the same sample and the two ages are in fair agreement with one another.

The sample is a medium-grained, light greenish grey, metamorphic rock composed of abundant quartz, with a little interstitial carbonate, and plentiful, colourless amphibole and pyroxene forming skeletal crystals. Other constituents include biotite, muscovite, and small amounts of orthoclase and microcline. The muscovite and most of the biotite is unaltered but some of the latter is interleaved with minor chlorite.

According to M.J. Frarey, the author of the map, the rock is probably a member of the Missi Group. The micas give minimum ages for the rocks.

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GSC 61-121 Biotite, K-Ar age 1,715 m.y.

K 7.66%, Ar^{40}/K^{40} .1639; radiogenic argon 99%. Concentrate: very clean biotite. A few flakes have slightly bleached edges and a few fragments of hornblende are present as an impurity. Chlorite not detected.

From paragneiss.

(63 P) Wintering Lake; 55°23'55"N, 97°54'50"W. Map-unit 1, GSC Map 51-3. Sample SH-144-59. Collected and described by C. H. Stockwell.

The sample is a medium-grained, grey paragneiss in which feldspathic layers alternate with biotite-rich layers. It is a quartz-oligoclase-biotite gneiss containing small amounts of hornblende, magnetite, and apatite. The biotite is brown. fresh, and clear.

On the outcrop the gneiss of the sample is interlayered with hornblende gneiss and the whole is injected by dykes and irregular bodies of fine-grained granite. The biotite age dates the period of metamorphism and igneous intrusion.

GSC 61-122 Muscovite, K-Ar age 1,840 m.y.

K 8.44%, Ar^{40}/K^{40} .1825; radiogenic argon 100%. Concentrate: clean muscovite with only minor quartz inclusions. Grain size varies from +28 to +100 mesh. Some flakes show air bubbles trapped between basal cleavages. Chlorite not detected.

From pegmatite.

(54 D) 6,900 feet southwest of Weir River, Kennco Exploration DHH No. 2 at a depth of about 660 feet beneath the surface and 320 feet beneath the base of Palaeozoic cover; 56°48'N, 94°07'W. GSC Map 9-1961. Sample SH-9b-61. Collected by J. J. Brummer. Described by C. H. Stockwell.

The pegmatite consists of quartz, sericitized oligoclase, microcline, muscovite, and minor apatite and chlorite. The muscovite is fresh and occurs in books 1/4 inch across.

The K-Ar age indicates that the rock lies in the extension of the Churchill province beneath the Palaeozoic cover.

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GSC 61-123 Muscovite, K-Ar age 1,665 m.y.

K 6.86%, Ar^{40}/K^{40}.1562; radiogenic argon 91%. Concentrate: impure concentrate consisting of about 50-60% clean muscovite, 20% muscovite-biotite-chlorite intergrowths, and 20% quartz and feldspar. Chlorite/muscovite 0.2.

From granite-gneiss.
(54 F) Drill-hole No. 5, from a depth of 948 to 950 feet, Kennco Exploration; 57°10'N, 93°13'W. Sample SH-13-61. Collected by J.J. Brummer. Described by C.H. Stockwell.

The granite-gneiss, which is cut by stringers of pink granite, contains phenocrysts of orthoclase in a fine-grained groundmass composed of quartz and orthoclase together with scattered small flakes of muscovite and biotite. The muscovite is fresh but the biotite is considerably altered to chlorite. The muscovite is thought to give the age of metamorphism.

The determination serves to extend the Churchill province beneath the Palaeozoic cover of the Hudson Bay Lowlands. In the drill-hole the cover rocks reach a depth of 852 feet beneath the surface and consist of limestones except for 4 1/2 feet of sandstone immediately overlying the Precambrian basement.

GSC 61-124 Biotite, K-Ar age 2,135 m.y.

K 7.28%, Ar^{40}/K^{40}.2321; radiogenic argon 97%. Concentrate is fresh mica. Minor impurities include quartz fragments and a few opaque grains. Chlorite not detected.

From garnetiferous paragneiss.
(63 I) Island near northwest shore of Cross Lake; 54°39'15"N, 97°58'00"W. Map-unit A2, GSC Map 1995. Sample SH-26-59. Collected and described by C.H. Stockwell.

(For description see determination GSC 60-84.)

The analytical work was repeated on this biotite concentrate and the result, 2,135 m.y., is in good agreement with the previously determined age of 2,065 m.y. (see GSC 60-84), the average being 2,100 m.y. The analytical work was repeated because of the large discrepancy between the biotite age and the muscovite age of 1,680 m.y. from the same sample (see GSC 61-125, below).

Manitoba

GSC 61-125 Muscovite, K-Ar age 1,680 m.y.

K 6.41%, Ar^{40}/K^{40} .1588; radiogenic argon 97%. Concentrate: consists of about 35% entirely clean muscovite; about 35% muscovite with adhering specks of biotite and chloritized biotite; about 15% muscovite with brown stained patches and fine inclusions of quartz and feldspar; and about 15% quartz and feldspar impurities. Chlorite/muscovite 0.01.

From garnetiferous paragneiss.
(63 I) Island near northwest shore of Cross Lake; 54°39'15"N, 97°58'00"W. Map-unit A2, GSC Map 1995. Sample SH-26-59. Collected and discussed by C.H. Stockwell.

The muscovite (1,680 m.y.) is from the same sample as the biotite of GSC 61-124 (average 2,100 m.y.). The determined ages present a problem because the difference of 420 m.y. is too great to be accounted for by analytical error and yet the two micas no doubt crystallized at about the same time. The situation is comparable to the problem of discrepant ages along the Grenville front as discussed in Part II of this report, and it seems reasonable to conclude that the K-Ar age of the muscovite is close to the true age of crystallization of both micas but that argon was later added to the biotite. In this case, however, the area of older ages lies to the south whereas along the Grenville front it lies to the north.

Although the position of the boundary between the Churchill and Superior provinces is still uncertain in this region, Cross Lake is thought to lie within the Superior province but is probably best considered as being within a subprovince of the Superior in which K-Ar ages are younger than normally found. As suggested by present inadequate information, the area of abnormally young biotites appears to be some 60 miles or more wide and extends easterly from Cross Lake for at least 270 miles. K-Ar ages so far found by the Geological Survey and by Moore et al. (1959) 1,600 and 2,190 m.y. All are considerably younger than the typical age of around 2,500 m.y. for the Superior province generally, and apparently indicate that the Archaean rocks were partly reworked by younger intrusives and metamorphism closely allied to the Hudsonian orogeny dated at 1,700 ± 150 m.y.

GSC 61-126 Biotite, K-Ar age 2,155 m.y.

K 7.26%, Ar^{40}/K^{40} .2359; radiogenic argon 100%. Concentrate: consists of brown biotite. Some flakes have bleached and chloritized edges. A few flakes contain inclusions of small zircons surrounded by pleochroic haloes. Chlorite/biotite 0.14.

Manitoba

From cordierite schist.
(63 P) South shore of island in Utik Lake; 55°15'18"N, 96°00'00"W. Map-unit 2, Manitoba Dept. Mines Map 53-1. Sample SH-152-59. Collected and described by C. H. Stockwell.

The cordierite schist is a dark grey, fine-grained rock with a poor cleavage. Abundant crystals of unchloritized, clear, brown biotite are randomly oriented in a finer-grained mosaic of quartz and a little plagioclase. Very large crystals of cordierite are present and full of inclusions of the other minerals. Apatite and pyrite are minor constituents.

The rock forms beds interlayered with other types of sedimentary rocks of the Hayes River Group. The determined age gives the approximate time of metamorphism and is a minimum for the Hayes River Group. The determined age is considerably younger than the prevalent age for the Superior province, and the rock apparently lies within the Cross Lake subprovince as discussed under GSC 61-125.

GSC 61-127 Biotite, K-Ar age 1,970 m.y.

K 7.94%, Ar^{40}/K^{40} .2035; radiogenic argon 100%. Concentrate: consists of mostly clean, green to greenish grey biotite. A few flakes contain inclusions of quartz. Chlorite not detected.

From microcline granite-gneiss.
(63 I) 7 miles south of Robinson Portage; 54°15'N, 96°16'W. Map-unit 8a, GSC PS Map 60-18. Sample BA-257D. Collected and interpreted by C.K. Bell.

The rock from which the sample was taken is typical of the large masses of granodiorite-tonalite gneiss that outcrops on the Superior side of the Superior-Churchill structural province boundary. These rocks contain up to 50% oligoclase, 25% quartz, 15% K-feldspar (microcline), and 10% biotite, with minor hornblende and muscovite.

The median age suggests that the rock is from the transition zone that seems to exist between the two provinces.

GSC 61-128 Biotite, K-Ar age 2,435 m.y.

K 7.62%, Ar^{40}/K^{40} .2907; radiogenic argon 100%. Concentrate: consists of about 70% reasonably clean brown biotite flakes and about 30% flakes that are partly bleached and have inclusions of quartz. Chlorite/biotite 0.14.

Manitoba

From mica schist.
(62 P) Manigotagan settlement; 51°06'40"N, 96°18'54"W. Map-unit 3, Manitoba Dept. Mines Map 50-2. Sample SH-159-59. Collected and described by C. H. Stockwell.

(For description see determination GSC 61-129.)

GSC 61-129 Muscovite, K-Ar age 2,455 m.y.

K 6.29%, Ar^{40}/K^{40}.2951; radiogenic argon 100%. Concentrate: impure, consisting of about 40% clean muscovite; 20% muscovite with adhering small flakes of chlorite and biotite; 20% intergrowths of muscovite-quartz-feldspar-biotite-chlorite; and about 20% free grains of quartz and feldspar. Chlorite/muscovite 0.4.

From mica schist.
(62 P) Manigotagan settlement; 51°06'40"N, 96°18'54"W. Map-unit 3, Manitoba Dept. Mines Map 50-2. Sample SH-159-59. Collected and described by C. H. Stockwell.

This muscovite, at 2,455 m.y., is from the same sample as the biotite of GSC 61-128, at 2,435 m.y. As seen in thin section, both micas have grown parallel with one another as if crystallized at the same time and the good agreement in their K-Ar ages confirms this conclusion.

The rock is a fine-grained, dark grey, sedimentary schist consisting of quartz and numerous, thin, parallel flakes of biotite, muscovite, and chlorite. A few small garnets are present. The biotite is fresh and probably crystallized later than chlorite during a period of increasing metamorphism.

The schist belongs to the Rice Lake Group and the two micas, being metamorphic, give minimum ages for the group.

Ontario

GSC 61-130 Muscovite, K-Ar age 2,385 m.y.

K 8.05%, Ar^{40}/K^{40} .2806; radiogenic argon 100%. Concentrate: most of the muscovite flakes are intergrown with quartz and some have attached biotite. Some free quartz grains are also present. The total quartz content is estimated at 15%. The total amount of biotite present is less than 5%. Only a trace of chlorite is present.

From mica schist.
(52 E) Road-cut on Highway 71; 49°29'25"N, 94°03'35"W. Map-unit 3a, Ontario Dept. Mines Map 52C. Sample SH-54-60. Collected and described by C.H. Stockwell.

The muscovite (2,385 m.y.) is from the same sample as the biotite (2,550 m.y.) previously reported under GSC 60-93 in Paper 61-17. Both micas undoubtedly crystallized at about the same time and, although the difference of 165 m.y. in their K-Ar ages is considerable, it is thought that the determinations fall within the limits of error inherent in the method.

GSC 61-131 Muscovite, K-Ar age 2,495 m.y.

K 7.18%, Ar^{40}/K^{40} .3038; radiogenic argon 100%. Concentrate: consists of about 70% reasonably clean muscovite; about 20% muscovite, stained brown by disintegrating biotite and containing quartz inclusions; and about 10% quartz, minor feldspar, and biotite. The quartz content is estimated at 12%. Only a trace of feldspar is present. Chlorite not detected.

From mica schist.
(52 C) Northeast end of Mackenzie Island, Rainy Lake; 48°36'10"N, 92°54'45"W. Map-unit 1, GSC Map 98A. Sample SH-61-60. Collected and described by C. H. Stockwell.

The muscovite was separated from the same sample as the biotite previously reported under GSC 60-95. Although both micas no doubt crystallized at about the same time, the K-Ar ages (2,330 m.y for the biotite as compared with 2,495 m.y. for the muscovite) are in poor agreement. Although the discrepancy of 165 m.y. is within the limits of error of the potassium-argon method, it is felt that the muscovite age is the more reliable. This is because muscovite apparently retains argon better under post-crystallization conditions that cause loss from biotite.

Ontario

The mica schist is from the Coutchiching Series at its type locality and the ages are minima for the series. (For description of sample and discussion see determination GSC 60-95.)

GSC 61-132 Biotite, K-Ar age 2,480 m.y.

K 7.53%, Ar^{40}/K^{40}.3007; radiogenic argon 99%. Concentrate: consists of brown biotite flakes. Some flakes have bleached patches and rare inclusions of quartz and opaque specks. Chlorite/biotite 0.08.

From paraschist.

(52 B) Road-cut on Highway 11, 3 miles southeast of Atikokan; 48°43'30"N, 91°35'00"W. Map-unit "Seine Series", Ontario Dept. Mines Map 48a. Sample SH-43-60. Collected and described by C.H. Stockwell.

This is a fine-grained, dark grey, sedimentary schist or argillite with a poor cleavage. Small biotite flakes lie in a groundmass of felsic material mixed with sericite and chlorite. The biotite flakes, though small, are large relative to the groundmass material. They are fresh and apparently formed from chlorite and other constituents under conditions of increasing metamorphism.

The sample was run chiefly to compare the result with the result from a thoroughly recrystallized phase of the same formation, which gave a biotite age of 2,500 m.y. (GSC 60-98). The agreement with the 2,480 m.y. date on the present sample is good.

The rock represented by the present sample is considered by E.S. Moore (Ontario Dept. Mines Map 48a) as belonging to the Seine Series but T.L. Tanton (Geol. Surv., Canada Map 534A) correlated it with the Coutchiching.

Moore (1939) concluded that the Seine is contemporaneous with the Steeprock Series and presented evidence to show that the Steeprock overlies a body of granite unconformably. An attempt was made to obtain material for K-Ar dating of the pre-Steeprock (Laurentian) granite but, wherever examined, the granite was found to be too highly chloritized and otherwise altered.

GSC 61-133 Muscovite, K-Ar age 2,560 m.y.

K 8.81%, Ar^{40}/K^{40}.3181; radiogenic argon 98%. Concentrate: consists mostly of clean flakes but some have small inclusions of quartz and biotite. Chlorite not detected.

Ontario

From pegmatite.

(52 B) Road-cut on Highway 11, about 12 miles west of Kashabowie; 48°39'30"N, 90°42'30"W. Dyke cutting map-unit 1, GSC Map 432A. Sample SH-45-60. Collected and described by C. H. Stockwell.

The pegmatite is composed of white microcline crystals (1/2 inch to 1 1/2 inches across), lying in a finer-grained mixture of quartz, albite, muscovite (generally less than 1/10 inch across), and a little biotite and garnet.

In the road-cut the pegmatite is in sill-like bodies 20 feet thick alternating, lit-par-lit, with layers of sedimentary biotite schist of similar width. Biotite from the schist gave an age of 2,500 m.y. (GSC 60-98) and the determination on muscovite from the pegmatite (2,560 m.y.) was run for comparison. The good agreement obtained for the two minerals agrees with the geological expectation that both minerals crystallized at practically the same time.

GSC 61-134 Biotite, K-Ar age 2,375 m.y.

K 7.58%, Ar^{40}/K^{40} .2783; radiogenic argon 99%. Concentrate: clean, consisting of a mixture of brown, olive, dark olive-green, and bright green biotite flakes. The bright green flakes are the most plentiful. Some flakes contain inclusions and a few are altered to chlorite. Chlorite/biotite 0.06.

From granite.

(52 K) Highway 105, 100 yards east of the falls at north end of Perrault Lake; 50°20'40"N, 93°08'00"W. Sample SH-50-60. Collected and described by C.H. Stockwell.

The sample is a massive, medium-grained, red, leucocratic granite containing a little biotite and scattered red garnets. The granite is spotted with dark knots, mostly about an inch across, which are apparently inclusions of sedimentary material for they consist chiefly of biotite, sillimanite, and cordierite. The biotite is fresh. The analyzed concentrate was obtained very largely from the knots but the age is, nevertheless, thought to indicate the time of crystallization of the granite.

Ontario

GSC 61-135 Biotite, K-Ar age 2,225 m.y.

K 7.70%, Ar^{40}/K^{40} .2487; radiogenic argon 97%.
Concentrate: consists of 75% clean red-brown biotite flakes, 20% bleached biotite, 3% free grains of chlorite, and 2% hornblende. Chlorite/biotite 0.22.

From paragneiss.
(52 K) Highway 105, immediately below Ear Falls Dam; 50°38'N, 93°12'W. Sample PC-81-61. Collected by V.K. Prest. Described by C.H. Stockwell.

The sample is a medium-grained, dark grey paragneiss with a fairly good foliation. The rock consists of a mosaic of quartz and labradorite through which are more or less parallel flakes of biotite and crystals of colourless amphibole. The biotite is fresh and undeformed.

The sample represents the sedimentary part of a lit-par-lit gneiss with interlayers of quartz and pegmatite. The gneiss lies, apparently, in the same belt of rocks that, 90 miles to the west, gave a biotite age of 1,700 m.y. (GSC 60-90) and the present sample was taken to see whether this surprisingly young date had regional significance. However, the problem has not been solved with entire satisfaction, for the 2,225-m.y. date obtained is intermediate between the 1,700 m.y. and the prevalent 2,500 m.y. for the Superior province generally.

GSC 61-136 Biotite, K-Ar age 2,420 m.y.

K 7.88%, Ar^{40}/K^{40} .2876; radiogenic argon 98%.
Concentrate: consists of 60% olive-green and 40% olive-brown biotite. A few of the olive-green flakes are bleached. Some flakes have zircon inclusions and pleochroic haloes. Chlorite not detected.

From granite.
(52 O) Shore of Lake St. Joseph; 51°6'44"N, 90°26'55"W. Map-unit 7, GSC Map 51-1960. Sample EC-60-187. Collected and interpreted by R.F. Emslie.

The granite is from a fresh, massive, large discordant batholith. Field evidence shows it to be younger than the sedimentary rocks to the south. The form and relationships of the batholith suggest that it is post-orogenic and one of the younger granites in the area. The K-Ar age agrees with this interpretation.

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GSC 61-137 Biotite, K-Ar age 2,630 m.y.

K 7.91%, Ar^{40}/K^{40} .3348; radiogenic argon 100%. Concentrate: clean, consisting of dark olive-green biotite. It contains about 7% partly chloritized flakes. Chlorite/biotite 0.03.

From biotite paragneiss and migmatite.
(53 G) Southwest shore of Big Trout Lake; 53°43'N, 90°06'W. Mineral Map of Ontario, 1957-A. Sample FB-20-59. Collected by Y.O. Fortier. Interpreted by S. Duffell.

The biotite age of 2,630 m.y. fits in with ages general in this region of Ontario, and is typical of the dates obtained from granites and granite-gneisses just to the south, in the Lake St. Joseph and adjacent areas.

GSC 61-138 Biotite, K-Ar age 1,000 m.y.

K 5.12%, Ar^{40}/K^{40} .0772; radiogenic argon 88%. Concentrate: contains about 50% clean brown biotite, 30% biotite coated with tiny specks, and 20% bleached and chloritized grains. Chlorite/biotite 0.27.

From granophyre.
(52 A) East end of peninsula opposite Naomi Island, Pine Bay; 48°01'30"N, 89°30'10"W. Map-unit 5, GSC Map 355A. Sample SH-40-60. Collected and described by C.H. Stockwell.

The granophyre is a massive, fine-grained, black rock speckled with red feldspar and containing scattered, small flakes of biotite. As seen in thin section, the texture is dominated by laths of labradorite whose interspaces are filled with orthoclase, quartz, and a graphic intergrowth of those two minerals. Dirty green amphibole is plentiful and is much altered to chlorite. Most of the biotite flakes are fresh but some are partly altered to chlorite. A black opaque mineral is disseminated as small grains and laths.

The granophyre occurs along the south contact of a diabase dyke and, according to Tanton (1931), formed by interaction between the country rock and volatile materials given off by the diabase magma. The determined age of 1,000 m.y. therefore dates the diabase. The diabase, which is mapped as Keweenawan in age, belongs to a group of sills and dykes known as the Logan intrusions, and the K-Ar age correlates it rather closely with the Duluth Complex of Minnesota, dated at approximately 1.1 b.y. and classed as Middle Keweenawan by

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Goldich et al. (1961). The 1,000 m.y. date compares with a 1.06 b.y. date obtained by Goldich on argillite of the Rove Formation that was recrystallized at the contact of a Logan sill on the Gunflint Trail, Minnesota.

The diabase dyke, to which the granophyre sample is related, cuts flat-lying to gently dipping rocks of the Rove Formation of the Animikie Group. The Animikie, Goldich finds, becomes involved, farther south, in his Penokean orogeny dated at about 1.7 b.y. The diabase, accordingly, is much younger than its country rock and is probably closely related in age to the Keweenawan flows of the Osler Group. It would be important to check this, if possible, by dating the flows.

GSC 61-139 Muscovite, K-Ar age 2,455 m.y.

K 8.78%, Ar^{40}/K^{40} .2950; radiogenic argon 100%. Concentrate: consists of mostly clean flakes but some contain numerous inclusions of quartz and a few specks of biotite. Chlorite not detected.

From granite.
(52 H) Highway 11, near north end of Helen Lake; 49°07'20"N, 88°14'40"W. Map-unit 6, GSC Map 308A. Sample SH-34-60. Collected and described by C.H. Stockwell.

This is a massive, medium-grained, light grey granite composed of quartz, microcline, sericitized oligoclase, myrmekite, biotite, and muscovite. The muscovite is fresh but the biotite is partly altered to chlorite.

The sample was taken from a body of massive granite in a belt of migmatite. The age obtained for the muscovite indicates the time of granitization.

GSC 61-140 Biotite, K-Ar age 2,555 m.y.

K 7.44%, Ar^{40}/K^{40} .3175; radiogenic argon 100%. Concentrate: consists of small irregular brown flakes with numerous fine-grained inclusions of quartz. Some chloritization is evident around the quartz inclusions. Chlorite/biotite 0.10.

From micaceous slate.
(42 E) Road-cut on Highway 11, 3.6 miles east of Jellicoe; 49°41'50"N, 87°27'10"W. Ontario Dept. Mines Map

Ontario

45a. Sample SH-33-60. Collected and described by C. H. Stockwell.

This is a dark grey micaceous slate in which flakes of fresh, brown biotite and scattered fragments of quartz and feldspar lie in a matrix of fine-grained material containing shreds of chlorite and sericite and considerable calcite. All the micaceous minerals lie about parallel with one another and give the rock a good cleavage.

The sample was taken from a 2-foot bed of slate in greywacke; both rocks are mapped as belonging to the Windigokan Series. The biotite is metamorphic and gives a minimum age for the Windigokan.

GSC 61-141 Biotite, K-Ar age 2,500 m.y.

K 7.30%, Ar^{40}/K^{40} .3051; radiogenic argon 100%. Concentrate: consists of about 80% clean, small, irregular, greenish brown flakes of biotite; about 10% biotite containing some coarse inclusions of quartz, opaque material, and red platy iron oxides; and 10% pale green chlorite. Chlorite/biotite 0.13.

From biotite schist.

(42 C) Road-cut on Highway 17, on west side of Catfish Lake; 48°05'20"N, 84°48'20"W. Map-unit A1, GSC Map 1972. Sample SH-88-60. Collected and described by C. H. Stockwell.

This is a fine-grained, grey sedimentary schist with excellent platy cleavage due to plentiful, parallel flakes of biotite. These lie in a mosaic of quartz and a little plagioclase. Minor constituents include hornblende, carbonate, chlorite, apatite, and magnetite. The biotite is fresh and is probably later than chlorite.

The schist is mapped as pre-Dorean in age but as the Dorean is also metamorphosed it is probable that the K-Ar age indicates the time of the overriding metamorphism.

GSC 61-142 Muscovite, K-Ar age 2,340 m.y.

K 8.05%, Ar^{40}/K^{40} .2714; radiogenic argon 100%. Concentrate: consists of (1) about 80% clean muscovite; (2) about 10% muscovite-quartz intergrowths; and (3) about 10% muscovite with opaque inclusions and small attached specks of chloritized biotite. Only a trace of chlorite is present.

Ontario

From quartz monzonite.
(41 N) Rock-cut at lookout on Highway 17, northeast of Montreal Island; 47°21'40"N, 84°40'20"W. Ontario Dept. Mines Map 1958B. Sample SH-90-60. Collected and described by C. H. Stockwell.

The quartz monzonite is a medium-grained, massive white rock consisting of quartz, andesine, microcline, biotite, and muscovite. The biotite is dirty and is almost completely altered to chlorite, but the muscovite is fresh. The K-Ar age is thought to date the approximate time of primary crystallization of the rock.

In the rock-cut, the quartz monzonite is seen to hold a few small pegmatite segregations and a few inclusions of biotite-rich paragneiss, which are not included in the sample.

GSC 61-143 Biotite, K-Ar age 2,405 m.y.

K 7.45%, Ar^{40}/K^{40} .2848; radiogenic argon 98%. Concentrate: consists of brown to olive-green biotite. Some flakes have inclusions of quartz. Chlorite/biotite 0.04.

From gneissic granodiorite.
(41 O) Road-cut on Highway 129, 6.2 miles south of Chapleau; 47°45'20"N, 83°22'40"W. Map-unit 4, GSC Map 1063A. Sample SH-80-60. Collected and described by C. H. Stockwell.

The granodiorite is a medium-grained, foliated rock with a granitic texture, and is composed of quartz, slightly sericitized oligoclase, microcline, myrmekite, biotite, and minor muscovite and apatite. Much of the biotite is fresh but some is partly altered to chlorite and opaque material. The biotite is primary and gives the age of intrusion.

GSC 61-144 Biotite, K-Ar age 1,090 m.y.

K 7.45%, Ar^{40}/K^{40} .0865; radiogenic argon 99%. Concentrate: reasonably clean fresh biotite, consisting of 65% pale to dark brown, 10% olive-brown, and 15% greenish flakes. About 5% bluish green pyroxene is present. Chlorite not detected.

From nepheline syenite.
(41 O) West wall of open pit on No. 6 magnetite-apatite body, 7 miles northeast of Nemegos; 47°47'10"N,

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83°07'50"W. Map-unit 3, Ontario Dept. Mines Map 2008. Sample SH-81-60. Collected and described by C.H. Stockwell.

The nepheline syenite is a medium-grained, mottled, purplish to grey rock composed of orthoclase, nepheline, aegirine-augite, biotite, and minor magnetite, calcite, and apatite. The biotite is fresh, medium grained, and forms lenses, streaks, and fracture-fillings in the syenite.

The sample is from the niobium-bearing, alkaline, Lackner Complex which consists of circular-trending, inwardly dipping zones of alkaline silicate rocks and a little carbonatite enclosed in nepheline syenite (Parsons, 1961). The biotite, although filling fractures in the syenite, probably gives the approximate age of the complex. The ring complex, dated at 1,090 m.y., intrudes gneisses of the Superior province which was stabilized by the Kenoran orogeny about 2,500 m.y. ago. Because of the very long lapse of time between the two events—about 1,400 m.y.—the alkaline complex can hardly be considered as a late phase of the Kenoran orogeny; it is closer in age and probably related to the Grenville orogeny which took place about 950 ± 150 m.y. ago.

The Lackner Complex is one of a number of niobium-bearing alkaline intrusions found in the Canadian Shield, evidently not all of the same age. For example, the Manitou Island Complex which invades gneisses of the Grenville province is dated at 560 m.y. (GSC 61-160), and the Oka Complex which intrudes rocks of an inlier of the Grenville province is dated at 95 m.y. (Hurley, 1960).

GSC 61-145 Biotite, K-Ar age 1,915 m.y.

K 8.09%, Ar^{40}/K^{40} .1941; radiogenic argon 95%. Concentrate: consists of clean "citrine" green biotite with some inclusions of zircon surrounded by ginger-brown pleochroic haloes. About 10% of the flakes contain long needle-like inclusions. Some flakes have small epidote inclusions along fractures and edges of flakes. Chlorite/biotite 0.02.

From plagioclase-biotite-quartz gneiss.

(41 J) Southeast end of Bright Lake, Bright township; 46°15'N, 83°15'W. Map-unit 1b, GSC PS Map 5-1961. Sample FKA-1-60. Collected and interpreted by M.J. Frarey.

Ontario

The biotite sample was obtained from gneiss of the pre-Huronian belt of basement rocks between Thessalon and Blind River, Ontario. The date of 1,915 m.y. is somewhat lower than the general age of the pre-Huronian basement terrain in the district north of Lake Huron, but is considerably older than post-Huronian ages. It is likely that the mica is older than the age indicates, and has lost argon during deformation, possibly during the development of the Murray fault, which is relatively near.

GSC 61-146 Whole Rock, K-Ar age 1,580 m.y.

K 6.58%, Ar^{40}/K^{40} .1447; radiogenic argon 100%. Concentrate: the sample submitted consists of the whole rock crushed to 150 mesh. It consists of sericite flakes, 10-15 microns in diameter, in part forming aggregates up to 100 microns in size; about 20% quartz fragments up to 50 microns in size; and chlorite flakes up to about 40 microns in cross-section. Chlorite/muscovite 1.2. Quartz is estimated at 15%. Note: the chlorite/muscovite ratio is probably inaccurate due to poor orientation of the mica flakes.

Argillite.
(41 J) Nordic mine, diamond-drill hole 931; 46°22'50"N, 82°36'20"W. GSC Paper 56-7, Fig. 3. Sample SH-78a-60. Collected and described by C.H. Stockwell.

The sample is fine-grained, black argillite showing a good cleavage parallel with the bedding and consisting predominantly of very fine grained sericitic material and some quartz. The sample is from the gently dipping Whiskey Formation, which lies within the lower part of the Huronian succession, and represents one of the least-metamorphosed members of the Huronian.

The whole rock age was run as an experiment as it was thought that the sericitic mica, lying on the bedding planes of a virtually undeformed rock, probably crystallized during the early stages of consolidation and, if so, would give an age close to the time of deposition of the sediment. However, the determined age of 1,580 m.y. is considerably younger than the 1,700-m.y. figure on uraninite from the Lower Huronian Mississagi Formation of the Blind River - Quirke Lake area as determined by Mair et al. (1960) who concluded that the sediments may be either of that age or older. It is noted that the 1,580-m.y. age compares with the 1,520-m.y. figure obtained on biotite from the nearby granitic gneiss of the pre-Huronian basement (GSC 61-147) and it is apparent that both of these K-Ar ages could be explained as due to loss of argon.

Ontario

GSC 61-147 Biotite, K-Ar age 1,520 m.y.

K 7.98%, Ar^{40}/K^{40}.1365; radiogenic argon 91%.
Concentrate: flakes are pale to medium brown.
Most are clear, but some have needle-like
inclusions. Chlorite/biotite 0.01.

From granitic gneiss.
(41 J) Road-cut on Highway 108, 6 miles north of its
junction with Highway 17; 46°17'50"N, 82°33'50"W.
Unmapped, but would fall within map-unit 1a, GSC
Map 1970. Sample SH-79-60. Collected and
described by C.H. Stockwell.

The sample is a strongly banded, grey, granitic gneiss containing biotite in some layers and hornblende in others. In addition to biotite and hornblende the rock contains quartz, plagioclase, orthoclase, microcline, and a little apatite and pyrite. The plagioclase is much altered to zoisite and epidote. The biotite is mostly fresh but some crystals are interleaved with chlorite.

In the road-cut the gneiss is seen to be cut along and across its strike by stringers of light grey biotite granite, which in turn are cut by stringers of white pegmatite. At a point 20 feet from where the sample was collected all are cut by a dyke of diabase 10 feet wide.

The gneiss is from the pre-Huronian basement complex of the Blind River - Quirke Lake area and lies in the Superior province, but the age of 1,520 m.y. is much younger than expected. The true age of granitic intrusion and strong metamorphism of the basement rocks of the area is thought to be close to 2,445 m.y. (GSC 60-105, on muscovite from quartz monzonite at Quirke Lake) and this is probably about the age of crystallization of the biotite of the granitic gneiss under discussion. The much younger age obtained may be explained by post-crystallization loss of argon due either to the relatively gentle post-Huronian deformation or to the effect of the nearby diabase dyke. The age of 1,520 m.y. agrees closely with that of 1,580 m.y. obtained on argillite from the nearby Whiskey Formation of the Lower Huronian (see GSC 61-146).

GSC 61-148 Biotite, K-Ar age 1,395 m.y.

K 7.94%, Ar^{40}/K^{40}.1207; radiogenic argon 91%.
Concentrate: biotite flakes are pale brown with dark
brown rims and fringes. Some flakes show zoning.
Chlorite not detected.

Ontario

From biotite lamprophyre.

(41 J) Bracemac drill-hole, depth 3,079-3,096 feet, south shore of Rangers Lake; 46°27'40"N, 82°21'W. Ontario Dept. Mines Map 2004. Sample PH-277-59. Collected and interpreted by S. M. Roscoe.

This sample is from a thin, biotite-rich lamprophyre dyke that cuts Huronian rocks (Mississagi Formation) a few miles east of Quirke Lake. The only other K-Ar dates that have been obtained in this area (west of Espanola) are from pre-Huronian material and give dates of 1,600 to 2,400 m.y., the greater figure being the more likely. Post-Huronian dates from the Espanola area are 1,400 to 1,600 m.y., dating the age of the Huronian orogeny and diabase intrusion. It is likely that the lamprophyre dykes are post-Nipissing diabase, and possible that they are late- or post-orogenic.

The date on this sample confirms the hypothesis that Huronian rocks were deposited, deformed, and intruded by diabase sills prior to 1,400 m.y. It suggests that the lamprophyre is probably appreciably younger and unrelated to the diabase sills. It shows that the lamprophyre was older and unrelated to the late diabase dykes (Keweenawan) likely to be about 1,000 m.y. old. It also confirms indirectly that the uranium-bearing deposits in the Elliot Lake area are no younger than the period of Huronian orogeny (1,400-1,600 m.y.).

GSC 61-149 Muscovite, K-Ar age 1,550 m.y.

K 4.31%, Ar^{40}/K^{40} .1407; radiogenic argon 100%. Concentrate: consists of about 40% clean muscovite flakes; about 50% quartz-muscovite-chlorite-feldspar intergrowths; and about 10% quartz and feldspar fragments. Chlorite/muscovite 0.26.

From schistose argillite.

(41 I) Road-cut on Highway 68, 700 feet north of bridge over Spanish River; 46°16'10"N, 81°46'30"W. Map-unit S2, GSC Map 291A. Sample SH-73-60. Collected and described by C. H. Stockwell.

This is a very fine grained, grey, schistose, argillaceous rock showing graded bedding crossed at a high angle by a secondary cleavage along which sericite has developed. As seen in thin section, the rock consists chiefly of quartz and, in addition to sericite, a considerable amount of chlorite and minor carbonate.

The rock belongs to the McKim Formation which is mapped as pre-Huronian in age. The determined age is a minimum for the McKim. The sericite (muscovite) age of 1,550 m.y. compares with a potassium-argon age of 1,600 m.y. on biotite (Fairbairn et al., 1960) separated from the same formation 40 miles to the northeast.

Ontario

GSC 61-150 Muscovite, K-Ar age 2,220 m.y.

K 9.02%, Ar^{40}/K^{40} .2482; radiogenic argon 87%. Concentrate: flakes have tiny specks on the surface and a few show yellow stained patches. Impurities include a minor amount of small biotite flakes and tiny inclusions of quartz. Chlorite not detected.

From pegmatite.
(41 I) Dam at outlet of Birch Lake (Gough Lake); 46°17'05"N, 81°55'50"W. Map-unit 4, GSC Map 291A. Sample SH-74-60. Collected and discussed by C.H. Stockwell.

The pegmatite dyke, which is about 2 feet wide, is composed of pink feldspar crystals up to 4 inches long, lying in a finer-grained mixture of white albite, quartz, and muscovite. The muscovite flakes are somewhat bent and broken and are slightly rusty due to weathering.

The dyke cuts grey, massive to gneissic microcline-albite granite containing a little muscovite and biotite, the latter mineral being almost completely altered to chlorite. This is called the 'Birch Lake Granite'. The pegmatite, no doubt, is a late phase of the granite and is practically the same age.

On GSC Map 291A this granite is shown as Killarnean in age, but it is obviously much older for the biotite from Killarney Granite of the type locality gave a K-Ar age of 1,170 m.y. (GSC 61-158).

According to Collins (GSC Map 291A, 1938), the Birch Lake Granite is post-Huronian but, according to Thomson (Ontario Dept. Mines Map P. 105, 1961), it is pre-Huronian. The K-Ar age of 2,220 m.y. does not solve the problem for it is intermediate between a maximum of 2,455 m.y. (GSC 60-105) and a minimum of 1,700 m.y. (Mair et al., 1960) for the Lower Huronian of the Blind River - Quirk Lake area, which area, it is here suggested, might be taken as the type region for the Lower Huronian.

GSC 61-151 Biotite, K-Ar age 2,640 m.y.

K 7.44%, Ar^{40}/K^{40} .3366; radiogenic argon 99%. Concentrate: consists of about 75% clean, brown and greenish brown biotite; about 10% biotite chloritized along the edges; and about 15% biotite containing fairly coarse inclusions of quartz. Some zircon inclusions surrounded by pleochroic haloes are present. Chlorite/biotite 0.11.

Ontario

From granodiorite

(41 P) On road, 1.7 miles southwest of Louis Lake; 47°07'20"N, 81°50'40"W. Map-unit 4, GSC Map 1063A. Sample SH-8-60. Collected and described by C. H. Stockwell.

(For description see determination GSC 61-152.)

GSC 61-152 Muscovite, K-Ar age 2,565 m.y.

K 8.29%, Ar^{40}/K^{40}.3199; radiogenic argon 99%. Concentrate: consists of about 40% clean muscovite, about 40% muscovite with quartz inclusions, and about 20% muscovite intergrown with quartz, feldspar, and chloritized biotite. Estimated impurities are 5% chlorite, 8% feldspar, and 3% quartz.

From granodiorite.

(41 P) On road, 1.7 miles southwest of Louis Lake; 47°07'20"N, 81°50'40"W. Map-unit 4, GSC Map 1063A. Sample SH-8-60. Collected and described by C. H. Stockwell.

This muscovite (GSC 61-152, 2,565 m.y.) and the biotite of GSC 61-151 (2,640 m.y.) were separated from the same sample and the two determinations are in good agreement.

The granodiorite is a medium-grained, grey, slightly gneissic rock composed of quartz, oligoclase, orthoclase, biotite, muscovite, and minor epidote, carbonate, apatite, magnetite, and zircon. The micas are fresh except that a little chlorite is interleaved with some of the biotite.

On the outcrop the granodiorite is crisscrossed by numerous dykelets of pink aplite and pegmatite; it is mapped as younger than the Ridout Group and the determined ages are minima for the group.

GSC 61-153 Biotite, K-Ar age 2,285 m.y.

K 6.95%, Ar^{40}/K^{40}.2603; radiogenic argon 99%. Concentrate: clean concentrate of heterogeneous biotite. The flakes vary in colour from brown to green and contain variable quantities of needle-like inclusions, possibly epidote. About 35% of the flakes are clean brown biotite. Chlorite/biotite 0.3.

Ontario

From gneissic granite.
(42 B) Road-cut 1/2 mile west of Scorch River; 48°14'00"N, 82°20'00"W. Ontario Dept. Mines Map 33g. Sample SH-22-60. Collected and described by C. H. Stockwell.

(For description see determination GSC 61-154.)

GSC 61-154 Muscovite, K-Ar age 2,495 m.y.

K 7.19%, Ar^{40}/K^{40} .3040; radiogenic argon 80%. Concentrate: consists of about 20% clean muscovite with only minor inclusions of quartz; about 60% muscovite-feldspar-quartz micrographic intergrowths; about 20% impurities made up of quartz-biotite-chlorite, with and without muscovite intergrowths; and minor zircon and epidote. Estimated impurities are 5% chlorite, 6% quartz, and 17% feldspar.

From gneissic granite.
(42 B) Road-cut 1/2 mile west of Scorch River; 48°14'00"N, 82°20'00"W. Ontario Dept. Mines Map 33g. Sample SH-22-60. Collected and described by C. H. Stockwell.

The biotite (GSC 61-153, 2,285 m.y.) and the muscovite (GSC 61-154, 2,495 m.y.) are from the same sample and the discrepancy in the determined ages is considerable. Although the difference of 210 m.y. may be analytical, it appears more likely that the muscovite, as is generally the case elsewhere, gives a more reliable age, the biotite presumably having lost part of its argon.

The sample is a medium-grained, light grey, gneissic granite composed of quartz, orthoclase, microcline, oligoclase, biotite, and muscovite. The biotite is only slightly chloritized but is altered to tiny specks of opaque material along cleavage planes and around crystal edges.

On the outcrop the gneissic structure is seen to be highly contorted and is cut along and across the structure by stringers of pink granite.

Ontario

GSC 61-155 Biotite, K-Ar age 2,440 m.y.

K 7.36%, Ar^{40}/K^{40} .2921; radiogenic argon 97%. Concentrate: colour varies from greenish brown to green. Some chloritized flakes and free chlorite occur. Chlorite/biotite 0.15.

From biotite-hornblende lamprophyre.

(32 D) Outcrop at Raven River mine 1/2 mile east of Larder Lake townsite; 48°05'40"N, 79°42°00"W. Map-unit 9d, Ontario Dept. Mines Map 50b. Sample SH-13-60. Collected and described by C.H. Stockwell.

The lamprophyre is a massive, dark grey rock with widely scattered phenocrysts of biotite, 1/10 inch across, in a fine-grained groundmass of albite, orthoclase, hornblende, and biotite. Most of the biotite is unchloritized. Titanite is accessory and carbonate is plentiful as an alteration product.

The rock intrudes sediments of the Timiskaming Series and the biotite gives the age of the intrusion and a minimum age for the Timiskaming.

GSC 61-156 Biotite, K-Ar age 2,605 m.y.

K 7.45%, Ar^{40}/K^{40} .3292; radiogenic argon 99%. Concentrate: consists of coarse olive-green biotite, mainly pure, but a few flakes have quartz inclusions. Chlorite/biotite 0.04.

From granodiorite.

(41 P) Road-cut 0.4 mile south of the east end of Hough Lake; 47°55'20"N, 80°11'30"W. Ontario Dept. Mines Map 31b. Sample SH-11-60. Collected and described by C.H. Stockwell.

The sample is a light grey, foliated granodiorite with a granitic texture, and is composed of quartz, oligoclase, microcline, biotite, and accessory titanite and apatite. The oligoclase is slightly zoned and partly altered to sericite. The biotite is fresh and is associated with coarse epidote.

According to the map the granite cuts "Keewatin" volcanic rocks and is overlain unconformably by sediments of the Cobalt Group. The biotite, being primary, gives the age of crystallization of the granodiorite and also gives a maximum age for the Cobalt.

Ontario

GSC 61-157 Biotite, K-Ar age 2,095 m.y.

K 6.54%, Ar^{40}/K^{40} .2245; radiogenic argon 97%. Concentrate: contains about 90% fresh reddish brown biotite. The remainder consists of grains of plagioclase and altered pyroxene. Chlorite not detected.

From olivine diabase.

(31 M) Road-cut on Highway 11, 3/4 mile southwest of North Cobalt; 47°25'00"N, 79°39'00"W. Map-unit 10, Ontario Dept. Mines Map 1956a. Sample SH-7-60. Collected and described by C. H. Stockwell.

The sample is a dark grey, massive, medium-grained diabase composed chiefly of laths of labradorite and irregular grains of pyroxene and olivine. The labradorite is only slightly altered to zoisite and epidote, and the olivine is partly gone to serpentine and magnetite. Deep-brown biotite occurs sparingly as tiny crystals; it is a primary mineral and is unaltered.

The sample is from a sill mapped as Nipissing Diabase and the occurrence is in the type region for the Nipissing. The sill cuts rocks of the Cobalt Group. The biotite age dates the approximate time of crystallization of the diabase and is a minimum for the Cobalt.

GSC 61-158 Biotite, K-Ar age 1,170 m.y.

K 6.74%, Ar^{40}/K^{40} .0947; radiogenic argon 90%. Concentrate: biotite flakes are mainly olive-green but some are brown to brownish green. A few grains of free chlorite are present. Some inclusions of quartz and orange-yellow stained patches occur. Chlorite/biotite 0.15.

From granite.

(41 H) 1/4 mile west of schoolhouse in the town of Killarney; 45°58'20"N, 81°31'10"W. Map-unit 4b, GSC Map 221A. Sample SH-93-60. Collected and described by C. H. Stockwell.

The granite of the sample is a massive, medium-grained, pink rock composed of microcline, oligoclase, interstitial quartz, biotite, and a little muscovite, apatite, and pyrite. The oligoclase is considerably altered to coarse sericite and some of the biotite crystals are partly to completely altered to chlorite.

Ontario

The sample is from the type locality of the Killarney Granite and lies within the Grenville province at a point about 1 1/4 miles southeast of the contact with the Penokean subprovince. Field relations and a detailed description are given by Quirke and Collins (1930, pp. 43-55) who present petrographic and chemical evidence to show that the rock was formed by granitization of Lorrain Quartzite—a formation of the Cobalt Group of Huronian age. The K-Ar age of 1,170 m.y. on biotite is somewhat older than the prevalent K-Ar age of around 950 m.y. for the Grenville orogeny, and the discrepancy may be due to the fact that the sample was taken from a locality close to the Grenville front. (For discussion of the problem of discrepant ages along the Grenville front, see Stockwell, Part II of this report.)

GSC 61-159 Biotite, K-Ar age, 1,395 m.y.

K 6.92%, Ar^{40}/K^{40} .1210; radiogenic argon 99%. Concentrate: composed mainly of red-brown biotite containing inclusions of long needles of rutile, coarse epidote, and minor quartz. Impurities are 5% partly chloritized flakes, 5% free chlorite and a few fragments of hornblende. Chlorite/biotite 0.08.

From paragneiss.
(31 L) Highway 11, northeast of Opechee Lake; 46°47'20"N, 79°48'20"W. Map-unit 4A, Plate 2, Bull. Geol. Soc. Amer., vol. 65 (W.G.Q. Johnson). Sample SH-4-60. Collected and described by C.H. Stockwell.

The paragneiss is a medium-grained, grey, well-foliated rock, composed of a mosaic of oligoclase and quartz through which are plentiful, roughly parallel flakes of brown, unchloritized biotite. Chlorite is also plentiful but occurs as grains distinct from those of biotite. Epidote is fairly abundant, and carbonate, apatite and titanite form minor constituents. On the outcrop the paragneiss is seen to be cut along and across its foliation planes by stringers of white granite which are not included in the sample.

The age of 1,395 m.y. contrasts with the prevalent K-Ar ages on biotite of around 850 to 950 m.y. for the Grenville province generally, and affords another example of an anomalously old age close to the Grenville front. (For discussion see Stockwell, Part II of this report.)

GSC 61-160 Biotite, K-Ar age 560 m.y.

K 7.77%, Ar^{40}/K^{40} .0382; radiogenic argon 99%. Concentrate: clean brown to reddish brown biotite. Chlorite not detected.

Ontario

From carbonatite.

(31 L) Mine dump from Newman deposit, Newman Island, Lake Nipissing; 46°15'00"N, 79°35'00"W. Fig. 14, GSC Econ. Geol. Ser. No. 18. Sample SH-2-60. Collected and described by C.H. Stockwell.

The sample is a grey, coarse-grained rock, composed chiefly of randomly oriented porphyroblasts of biotite and pyroxene (probably acmite) in a matrix of coarse white carbonate and pale green apatite. Blue amphibole, pyrite, and pyrochlore occur in minor amounts.

The geological setting and mineralogy of the Newman deposit, which carries niobium and uranium, is described by Rowe (1958). The deposit lies within the alkaline Manitou Island Complex, composed of concentric rings of syenitic soda-pyroxene rocks, locally with calcite rock. The age of 560 m.y. indicates that the biotite and probably the other minerals of the deposit crystallized in Cambrian time and are much younger than prevalent ages of around 950 m.y. of the Grenville province in which the complex lies. The complex is overlain unconformably by small outliers of the Birds Eye and Black River Formations of Ordovician age. This is one of a number of alkaline complexes found in the Canadian Shield. (See also GSC 61-144.)

Quebec

GSC 61-161 Biotite, K-Ar age 940 m.y.

K 7.81%, Ar^{40}/K^{40} .0713; radiogenic argon 100%. Concentrate: clean concentrate of pale brownish grey biotite. A few flakes contain red platy aggregates of iron oxide on the surface. Chlorite not detected.

From pegmatite.
(31 F) Lot 5, rge. X, Litchfield tp.; 45°52'N, 76°38'W. GSC Map 703A. Sample RG-61-A-3. Collected and interpreted by E.R. Rose.

This sample is from medium-grained, fresh flakes of biotite developed at the contact of a uranium-thorium-rich pegmatite and a body of dark gabbro rich in titaniferous magnetite, both intrusive into granitic gneiss of the Grenville province. The age of the biotite dates the emplacement of the pegmatite into the gabbro, and gives a minimum age for the gabbro and titaniferous magnetite there.

The age of the pegmatite agrees well with that of 935 m.y. measured for determination GSC 59-86, another radioactive, biotite-bearing pegmatite from Lac Pied Des Monts, Quebec.

GSC 61-162 Muscovite, K-Ar age 960 m.y.

K 8.10%, Ar^{40}/K^{40} .0733; radiogenic argon 100%. Concentrate: contains about 85% clean muscovite flakes, 10% muscovite intergrown with quartz, and 5% muscovite intergrown with biotite. Only a trace of chlorite is present.

From biotite-muscovite orthogneiss.
(32 G) Road-cut on Chibougamau Highway at mile 117.7, Charron tp.; 49°34'00"N, 74°14'25"W. Quebec Dept. Mines Map 1235. Sample SH-8-59. Collected and interpreted by C.H. Stockwell.

The muscovite at 960 m.y. is from the same sample as the biotite at 1,270 m.y. (GSC 60-108). The sample is from the Grenville province at a point 1 1/2 miles southeast of the Grenville front which marks the contact with the Superior province. The muscovite age is normal for the Grenville province but the biotite age is abnormal and the discrepancy is too great to be interpreted as an analytical error. Moreover, the muscovite and biotite flakes lie about parallel with one another, suggesting that they crystallized at about the same time. The problem of discrepant ages along the Grenville front is discussed in Part II of this report.

Quebec

GSC 61-163 Biotite, K-Ar age 935 m.y.

K 7.88%, Ar^{40}/K^{40} .0709; radiogenic argon 100%. Concentrate: consists of clean brown biotite. A few flakes are slightly greenish with fine-grained epidote along the edges. Chlorite/biotite 0.03.

From granitic gneiss.
(22 K) Outardes River; 50°15'30"N, 69°15'30"W. Sample HF-45-1961. Collected by W.W. Heywood. Described by C.H. Stockwell.

This is a medium-grained gneissic rock composed chiefly of white andesine with lesser amounts of quartz, hornblende, and biotite, and a little zircon, epidote, apatite, and carbonate. The biotite is of metamorphic origin and is unaltered.

GSC 61-164 Muscovite, K-Ar age 910 m.y.

K 9.08%, Ar^{40}/K^{40} .0683; radiogenic argon 98%. Concentrate: reasonably clean. About 40% of flakes contain small scattered inclusions of quartz; about 10% contain numerous quartz inclusions and some opaque material. A few flakes have attached fragments of biotite. Chlorite not detected.

From muscovite-quartz-schist.
(23 C) Lake Schelles; 52°13'30"N, 68°52'W. Sample 60-GF-140. Collected and interpreted by G.A. Gross.

(For interpretation see determination GSC 61-165.)

GSC 61-165 Biotite, K-Ar age 900 m.y.

K 7.93%, Ar^{40}/K^{40} .0673; radiogenic argon 98%. Concentrate: consists of ginger-brown flakes with lighter and darker patches. About 5% of flakes are greenish grey, chloritized, and contain needle-like inclusions; about 20% show one or more grey to black pleochroic haloes. Chlorite/biotite 0.05.

From muscovite-quartz-schist.
(23 C) Lake Schelles; 52°13'30"N, 68°52'W. Sample 60-GF-140. Collected and interpreted by G.A. Gross.

Quebec

These samples (GSC 61-164 and GSC 61-165) were analyzed to date the age of metamorphism of rocks near the northwest boundary of the Grenville orogenic belt, and to define further the boundary zone of the Grenville province. The schists and iron-formation are recognized on the basis of stratigraphy as being the metamorphosed equivalent of the Knob Lake Group in the Labrador geosyncline.

GSC 61-166 Biotite, K-Ar age 950 m.y.

K 6.95%, Ar^{40}/K^{40} .0723; radiogenic argon 96%. Concentrate: contains about 80% fresh, clean, brown biotite, of which about 30% of the flakes exhibit prominent (001) parting and the other 50% are compact. Approximately 20% of the flakes are altered in varying degrees, from slightly bleached and greenish along fractures and edges to entirely green chlorite with small inclusions of epidote. Chlorite/biotite 0.13.

From biotite paragneiss.
(22 P) West Shore of Canatiche Lake; 51°13'N, 65°41'W. Sample FB-16-59. Collected by Y.O. Fortier and C.S. Lord. Interpreted by W.F. Fahrig.

The biotite is from a well-foliated hornblende-biotite-feldspar-quartz gneiss. The estimated composition of the gneiss is 40% potash feldspar, 30% quartz, 10% oligoclase, 15% biotite and 5% hornblende. Accessories are sphene, apatite, pyrite, iron oxides, and zircon.

This sample is from the interior of the Grenville province and, as expected, the K-Ar age of the biotite lies within the range of ages characteristic of the Grenville orogeny.

GSC 61-167 Biotite, K-Ar age 2,555 m.y.

K 8.03%, Ar^{40}/K^{40} .3168; radiogenic argon 99%. Concentrate: flakes vary from brown to greenish. Some flakes have needle-like inclusions. A few fragments of bluish green amphibole occur as impurities. Chlorite not detected.

From syenite.
(32 D) 1 1/4 miles northwest of the town of Aldermac; 48°13'10"N, 79°12'20"W. Map-unit 3, GSC Map 240A. Sample SH-14-60. Collected and described by C.H. Stockwell.

Quebec

The sample, which is of diamond-drill core, consists of massive, medium-grained, green to black syenite with a few phenocrysts of feldspar up to 2 inches long. The dark groundmass is composed of dark green pyroxene, brown biotite, microcline, and a little shreddy blue amphibole, albite, titanite, apatite, and magnetite. The biotite is clear and fresh.

The sample is from a complex stock of syenite porphyry about 1 1/2 miles long and 1 mile wide which invades volcanic rocks and is cut by a dyke of diabase. The age obtained for the biotite indicates the time of crystallization of the syenite and is a maximum for sediments of the Cobalt Group which occur 2 miles to the south.

A detailed petrographic description of the syenite is given by Gunning (1927).

GSC 61-168 Biotite, K-Ar age 2,545 m.y.

K 7.86%, Ar^{40}/K^{40} .3145; radiogenic argon 100%. Concentrate: consists of 80% green biotite and 20% brownish biotite. Small inclusions of quartz and iron oxides are present in some flakes. Chlorite/biotite 0.05.

From granodiorite.
(32 D) Boundary between Ranges IV and V, Desmeloizes tp.; 48°55'25"N, 79°30'00"W. Map-unit 4, GSC Map 284A. Sample SH-21-60. Collected and described by C.H. Stockwell.

The granodiorite of the sample is a medium-grained, massive grey rock, composed of oligoclase, microcline, orthoclase, quartz, biotite, and minor hornblende. The biotite is unchloritized and is associated with abundant epidote.

The sample is from a pluton intruding metavolcanic rocks and the age obtained for the biotite is thought to date the approximate time of crystallization of the pluton.

GSC 61-169 Biotite, K-Ar 2,510 m.y.

K 7.24%, Ar^{40}/K^{40} .3073; radiogenic argon 99%. Concentrate: consists of coarse greenish biotite. Contains about 80% fresh clean biotite; 15% biotite with inclusions of epidote, quartz, and long needles intersecting at 60 and 120°; and 5% chloritized biotite, free chlorite, and hornblende fragments. Chlorite/biotite 0.08.

Quebec

From quartz-monzonite.

(32 F) Road-cut on highway, 22 1/2 miles north of bridge over Bell River; 49°16'10"N, 76°39'20"W. Map-unit 3, Quebec Dept. Mines Map 961. Sample SH-18-60. Collected and described by C.H. Stockwell.

The quartz monzonite is a medium-grained, massive, pinkish grey rock composed of strongly zoned oligoclase, microcline, quartz, and plentiful green hornblende and biotite. Titanite and magnetite are accessory. The oligoclase is somewhat clouded with sericite; the biotite is generally fresh but some books are interleaved with chlorite.

The sample is from a stock about 3 miles in diameter which cuts volcanic rocks. The biotite age indicates the time of crystallization of the quartz monzonite.

GSC 61-170 Muscovite, K-Ar age 2,465 m.y.

K 8.58%, Ar^{40}/K^{40} .2972; radiogenic argon 100%. Concentrate: good concentrate of muscovite flakes, mostly with rare inclusions of quartz but about 5% contain numerous inclusions. Chlorite not detected.

From pegmatite.

(32 L) East shore of Harricanaw River; 50°20'N, 79°00'W. Sample SH-98-60. Collected and described by J.H. Remick, Quebec Department of Mines.

The pegmatite is unzoned and is composed of coarse-grained quartz, light pink perthitic microcline, muscovite, and beryl. The beryl is pale green and occurs in prismatic crystals from 1/2 to 3/4 inch across and up to 2 inches long. A fine-grained granitic phase of the pegmatite contains reddish brown garnets about 2 mm in diameter.

The pegmatite mass cuts across an outcrop of hornblende schist and biotite-hornblende schist that is part of an east-west belt about 3/4 mile wide surrounded by a large mass of granite and gneissic granite. Pegmatite also occurs in the granitic rocks and elsewhere in the schist. These pegmatites are composed chiefly of quartz and feldspar and generally lack mica, but some contain biotite or, more rarely, muscovite; no beryl was observed in them.

The pegmatite from which the sample was collected is undoubtedly related to the nearby granitic rocks and the age obtained on the muscovite is approximately that of the crystallization of the pegmatite and granite, and gives a maximum age for the rock from which the schist was derived.

Quebec

GSC 61-171 | Biotite, K-Ar age 2,485 m.y.

K 7.11%, Ar^{40}/K^{40} .3018; radiogenic argon 99%. Concentrate: very impure; contains about 50% pure brown biotite flakes; 40-45% partly chloritized biotite with green chloritized patches and inclusions; and 5% pale green chlorite with needle-like inclusions. Chlorite/biotite 0.35.

From granite-gneiss.

(23 C) Atticoupis Lake; 52°50'N, 69°57'W. Sample SG-2-60(60-127). Collected and interpreted by I.M. Stevenson.

The age determined for this specimen indicates that these rocks were unaffected by the Grenville orogeny. The Grenville front lies some 50 miles to the southeast.

GSC 61-172 | Biotite, K-Ar age 2,430 m.y.

K 8.19%, Ar^{40}/K^{40} .2904; radiogenic argon 100%. Concentrate: consists of clean reddish brown biotite. Some flakes are slightly discoloured. Chlorite/biotite 0.01.

From granite.

(34 G) East side of Lake Minto; 57°07'N, 74°33'W. Unmapped area. Sample SG-204. Collected and interpreted by I.M. Stevenson.

(For interpretation see determination GSC 61-177.)

GSC 61-173 | Biotite, K-Ar age 2,510 m.y.

K 8.15%, Ar^{40}/K^{40} .3070; radiogenic argon 99%. Concentrate: consists of clean light to dark brown biotite. Some flakes have crusts of ginger-red iron oxide. Chlorite not detected.

From granite-gneiss.

(34 J) Quebec; 58°16'N, 75°02'W. Unmapped area. Sample CP-187. Collected by K. Currie. Interpreted by I.M. Stevenson.

(For interpretation see determination GSC 61-177.)

Quebec

GSC 61-174

Mucovite, K-Ar age 2,470 m.y.

K 8.59%, Ar^{40}/K^{40} .2980; radiogenic argon 99%. Concentrate: reasonably clean. Some flakes are coated with ginger-brown films of iron oxide. Impurities consist of about 10% alkali feldspar and quartz. Chlorite not detected.

From granite.
(34 P) Southeast corner of Lac Maguire; 58°10'N, 73°04'W. Unmapped area. Sample SG-160. Collected and interpreted by I.M. Stevenson.

(For interpretation see determination GSC 61-177.)

GSC 61-175

Biotite, K-Ar age 2,415 m.y.

K 8.12%, Ar^{40}/K^{40} .2862; radiogenic argon 100%. Concentrate: consists of fresh biotite varying from brown (70%) to greenish (30%). Impurities are minor and consist of a few flakes of green chlorite with inclusions of quartz, epidote, and opaque grains. Chlorite content less than 1%.

From granite-gneiss.
(24 L) South of Leaf River; 58°08'N, 71°26'W. Unmapped area. Sample SG-62. Collected and interpreted by I.M. Stevenson.

(For interpretation see determination GSC 61-177.)

GSC 61-176

Biotite, K-Ar age 2,225 m.y.

K 7.49%, Ar^{40}/K^{40} .2489; radiogenic argon 98%. Concentrate: consists of dark brown biotite with inclusions along fractures and edges. Chlorite not detected.

From granite-gneiss.
(24 M) Quebec; 59°31'N, 71°50'W. Unmapped area. Sample SG-192. Collected and interpreted by I.M. Stevenson.

(For interpretation see determination GSC 61-177.)

Quebec

GSC 61-177 Biotite, K-Ar age 2,475 m.y.

K 8.04%, Ar^{40}/K^{40} .2993; radiogenic argon 100%. Concentrate: consists of mostly clean red-brown biotite. A few flakes are partly coated with thin opaque crusts and contain very fine grained inclusions of quartz. Chlorite/biotite 0.05.

From granite-gneiss.
(34 O) Quebec; 59°02'N, 74°33'W. Unmapped area. Sample SL-157. Collected by E.A. Schiller. Interpreted by I.M. Stevenson.

These specimens (GSC 61-172, GSC 61-173, GSC 61-174, GSC 61-175, GSC 61-176, and GSC 61-177) were collected from widely separated localities. The relative uniformity of the ages determined offers additional proof that the last major orogeny in this part of the Shield took place some 2,400 m.y. ago. These age determinations are the first made from this large area of the Shield. (See also determination GSC 61-178.)

GSC 61-178 Biotite, K-Ar age 1,690 m.y.

K 8.21%, Ar^{40}/K^{40} .1599; radiogenic argon 100%. Concentrate: consists of clean biotite. Some flakes contain brown spots. Chlorite not detected.

From granite.
(24 M) Quebec; 59°36'N, 70°10'W. Unmapped area. Sample SG-106. Collected and interpreted by I.M. Stevenson.

The date of this specimen, considerably less than that of the neighbouring granites and granite-gneisses immediately to the west (see determination GSC 61-177), reflects the influence of the younger Labrador Trough metamorphism.

GSC 61-179 Biotite, K-Ar age 1,560 m.y.

K 7.99%, Ar^{40}/K^{40} .1422; radiogenic argon 92%. Concentrate: consists of small brown flakes, rounded and slightly bleached. Some inclusions of quartz, and about 2% muscovite are present. Chlorite not detected.

Quebec

From mica schist.

(24 N) Hopes Advance Bay, 250 yards northwest of Merganser Point; 59°20'45"N, 69°41'15"W. Quebec Dept. Mines Map 1060. Sample SH-68-60. Collected by V.W. Sim. Described by C.H. Stockwell.

(For description see determination GSC 61-180.)

GSC 61-180 Muscovite, K-Ar age 1,555 m.y.

K 9.08%, Ar^{40}/K^{40} .1411; radiogenic argon 92%. Concentrate: colourless to pale pinkish buff. A few attached remnants of biotite and inclusions of quartz occur. Chlorite not detected.

From mica schist.

(24 N) Hopes Advance Bay, 250 yards northwest of Merganser Point; 59°20'45"N, 69°41'15"W. Quebec Dept. Mines Map 1060. Sample SH-68-60. Collected by V.W. Sim. Described by C.H. Stockwell.

The biotite (GSC 61-179) and the muscovite (GSC 61-180) are from the same sample. The ages agree very well and indicate the time of metamorphism.

The sample is a grey, medium-grained, muscovite-biotite schist with a very good cleavage. The biotite is more plentiful than the muscovite and is somewhat finer grained. Both micas are fresh. The flakes lie about parallel with one another in a mosaic of quartz, microcline, and plagioclase.

GSC 61-181 Muscovite, K-Ar age 1,720 m.y.

K 7.99%, Ar^{40}/K^{40} .1645; radiogenic argon 100%. Concentrate: muscovite flakes contain variable amounts of dark brown, platy inclusions. Rare inclusions of zircon, apatite, and tourmaline occur. About 20% of the flakes have small attached specks of biotite. Minor quartz and feldspar impurities are present. Chlorite not detected.

From mica schist.

(23 P) 12 miles northeast of Laporte Lake; 55°13'50"N, 65°33'15"W. Map-unit 1b, GSC Map 34-1960. Sample SH-12-61. Collected by Roger A. Blais. Described by C.H. Stockwell.

Quebec

The sample is a medium-grained, grey, crenulated schist in which plentiful flakes of fresh biotite and muscovite have grown through a mosaic of quartz and a little feldspar. Although the schist is crenulated the micas are undeformed.

Roger A. Blais, who collected the sample, assigns the rock to the Laporte Group. The determined age is a minimum for the group.

GSC 61-182 Muscovite, K-Ar age 420 m.y.

K 8.24%, Ar^{40}/K^{40} .0274; radiogenic argon 98%. Concentrate: consists of about 75% reasonably clean muscovite with minor quartz inclusions; about 12% muscovite intergrown with quartz, feldspar, and chlorite; and about 12% muscovite containing inclusions of quartz, feldspar and opaque grains. Estimated impurities are 8% chlorite, 12% feldspar and 5% quartz.

From greywacke.

(31 H) West of Sutton Hamlet, Eastern Townships; 45°07'30"N, 72°40'18"W. Sample A1. Collected by M. J. Rickard. Interpreted by M. J. Rickard and W. H. Poole.

(For interpretation see determination GSC 61-183.)

GSC 61-183 Muscovite, K-Ar age 440 m.y.

K 8.20%, Ar^{40}/K^{40} .0289; radiogenic argon 100%. Concentrate: consists of about 65% clean, colourless muscovite with minor small inclusions of graphite; about 10% muscovite intergrown with quartz, feldspar, and minor chlorite and coarser graphite; and about 5% grains of feldspar and quartz. Chlorite not detected.

From schist.

(31 H) 2 miles southeast of Sutton Village, Eastern Townships; 45°04'36"N, 72°36'W. Sample A2. Collected by M. J. Rickard. Interpreted by M. J. Rickard and W. H. Poole.

Sample GSC 61-182 is a greywacke from the Pinnacle Formation of the latest Precambrian or Lower Cambrian Oak Hill Formation (Clark, 1934; Cady, 1960). The greywacke is light grey, medium grained, and schistose. Schistosity parallels axial planes of folds and results from a strong parallel orientation of fine-grained muscovite.

Quebec

Sample GSC 61-183 is a medium-grey to white, fine-grained, muscovite-chlorite schist from the Lower Cambrian Sutton Formation. Schistosity parallels bedding and has been crenulated and cut by a late slip-cleavage formed during a superimposed younger deformation. Albite porphyroblasts, some with helicitic structure, lie between cleavage planes. Some muscovite lies in the axial plane of crenulations and along cleavage surfaces. Individual mica crystals throughout the rock are straight and underformed, thus indicating complete recrystallization during the younger deformation, and, it is hoped, complete expulsion of argon formed in the early muscovite.

The muscovite concentrates analyzed were separated from minus 60 mesh (0.2 mm) fraction of crushed and pulverized rock.

The two samples were chosen in an attempt to identify two ages of muscovite formed by the two indicated deformations in the Sutton-Green Mountain anticlinorium along the western edge of the Appalachian geosynclinal belt. The western sample, GSC 61-182, came from greywackes considered to have been deformed during the older orogeny. The axial plane cleavage of sample GSC 61-182 is represented about 5 miles to the southeast by bedding schistosity in sample GSC 61-183. During the younger orogeny the greywacke of sample GSC 61-182 was undisturbed, while the schistosity of sample GSC 61-183 was deformed and muscovite completely recrystallized during growth of albite porphyroblasts. Clark (1934) believed the older orogeny to be Taconic, of Middle to Upper Ordovician age, and the younger to be Acadian, of about Middle Devonian age. Cady (1960), on the other hand, favoured the Acadian orogeny for the time of formation of the early folds. By a recent geological time-scale (Kulp, 1961), the expected age of muscovite formed during the Taconic orogeny is 450 to 425 m.y. and during the Acadian orogeny is 390 to 360 m.y.

The two muscovite dates—420 m.y. for the "older" muscovite and 440 m.y. for the "younger" muscovite, each with an analytical error of ± 30 m.y.—must at this stage, be considered the same and probably measuring the same metamorphic event. If there is indeed a detectable difference in age between the two muscovites, the analyses did not show it; perhaps the younger orogeny was not strong enough to expel relic argon during recrystallization and/or reorientation of old muscovite.

On the other hand, the muscovite dates do coincide reasonably well with the presumed age of the Taconic orogeny. Both deformations probably are of Taconic age. However, assuming that no appreciable argon leakage took place, the dates are much too young to represent the event indicated by the 495-m.y. concordant dates on biotite and muscovite from the contact-metamorphic aureole of the Mount Albert ultramafic body (see GSC 61-186), generally considered to be contemporaneous with Taconic orogeny.

Quebec

Similarly, the dates are too young to be equivalent to the 530-m.y. date on muscovite from schist in the probable Lower Ordovician or older Shickshock Group, again generally considered to have been deformed first during the Taconic orogeny (see GSC 61-184).

GSC 61-184 Muscovite, K-Ar age 530 m.y.

K 7.47%, Ar^{40}/K^{40} .0357; radiogenic argon 93%. Concentrate: reasonably clean. About 10% of the flakes are stained ginger-brown by iron oxides and some contain hematite inclusions. Impurities total about 5% and consist mainly of fine-grained quartz-sericite aggregates peppered with opaque specks. Chlorite not detected.

From schist or muscovitic phyllite.
(22 B) On a stream about 600 feet northeast of, and above, the mouth of Diviviet River; this point is 1.4 miles north of Diviviet River's mouth on Matane River, Cuoq tp., Matane county; 48°40'52"N, 67°04'20"W. Map-unit 1, Quebec Dept. Mines Map 1000. Sample NCO-16-2. Collected by N.C. Ollerenshaw, University of Toronto. Interpreted by W.H. Poole and N.C. Ollerenshaw.

The phyllite or fine-grained schist is an unusual rock with a medium-grey argillaceous matrix and large secondary, anhedral muscovite crystals ranging up to 5 mm in diameter. The muscovite crystals are thin, have strongly undulose surfaces, and have grown from an extremely fine grained sericitic matrix containing tiny secondary garnets, silt and sand grains of quartz and plagioclase, and accessory tourmaline and hematite. The crystals parallel the plicated schistosity and are attenuated on the schistosity surfaces, forming a distinct lineation.

The sample was taken from sedimentary beds intercalated in a dominantly volcanic sequence of the probable Lower Ordovician or older Shickshock Group, a facies equivalent of part of the Quebec Group. These strata have probably been deformed and perhaps metamorphosed during the Middle or Upper Ordovician Taconic orogeny. The Quebec Group is unconformably overlain by gently dipping Silurian strata elsewhere along the belt.

The muscovite concentrate analyzed was separated from the minus 60 mesh (0.2 mm) fraction of crushed and pulverized rock.

Quebec

The 530-m.y. date is older than expected. The most recent time-scale of Kulp (1961) places the boundary between Middle and Upper Cambrian at 530 m.y., and the middle of the Ordovician at about 460 m.y.

Even by applying the limit of the analytical error of ± 35 m.y., the supposed date of the Taconic orogeny is not approximated, although the 495-m.y. dates on two coexisting micas in the contact-metamorphic aureole of the Mount Albert ultrabasic body, some 42 miles on trend to the east, are about equalled (see GSC 61-186).

A number of explanations and interpretations of the 530-m.y. date are possible.

1. The bed sampled and the age of the growth of muscovite are actually Upper Cambrian or older, and not Ordovician.

2. The sample of muscovite analyzed contained either original detrital muscovite of much older age (e.g. as old as Grenville, 800-1,100 m.y.) or relics of detrital muscovite overgrown by younger muscovite of Taconic age. Or, the muscovite of the sample may have absorbed old argon during growth. These possibilities appear to be slight.

3. The Cambrian and the Lower and Middle Ordovician are much older than current time-scales depict them. Perhaps the post-Middle Ordovician Taconic orogeny occurred 500 m.y. ago (or even earlier), and this 530-m.y. muscovite grew during either this orogeny or the pre-Middle Ordovician orogeny that gave rise to the Caldwell-Beauceville unconformity found in the Eastern Townships (Riordon, 1957).

4. An analytical error larger than that expected is present.

Clarification of the interpretation must await further evidence. The simple existence of muscovite with such an old K-Ar date supports at least the generally accepted contention that much of the Quebec Group of southern Quebec was strongly deformed well before, and not during, the Devonian Acadian orogeny (about 350 to 400 m.y.).

GSC 61-185 Muscovite, K-Ar age 495 m.y.

K 8.34%, Ar^{40}/K^{40} .0330; radiogenic argon 91%. Concentrate: reasonably pure, but most flakes contain brown inclusions and coatings of hydrous iron oxides, and small specks of biotite adhering to the surface. Chlorite not detected.

Quebec

From garnetiferous micaceous quartzite.

(22 B) On small brook southeast of Mount Albert Creek, 700 feet northeast of the contact of the ultramafic pluton; 48°54'N, 66°07'W. Map-unit 05, GSC Map 2060. Sample SDM 60-673. Collected by I.D. MacGregor. Interpreted by C.H. Smith.

(For interpretation see determination GSC 61-186.)

GSC 61-186 Biotite, K-Ar age 495 m.y.

K 7.64, Ar^{40}/K^{40} .0331; radiogenic argon 84%. Concentrate: consists of about 65% reddish brown biotite with fine inclusions and a few specks of red iron oxide; about 30% slightly bleached flakes; and about 5% biotite flakes with prominent bleached and greenish patches. A few quartz fragments are present as impurity. Chlorite/biotite 0.09.

From garnetiferous micaceous quartzite.

(22 B) On small brook southeast of Mount Albert Creek, 700 feet northeast of the contact of the ultramafic pluton; 48°54'N, 66°07'W. Map-unit 05, GSC Map 2060. Sample SDM 60-673. Collected by I.D. MacGregor. Interpreted by C.H. Smith.

Samples GSC 61-185 and GSC 61-186 were chosen to date the Mount Albert ultramafic intrusion, Gaspe, Quebec, and thus arrive at an age for the period of ultramafic intrusion in this part of the Appalachian province.

The biotite and muscovite used are from the contact-metamorphic aureole formed by the intrusion of the ultramafic rocks into the Shickshock Group of basic volcanic rocks. The rock sample used is a muscovite-quartz-garnet-biotite-kyanite schist, 700 feet from the ultramafic contact. The interbedded basic volcanic members are in the amphibole-almandine facies.

The 495-m.y. date is significant in providing the first quantitative estimate of the age of ultramafic intrusion in the Appalachian province. Previous workers have considered ages varying from Ordovician to Devonian based on geological interpretations. The date also gives a minimum age for the Shickshock Group and indicates that they are pre-Lower Ordovician as suggested by Ells, Low, and McGerrigle, rather than post-Lower Ordovician as suggested, on structural grounds, by Logan, Alcock, and Mattinson.

New Brunswick

GSC 61-187 Biotite, K-Ar age 387 m.y.

K 7.39%, Ar^{40}/K^{40}.0251; radiogenic argon 97%. Concentrate: reasonably clean brown biotite. About 50% of the flakes contain numerous small inclusions. About 5-10% have greenish chloritized patches. A few separate flakes of green chlorite are present.

From biotite-quartz monzonite.
(21 J) Keswick River, east shore, 11,300 feet upstream from railway bridge at Barton; 46°10'03"N, 67°01'06"W. Map-unit 20, GSC Map 37-1959. Sample 4-42-1/PB. Collected and interpreted by W.H. Poole.

The biotite-quartz monzonite is lithologically typical of much of the Devonian batholith of southwestern New Brunswick. The sample was analyzed to check an anomolously low K-Ar biotite age of 312 m.y. from the same batholith some 17 miles to the southwest, near Hawkshaw (GSC 60-136). The quartz monzonite is massive, undeformed, grey, and coarse grained, and contains a few phenocrysts of pink potash feldspar. The batholith intrudes deformed strata as young as Middle Silurian and contributes detritus to flat-lying Carboniferous sediments probably not older than late Mississippian.

The 387-m.y. biotite date compares very favourably with the 380 m.y. to 398 m.y. range reported by Tupper and Hart (1961) for four of five granite samples from the central belt of New Brunswick. The dates undoubtedly represent mid-Devonian batholithic intrusions. The 312-m.y. date from biotite near Hawkshaw almost certainly does not indicate the age of the original formation of the biotite; rather it probably reflects a normal aged biotite that has been affected or updated by an undetected younger deuteric alteration or metamorphic event, probably the former.

GSC 61-188 Biotite, K-Ar age 411 m.y.

K 7.73%, Ar^{40}/K^{40}.0269; radiogenic argon 90%. Concentrate: contains 80% entirely clean biotite flakes, and 20% biotite flakes containing scattered inclusions of sillimanite needles. Chlorite not detected.

From quartz-biotite gneiss.
(21 J) On hill, 10,000 feet at N39°W from mouth of McKiel Brook on southwest Miramichi River; 46°32'16"N, 66°58'33"W. Sample 5-33-8/PB. Collected and interpreted by W.H. Poole.

(For interpretation see determination GSC 61-191.)

New Brunswick

GSC 61-189 Biotite, K-Ar age 497 m.y.

K 7.16%, Ar^{40}/K^{40} .0332; radiogenic argon 83%. Concentrate: consists of 40% nearly opaque biotite; 40% brown biotite; and 20% greenish grey flakes, slightly bleached and chloritized. Some of the brown flakes contain zircon inclusions surrounded by prominent pleochroic haloes. Chlorite/biotite 0.10.

From biotite-quartz monzonite.
(21 J) Southwest of Miramichi River, west shore, 2,400 feet upstream from mouth of McKiel Brook; 46°30'35"N, 66°57'05"W. Sample 5-35-2/PB. Collected and interpreted by W. H. Poole.

(For interpretation see determination GSC 61-191.)

GSC 61-190 Biotite, K-Ar age 410 m.y.

K 6.98%, Ar^{40}/K^{40} .0269; radiogenic argon 100%. Concentrate: consists of mostly clean biotite. About 10% of the flakes have acicular inclusions along slightly chloritized edges. A small amount of green chlorite is present. Chlorite/biotite 0.04.

From cataclastic muscovite-biotite granite.
(21 J) New lumber road, 1.3 miles west-southwest of South Burnthill Brook bridge; 46°40'25"N, 66°59'37"W. Sample 5-30-5/PB. Collected and interpreted by W. H. Poole.

(For interpretation see determination GSC 61-191.)

GSC 61-191 Muscovite, K-Ar age 435 m.y.

K 8.63%, Ar^{40}/K^{40} .0287; radiogenic argon 91%. Concentrate: consists of mostly clean flakes of muscovite. Some are fractured and some contain air trapped between (001) sheets. A few flakes are intergrown with quartz along the edges and are stained ginger-brown by iron oxides. Chlorite not detected.

From cataclastic muscovite-biotite granite.
(21 J) New lumber road, 8,000 feet southwest of South Burnthill Brook bridge; 46°40'02"N, 66°59'18"W. Sample 5-30-6/PB. Collected and interpreted by W.H. Poole.

New Brunswick

These four samples (GSC 61-189, GSC 61-188, GSC 61-190, GSC 61-191) were analyzed to test a field hypothesis that the granites and gneisses are distinctly older than the typical Devonian granites in the region. The hypothesis was confirmed.

The biotite-quartz monzonite of GSC 61-189 is an undeformed, fine- to medium-grained, pink-buff rock with schlieren-like streaks of fine biotite in planar orientation. Biotite amounts to 2-3% of the rock.

The quartz-biotite gneiss of GSC 61-188 is a fine- to medium-grained rock with about 10% each of muscovite, sillimanite, and plagioclase. The gneiss is in intrusive contact to the southwest with the quartz monzonite of GSC 61-189 and to the northeast grades through biotitic quartzite and schist to quartzite and slate. Gneissosity parallels bedding and near the quartz monzonite strikes athwart the regional northeast trend.

The cataclastic granites of GSC 61-190 and GSC 61-191 represent normal medium- to coarse-grained, even-grained, grey and pink quartz monzonites and granodiorites that have been intimately sheared over a large area. Quartz crystals have been flattened and attenuated, and feldspar crystals broken, bent, and granulated along their edges. Most of the biotite has been bent and altered to chlorite. Secondary muscovite has grown within and across deformed minerals, particularly biotite, and is itself slightly bent.

Field relations suggest that the biotite-quartz monzonite of GSC 61-189 and the cataclastic granites of GSC 61-190 and GSC 61-191 are intergradational and intrude and metamorphose the quartzite and slate formation of Middle Ordovician or older age. The gneiss of GSC 61-188 appears to be genetically related to the intrusion of quartz monzonite of GSC 61-189. Hence, a similar age, but older than the 380 m.y. to 400 m.y. age of the Devonian granite, was expected for the biotites of these rocks. Secondary muscovite of GSC 61-191 was expected to date the shearing.

The 497-m.y. biotite date from the quartz monzonite of GSC 61-189 is the oldest of the group. It is remarkably similar to the concordant 495-m.y. dates on the biotite-muscovite pair from the contact-metamorphic aureole surrounding the Mount Albert ultramafic body in the Gaspé Peninsula of Quebec (see determinations GSC 61-185 and GSC 61-186). The 411-m.y. and 410-m.y. dates on the biotites of the gneiss of GSC 61-188 and the cataclastic granite of GSC 61-190, respectively, are probably too young, and, if so, reflect loss of argon by superposed weak metamorphic events. The biotite of the gneiss probably has been updated by a body of Devonian granodiorite exposed about 1/2 mile from the sample locality. The same granite body also lies about 1/2 mile from the sample locality of the quartz monzonite of GSC 61-189, and appears to have had little effect on the K-Ar ratio.

New Brunswick

Shearing in the cataclastic granites took place after the emplacement and solidification of the granite and pegmatite. The petrographically younger muscovite with the 435-m.y. date is "older" than the biotite with the 410-m.y. date. Apparently, the biotite independently lost argon after shearing and after muscovite had stopped growing, if it is assumed that the muscovite is indeed contemporaneous with shearing and did not inherit or absorb argon from outside its crystal. These samples were taken 2 1/2 miles from the contact with the Devonian biotite-quartz monzonite with the 339-m.y. biotite date (see determination GSC 61-192).

Interpretation of geological history in terms of these dates is still somewhat uncertain. Biotites of the gneiss and cataclastic granite almost certainly have been updated by the effects of nearby younger Devonian granites. Using a recent geological time-scale (Kulp, 1961), the biotite-quartz monzonite of GSC 61-189 is lowermost Ordovician, and the shearing as indicated by the muscovite date is between Middle and Upper Ordovician, if excessive argon has not escaped the minerals. The latter date corresponds reasonably well to the Taconic orogeny, and the former date to an early Ordovician orogeny, perhaps that which gave rise to the Beauceville-Caldwell unconformity in the Eastern Townships, Quebec (Riordon, 1957) and to the emplacement of the Mount Albert ultramafic body. Support of these speculations must await further investigations.

GSC 61-192 Biotite, K-Ar age 339 m.y.

K 7.78%, Ar^{40}/K^{40} .0217; radiogenic argon 99%. Concentrate: mainly olive-brown biotite. About 15% of the flakes are olive-green, and 20% have ginger-brown stained patches. Some flakes have small zircon inclusions surrounded by prominent pleochroic haloes. A few inclusions of quartz and prismatic crystals of apatite are present. Chlorite biotite 0.08.

From biotite-quartz monzonite.
(21 J) On road near Clearwater Brook, 6,500 feet at S30°E from mouth of Otter Brook, 46°39'08"N, 66°46'16"W. Sample 5-51-3/PB. Collected and interpreted by W.H. Poole.

The biotite-quartz monzonite is massive, undeformed, coarse grained and grey, with pink potash feldspar. Some potash feldspar forms phenocrysts, of which a few are rimmed with white plagioclase. The rock disintegrates readily through normal weathering.

New Brunswick

The 339-m.y. date is younger than the 380 m.y. to 400 m.y. range of mid-Devonian granitic rocks (see determination GSC 61-187) and may have resulted from loss of argon from the biotite by undetected deuteric or metamorphic effects. On the other hand, the quartz monzonite grades southward into buff-weathering granites containing greisen and quartz veins with minerals of W, Mo, F, Sn, and Bi, all indicative of granites late in the plutonic development of the region. It is possible then that the true age of the biotite may be less than the expected range and is indeed approximated by 339 m.y.

GSC 61-193 Muscovite, K-Ar age 590 m.y.

K 8.31%, Ar^{40}/K^{40} .0406; radiogenic argon 100%. Concentrate: muscovite flakes contain a minor amount of quartz. Chlorite not detected.

From muscovite-quartz gneiss, from boulders in conglomerate.

(21 B) From the southwest coast of Ross Island, half-way between Fish Fluke Point and Indian Camp Point; 44°39'43"N, 66°44'50"W. Map-unit 2, GSC Map 965A. Sample TA 61-T146. Collected and interpreted by F. C. Taylor.

The conglomerate is contained within volcanic rocks tentatively correlated with the Coldbrook Group of Proterozoic age. If there has been no argon loss since original formation, then the conglomerate and Coldbrook Group are younger than 590 m.y. If, on the other hand, argon has leaked from the muscovite, then the muscovite is older than 590 m.y. and the conglomerate and Coldbrook Group are either older or younger than 590 m.y. Argon loss is a distinct possibility as this area has been affected by Palaeozoic orogenies.

Nova Scotia

GSC 61-194 Biotite, K-Ar age 290 m.y.

K 6.80%, Ar^{40}/K^{40} .0184; radiogenic argon 99%. Concentrate: contains about 80-85% biotite varying from olive-green to brown. Some flakes are coated with yellow crusts of iron oxides. The concentrate also contains 15-20% free grains of chlorite. Chlorite/biotite 0.25.

From granite.
(20 P) 1/4 mile northeast of Upper Wedgeport; 43°45'30"N, 65°59'10"W. Map-unit 7, GSC Map 44-1960. Sample TA 60-T13. Collected and interpreted by F. C. Taylor.

The granite pluton from which this sample was obtained intrudes quartzite of the Goldenville Formation 5 miles southwest of the sample site. Elsewhere in the province, granite, of which this pluton is probably a satellite body, intrudes the fossiliferous Torbrook Formation of Lower Devonian age (Smitheringale, 1960; Fairbairn et al., 1960).

This granite, in which the biotite is extensively altered to chlorite, is from a pluton previously sampled by Fairbairn et al. (1960) from near Wedgeport, Nova Scotia. The previous determination of 245 m.y. was anomalously low as compared with all other ages found in the southwestern part of Nova Scotia. These ages range from 315 m.y. to 380 m.y. in the southern and central parts of the province. However all age determinations along the southern coast are consistently lower (in the order 315 m.y. to 335 m.y.) than those in the main granite areas farther north. This suggests that all the granitic rocks in the southernmost part of the province are distinctly younger than the granites to the north. If this is the case then the age of 290 m.y. is probably reliable.

Newfoundland

GSC 61-195 Biotite, K-Ar age 2,035 m.y.

K 7.51%, Ar^{40}/K^{40}.2140; radiogenic argon 100%. Concentrate: clean concentrate of biotite that varies from brown to greenish brown. The flakes contain aligned rutile needles and small, roughly hexagonal plates of (probably) iron hydroxide. Chlorite/biotite 0.04.

From pegmatite.
(14 E) 5 miles northwest of Tessiuyakh Bay, Labrador; 57°19'00"N, 62°07'30"W. Map, Plate 1, Geol. Soc. Amer., vol. 71, p. 1762. Sample SH-3-61. Collected by E.P. Wheeler (2nd). Described by E.P. Wheeler (2nd) and C.H. Stockwell.

The pegmatite forms a pod in biotite-bearing tonalite gneiss and consists of pink and white microcline perthite, oligoclase, myrmekite, quartz, biotite, magnetite, epidote, and a very small amount of hornblende. The potash feldspar is fresh but the oligoclase is considerably altered to epidote, sericite, and minor green biotite. Most of the biotite of the sample is brown, unchloritized, considerably bent and broken, and, in minor amount, fills cracks in magnetite.

Because of the evidence of deformation and alteration of the rock, the K-Ar age is thought to be, in all probability, younger than the true age of crystallization of the pegmatite.

GSC 61-196 Biotite, K-Ar age 2,390 m.y.

K 7.10%, Ar^{40}/K^{40}.2814; radiogenic argon 99%. Concentrate: clean, but about half the biotite flakes are partly altered to chlorite and epidote. Chlorite/biotite 0.36.

From granitic gneiss.
(13 K) North end of an unnamed lake 7 miles east of Mistinippi Lake, Labrador; 54°48'20"N, 61°07'00"W. Map-unit 1, GSC Map 1079A. Sample SH-17-61. Collected by K.E. Eade. Interpreted by W.F. Fahrig.

The sample was taken from granitic gneiss that unconformably underlies the Seal and Croteau Groups. The age of the biotite is a maximum for these groups.

Newfoundland

The apparent great antiquity of the biotite is remarkable, as Grenville and Hudsonian ages have been obtained on biotite concentrates from rocks that surround this site, although at some distance. The gneiss may be a remnant of the Superior province which escaped later metamorphism. It apparently lies north of the limit of Grenville metamorphism and east of the limit of Hudsonian metamorphism. If further work north of this site yields similar ages, it will suggest that the strata of the Labrador Trough were indeed laid down in a depression in basement gneisses of the Superior province.

It is also possible, in an instance such as this, where surrounding rocks have undergone younger metamorphism, that the older rock has been influenced by the younger metamorphisms and is a remnant of still more ancient lineage.

GSC 61-197 Biotite, K-Ar age 1,395 m.y.

K 6.99%, Ar^{40}/K^{40} .1210; radiogenic argon 100%. Concentrate: consists of brownish to olive-green biotite flakes containing numerous inclusions of hydrated iron oxides. Most flakes are bleached along fractures and edges and some have inclusions of quartz and epidote. Less than 50% of the flakes are clean. Chlorite/biotite 0.30.

From granite.
(13 L) Small lake between MacKenzie and Windbound Lakes, Labrador; 54°03'N, 62°23'W. Sample FB-11-59. Collected by Y.O. Fortier and C.S. Lord. Interpreted by W.F. Fahrig.

The biotite is from a slightly foliated, medium- to coarse-grained, porphyritic biotite granite. The estimated composition of the granite is 40-45% potash feldspar, 15-20% plagioclase, 40% quartz, 1% biotite and 1% accessory minerals. The plagioclase occurs in strongly zoned euhedral crystals. The central zones are sericitized.

The sample was taken from near the boundary of the Grenville province. The age of the biotite probably reflects in some way the interaction of two or more metamorphic or igneous events, the latest being the Grenville. The simplest such interaction would be the metamorphism during Grenville time of older rocks; part of the argon was driven from older biotite and a resultant intermediate K-Ar age attained.

Newfoundland

GSC 61-198 Muscovite, K-Ar age 930 m.y.

K 5.63%, Ar^{40}/K^{40} .0704; radiogenic argon 100%. Concentrate: contains about 70% clean muscovite flakes and 30% impure flakes containing inclusions of apatite and quartz, and adhering fragments of biotite and chlorite. Only a trace of chlorite is present.

From garnetiferous biotite-muscovite schist.
(23 G) 7 1/2 miles southeast of Evening Lake, Labrador; 53°31'N, 66°09'W. Map-unit 5a, GSC Map 9-1960. Sample FA-DS-110-59. Collected by D. Sangster. Interpreted by W. Fahrig.

This sample is believed to represent argillaceous sediments of the Labrador Trough which were metamorphosed during the Grenville orogeny. The date of 930 m.y. for the muscovite of the sample is consistent with this geological interpretation and with the position of the Grenville metamorphic front as indicated on Map 9-1960.

Sample GSC 60-140 was collected from rock lying about the same distance from the Grenville front as was GSC 61-198. This suggests that GSC 60-140 must also have been involved in Grenville metamorphism and the K-Ar date of 1,645 m.y. for its biotite is the result of imposing the Grenville metamorphism on a much earlier metamorphic event.

GSC 61-199 Biotite, K-Ar age 900 m.y.

K 7.83%, Ar^{40}/K^{40} .0677; radiogenic argon 99%. Concentrate: consists of mainly clean reddish brown biotite. Some flakes are slightly chloritized along fractures and contain tiny inclusions between the (001) layers. Chlorite/biotite 0.06.

From granitic pegmatite dykelet.
(12 B) Indian Head mine, Harmon Base; 48°31'N, 58°31'W. Map-unit 10, GSC Bull. 27, Figs. 12, 13. Sample RG-61-A-1. Collected and interpreted by E.R. Rose.

This sample of fresh biotite flakes is from a small pegmatite dykelet that intrudes gneissic gabbroic anorthosite (noritic gneiss) and its associated titaniferous magnetite at the Indian Head mine on Harmon Base in western Newfoundland. The age of the biotite dates the emplacement of the pegmatite into the gabbroic anorthosite, giving a minimum age for the latter and its titaniferous magnetite.

Newfoundland

The date of 900 m.y. compares with that of 830 m.y. (GSC 60-147) on biotite from granitic augen gneiss collected by E.R.W. Neale, representing the Indian Head Intrusive Complex, and with that of 890 m.y. (GSC 60-114) on biotite from the Bignell titaniferous deposit collected by the writer from St. Urbain, Quebec.

GSC 61-200 — Biotite. K-Ar age 960 m.y.

K 7.75%, Ar^{40}/K^{40} .0732; radiogenic argon 98%. Concentrate: consists of pale olive-greenish biotite. Some flakes are slightly bleached along edges and fractures and have minor amounts of fine-grained inclusions in bleached areas. A few coarse inclusions of apatite and epidote are present. Chlorite/biotite 0.07.

From porphyritic granite.

(12 I) Island in south end of lake at 4.7 miles from the main brook's mouth on the south side of the east end of Leg Pond; 50°51'45"N, 56°40'45"W. Geol. Surv. Newfoundland, Rept. 4, by C.E. Fritts. Sample NA-3. Collected by D.M. Baird. Interpreted by E.R.W. Neale.

(For interpretation see determination GSC 61-201.)

GSC 61-201 — Biotite, K-Ar age 945 m.y.

K 7.53%, Ar^{40}/K^{40} .0719; radiogenic argon 70%. Concentrate: consists of biotite varying from brown (60%) to greenish brown (40%) and containing minor inclusions of quartz. Chlorite/biotite 0.02.

From granite.

(12 I) Point on the south (midway) side of West Twin Pond in Cloud River; 50°48'20"N, 56°22'25"W. Geol. Surv. Newfoundland, Rept. 4, by C.E. Fritts. Sample NA-4. Collected by D.M. Baird. Interpreted by E.R.W. Neale.

Samples GSC 61-200 and GSC 61-201 are the first age determinations on the dominantly Precambrian complex that underlies the Great Northern Peninsula of Newfoundland. Both the granite from Leg Pond (GSC 61-200), known as the "western porphyritic biotite granite", and that from Cloud River (GSC 61-201), were interpreted as Precambrian by Fritts (1953). On textural evidence, he suggested that the Cloud River granite was the younger of the two. The age determinations bear out Fritts' interpretation and also show that these granites fall into the age pattern established within the Grenville geological province in nearby parts of Quebec. These dates are also reasonably close to the 830-m.y. date reported for granitic rocks of the Indian Head Complex (Lowdon, 1961) in southwestern Newfoundland.

GSC 61-202 Muscovite, K-Ar age 415 m.y.

K 9.05%, Ar^{40}/K^{40}.0272; radiogenic argon 88%. Concentrate: most of the muscovite flakes are clean. About 10% of flakes contain minor inclusions of quartz and altered biotite. Chlorite not detected.

From pegmatite.

(11 O) Canadian National Railways station and dock, Port aux Basques; 47°34'12"N, 59°8'20"W. Sample NA-3087. Collected and interpreted by E.R.W. Neale.

The muscovite was taken from a pegmatitic layer in schistose quartzite and amphibolite of the Cape Ray Cove schists and gneisses (G. Phair, Geology of Port aux Basques Area, unpub. Ph.D. thesis, Princeton Univ., 1949). The purpose of the age determination was to ascertain whether or not metamorphism and intrusion of these gneisses took place in the Precambrian, as recently shown for gneisses of the Indian Head Complex of St. Georges Bay (Lowdon, 1961). However, the age obtained, according to recent time-scales, is Latest Silurian or Early Devonian (within limits of error) and suggests that the Cape Ray schists and gneisses were affected by the Acadian orogeny and intrusion.

GSC 61-203 Muscovite, K-Ar age 484 m.y.

K 8.91%, Ar^{40}/K^{40}.0323; radiogenic argon 84%. Concentrate: consists mostly of clean muscovite flakes but some have a few inclusions of quartz, crusts of iron oxides, and small adhering specks of chlorite. Some flakes show concentric growth and multiple twinning zoning. Impurities, in the form of quartz, quartz-feldspar intergrowths, and a few flakes of chlorite, constitute less than 5% of the concentrate. Chlorite/muscovite 0.06.

Newfoundland

(12 H) From quartz monzonite.
1,000 feet due east of Kitty Brook railway station; 49°11'N, 56°51'W. Map-unit 17, GSC Map Sandy Lake E 1/2, Newfoundland, in preparation. Sample ND-64. Collected by W.A. Nash. Interpreted by E.R.W. Neale.

The granite specimen on which this date was obtained was interpreted in the field as part of a large batholith that intrudes the Springdale Group of Silurian or later age (GSC Map 54-4). According to recently published time-scales, the age obtained is Lower Ordovician. This apparently anomalous age could be due to contamination of the granite by rocks of the Precambrian (?) Fleur de Lys Group that outcrops 8 miles to the north. However, there is no field evidence of such contamination.

Ages around 500 m.y. have been obtained for granitic rocks in southeastern Nova Scotia (Fairbairn et al., 1960) and, more recently, for granitic rocks of central New Brunswick. It is, then, possible that Ordovician granites are more common than previously recognized in the Canadian Appalachian region, and the field relationships of this granite batholith will merit further study.

GSC 61-204 Biotite, K-Ar age 373 m.y.

K 4.59%, Ar^{40}/K^{40} .0241; radiogenic argon 93%. Concentrate: contains only about 20% fresh clean brown biotite. About 75% of the flakes are speckled in appearance and chloritized, and contain numerous inclusions. About 5% of free chlorite is also present. Chlorite/biotite 1.0.

(12 H) From biotite-hornblende quartz monzonite.
North shore of Middle Arm; 49°42'20"N, 56°04'W. Map-unit 9, GSC Map 51-21A. Sample NA-3045. Collected and interpreted by E.R.W. Neale.

This specimen is typical of the Burlington granitic rocks (Map-unit 9, GSC Map 51-21A; Map-unit 9a, GSC Map 35-1960) which underlie a large part of Burlington Peninsula. These greenish grey, commonly epidotized, granitic rocks, intrude Ordovician and Silurian (?) sedimentary and volcanic sequences. Field evidence also suggests that they are older than nearby pinkish grey, potash-rich granitic rocks. The K-Ar date of 373 m.y., Middle Devonian on recently published time-scales, bears this out as the pinkish grey granitic rock of the area (Map-unit 10b, GSC Map 35-1960) are dated as 358 m.y.

K-AR AGE MEASUREMENTS ON MINERAL PAIRS

by R.K. Wanless and J.A. Lowdon

Several of the samples submitted for K-Ar age measurement have contained more than one micaceous mineral in sufficient quantity to permit the determination of the K^{40} - Ar^{40} ratio representative of each mineral. The results obtained for twelve mineral pairs were presented in a previous report (Wanless and Lowdon, in Lowdon, 1961, pp. 119-124). In five instances the minerals yielded concordant ages, but in seven the age difference was significant. From a consideration of these seven cases, it was apparent that either biotite or muscovite might yield the lower age.

The results obtained for an additional twenty-three biotite-muscovite pairs examined during 1961 are presented in the accompanying table. The age measurements and details of the mineral concentrates are given in the foregoing or in earlier reports (Lowdon, 1961).

The calculated ages for the first fourteen mineral pairs are in agreement. The maximum variation within this group is only 3.9% (pair No. 11), which is well within the experimental limits. However, for the nine remaining pairs the difference may be as much as 32%. In five of these (pairs 15 to 19) the biotite age is lower than the muscovite age and in the other four (pairs 20 to 23) the biotite age is the higher.

Attempts have been made to relate these observed differences in the ages determined for biotite and muscovite from the same sample to the paragenetic relationships of the minerals in the rock. As yet no conclusive kinship has been observed, but detailed investigations of this nature are continuing.

Sample Pair	Sample Number*	Mineral	% K	Chlorite/Mica	Age (m.y.)	% Difference
1	GSC 61-32	Biotite	7.87	0.00	77	+ 2.6
	GSC 61-31	Muscovite	8.61	0.00	75	
2	GSC 61-10	Biotite	7.50	0.08	82	+ 2.5
	GSC 61-11	Muscovite	8.80	0.00	80	
3	GSC 61-2	Biotite	7.50	0.15	135	- 3.6
	GSC 61-3	Muscovite	8.80	0.05	140	
4	GSC 61-186	Biotite	7.64	0.09	495	+ 0.0
	GSC 61-185	Muscovite	8.34	0.00	495	
5	GSC 61-165	Biotite	7.93	0.05	900	- 1.1
	GSC 61-164	Muscovite	9.08	0.00	910	
6	GSC 61-179	Biotite	7.99	0.00	1,560	+ 0.3
	GSC 61-180	Muscovite	9.08	0.00	1,555	
7	GSC 61-116	Biotite	8.10	0.02	1,720	- 1.5
	GSC 61-117	Muscovite	7.51	0.00	1,745	
8	GSC 60-74	Biotite	7.83	0.00	1,745	- 1.7
	GSC 61-118	Muscovite	8.52	0.00	1,775	
9	GSC 61-109	Biotite	6.22	0.40	1,830	+ 2.8
	GSC 61-110	Muscovite	8.03	0.07	1,780	
10	GSC 61-79	Biotite	5.27	0.50	1,780	- 3.3
	GSC 61-80	Muscovite	6.39	Trace Chl.	1,840	
11	GSC 60-51	Biotite	7.84	0.06	2,370	- 3.9
	GSC 61-69	Muscovite	7.48	Trace Chl.	2,465	
12	GSC 61-128	Biotite	7.62	0.14	2,435	- 0.8
	GSC 61-129	Muscovite	6.29	0.40	2,455	
13	GSC 61-71	Biotite	7.34	0.21	2,465	+ 2.3
	GSC 61-70	Muscovite	8.72	0.00	2,410	
14	GSC 61-151	Biotite	7.44	0.11	2,640	+ 2.9
	GSC 61-152	Muscovite	8.29	0.05	2,565	
15	GSC 61-75	Biotite	7.24	0.15	1,890	- 10
	GSC 61-74	Muscovite	8.79	0.00	2,100	
16	GSC 61-60	Biotite	7.84	0.00	1,905	- 12
	GSC 61-61	Muscovite	8.47	n.d.[1]	2,155	
17	GSC 61-63	Biotite	6.61	0.90	1,755	- 27
	GSC 61-62	Muscovite	8.50	0.00	2,415	
18	GSC 61-153	Biotite	6.94	0.30	2,285	- 8.4
	GSC 61-154	Muscovite	7.19	0.05	2,495	
19	GSC 60-95	Biotite	7.83	0.01	2,330	- 6.4
	GSC 61-131	Muscovite	7.18	0.00	2,495	
20	GSC 60-108	Biotite	8.05	0.00	1,270	+ 32
	GSC 61-162	Muscovite	8.10	0.00	960	
21	GSC 61-119	Biotite	7.23	0.10	1,770	+ 9.3
	GSC 61-120	Muscovite	7.44	Trace Chl.	1,620	
22	GSC 60-84	Biotite	7.28	0.00	2,100	+ 25
	GSC 61-125	Muscovite	6.41	0.01	1,680	
23	GSC 60-93	Biotite	6.68	0.08	2,550	+ 6.9
	GSC 61-130	Muscovite	8.05	Trace Chl.	2,385	

[1]"n.d." indicates not determined.

*"GSC 60-.." numbers are from Lowdon (1961) and "GSC 61-.." numbers are from this report.

PART II

GEOLOGICAL STUDIES

SECOND REPORT ON STRUCTURAL PROVINCES, OROGENIES, AND TIME-CLASSIFICATION OF ROCKS OF THE CANADIAN PRECAMBRIAN SHIELD

by C. H. Stockwell

The first report (Stockwell, in Lowdon, 1961, pp. 108-118) covered results up to the end of 1960, when about 180 potassium-argon age determinations on micas from Shield rocks had been completed in the laboratories of the Geological Survey of Canada. The present report adds the results of an additional 130 ages determined during 1961. The new dates help to fill in large gaps in the main part of the Shield and extend knowledge into the more northerly regions which, however, are still inadequately covered. The new results substantiate the previously proposed structural provinces, orogenies, and time-classification, and throw further light on problems of interpretation of potassium-argon ages.

Structural Provinces

The division of the Shield into structural provinces and subprovinces is useful for the purpose of description and discussion of the geology. The divisions are made mainly on the basis of important unconformities and overall structural characteristics, and each may contain rocks of widely different ages; but because of the close relationship between structural features and the last orogeny, the provinces correspond closely to orogenic divisions based on potassium-argon ages.

The provinces and subprovinces are shown in Figure 2, which is much the same as the map presented in GSC Paper 61-17 except for the addition of the new ages. The Churchill province may now be extended farther north on the mainland and, as indicated by a few dates in the Arctic Islands, it apparently covers most of Baffin Island and part of Ellesmere Island still farther north. The extreme eastward extension of the boundary of the Grenville province is still open to question, and information along and near the Labrador coast is still too meagre to permit the assignment of that area to a particular province. Two areas of the Shield that extend beyond the Canadian boundary into the United States have been added; namely, the Adirondack region which forms part of the Grenville province, and the Lake Superior region which lies partly in the Superior province and partly in the Southern province.

Orogenies and Tectonic Cycles

The word 'orogeny' is here used for a period of mountain building accompanied by folding and commonly by metamorphism and granitic intrusion. It contrasts with the broader concept of an orogenic or tectonic cycle which encompasses a long succession of events beginning with deposition of material, accompanied by subsidence, and ending with mountain building and the formation of a relatively stable craton. Some authors would include as late stages of a tectonic cycle, certain post-tectonic intrusions and the deposition of sediments derived by erosion of the mountains but, at the present stage of study of the Shield, it appears best to end the cycle at the time of the orogeny and the stabilization of the craton. Subsequent events, including erosion and deposition of material from various sources, continued until the present and are not so obviously a part of any cycle. An orogeny proper is readily dated, at least approximately, by the potassium-argon method on micas, but the dating of a tectonic cycle is more difficult because it requires knowledge also of the time of deposition of contained sedimentary and volcanic materials.

The three main orogenies of the Shield are illustrated in the histogram of Figure 3; the Kenoran with a potassium-argon age of around 2,500 m.y., the Hudsonian, about 1,700 m.y., and the Grenville, about 950 m.y. The concentration of most of the dates into the three main groups results from a remarkable consistency in the ages over huge areas of each structural province. These areas have evidently remained stable since the time of their last major orogeny. Other dates, much fewer in number, are scattered through the long periods of time between the three main orogenic events. These scattered dates generally result from unusual circumstances. Those that are older than the characteristic age for any particular province may be survival values from older rocks not completely reworked by the prevalent orogeny. Those that are younger seem to represent local superposition of later events over incompletely stabilized parts of the older craton. A few of the younger dates, however, are on post-orogenic intrusions, such as alkaline rocks and dykes of diabase.

The three main age-groupings, which indicate the three main orogenies, show a considerable spread, falling off on either side from the peak values mainly through a range of about ± 150 m.y. This spread is probably due partly to analytical uncertainty and partly to the time-span of the orogenies themselves. The analytical error—taken to be ± 60 m.y. in the Grenville, ± 90 m.y. in the Hudsonian, and ± 125 m.y. in the Kenoran—may account for much of the spread of ± 150 m.y., so that the time-span of the orogenies themselves may be considerably shorter, say within a range of ± 50 m.y. from the peak values indicated. This rough estimate of 100 m.y. for the length of each orogeny is indicated in Figure 3.

The Kenoran orogeny, which marks the end of Archaean time, is typically developed throughout almost all of the Superior province and is well represented in the southern and eastern parts of the Slave province. It is the last major orogeny that affected these regions. Local geological evidence indicates the presence of a still older orogeny but this has not been detected with certainty by isotopic methods. As the age of deposition of the sedimentary and volcanic rocks is unknown, no tectonic cycle can yet be clearly defined in the Archaean.

The Hudsonian orogeny, which marks the upper limit of Lower Proterozoic time, is typically developed throughout almost all of the Churchill province and is found also in the Bear and Southern provinces. In the main body of the Churchill province the orogeny produced chiefly gneisses and granites and generally obscured the earlier history, but geological considerations suggest that large parts may be as old as Archaean and that rocks originally involved in the Kenoran orogeny may have been completely reworked during the Hudsonian to give the prevalent age of 1,700 ± 150 m.y. Certain parts of the Churchill province, however, appear to have escaped complete reworking so that some older dates survive. This is illustrated in a large, poorly defined region some 200 miles wide and 600 miles long that extends from Nonacho Lake (which lies southeast of Great Slave Lake) eastward toward Hudson Bay. In this region a number of survival dates, varying erratically from 1,900 to 2,460 m.y., are found here and there among the more common ages of 1,700 ± 150 m.y. that characterize the Hudsonian orogeny. In this area of mixed dates the effect of the Hudsonian was, apparently, more severe in some places than in others. Similarly, a survival date of 2,390 m.y. (GSC 61-196)* has been found near the Labrador coast north of the Grenville front.

In the main body of the Churchill province the early history has become so obscured that no tectonic cycle can be defined. In some of the bordering subprovinces, however, such as the Labrador Trough and the East Arm fold belt, and also in the Penokean fold belt and the southern part of the Bear province, there is clear evidence of complete tectonic cycles, for the rocks have been deposited on an Archaean basement and have been involved in the Hudsonian mountain building period. These areas show that processes similar to those that produced Phanerozoic geosynclines and subsequent mountain belts were in operation between 2,500 and 1,700 m.y. ago.

The effects of the Hudsonian orogeny were not confined entirely within the boundaries of the Churchill, Bear, and Southern provinces but are noticeable also in the central and northern parts of the Slave province and in limited areas of the Superior province.

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*Numbers "GSC 61-.." refer to detailed accounts in Part I of this report; Nos. "GSC 60-.." refer to Lowdon (1961); and Nos. "GSC 59-.." refer to Lowdon (1960).

In these places the otherwise stable cratons of the Kenoran were partly reworked by the Hudsonian to give intermediate dates. For example, in the central and northern parts of the Slave province, as may be seen in Figure 2, ages vary erratically from 1,790 to 2,175 m.y.; and in the Superior province at Cross Lake, Manitoba, and eastward, dates determined by the Geological Survey and by Moore et al. (1959) vary between 1,600 and 2,190 m.y.

The next important orogeny is the Grenville, which marks the upper limit of Middle Proterozoic time. It is typically developed in the Grenville province where, like the Hudsonian, it produced predominantly gneissic and granitic rocks. A notable feature about the Grenville is that its north boundary, or front, follows a fairly straight course and truncates the rocks of the Southern, Superior, and Churchill provinces. The rocks of these provinces can be traced, in a much more highly metamorphosed condition, for short distances into the Grenville and may continue much farther. In fact it seems possible that much of the Grenville province is made up of rocks that were first deformed during either the Kenoran or Hudsonian orogenies and were later reworked during the Grenville. There is no good evidence of an intervening period of extensive geosynclinal sedimentation between the Hudsonian and the Grenville and, consequently, no clear indication of an orogenic cycle culminating in the Grenville orogeny. The presence of reworked materials within the Grenville and the lack of convincing evidence of an intervening period of extensive sedimentation suggest that the Grenville orogeny may have taken place without the usual, immediately preceding, geosynclinal phase.

The next definable tectonic cycle spanned the Precambrian-Phanerozoic boundary and, in the Appalachian region for example, culminated in the Taconic (Ordovician) and, more strongly, in the Acadian (Devonian) orogenies (Neale et al., 1961).

Stratigraphic Classification

The Precambrian of the Canadian Shield is divisible into four main time-units: the Archaean, and the Lower, Middle, and Upper Proterozoic. As indicated in Figure 3, Archaean time was brought to a close with the Kenoran orogeny, Lower Proterozoic with the Hudsonian, Middle Proterozoic with the Grenville, and Upper Proterozoic with the beginning of Cambrian time. It is expected that the three subdivisions of the Proterozoic will, for greater convenience, be given geographic or other names when more age information becomes available at suitable type localities.

Further progress has been made in bracketing named stratigraphic units between maximum and minimum limits and these have been added to Figure 3. The additions include the Upper Huronian Series and the Animikie and Great Slave Groups which fall in the Lower

Proterozoic. The long-debated problem of the relationship between the Huronian and the Animikie has not been solved but both, at least, are Lower Proterozoic. The Lower and Middle Keweenawan fall within the Middle Proterozoic. The classification of the Upper Keweenawan is more problematical as its maximum is given by a date (on the Duluth Complex) somewhat older than the Grenville orogeny and its minimum by overlying Upper Cambrian sediments. Data on the Keweenawan are from the publication by Goldich et al. (1961). The Dubawnt is now removed from the diagram because of problems arising from more recent age work (see discussion under GSC 61-101).

A representative selection of named igneous and metamorphic rock units is also shown in Figure 3. An interesting feature is the virtual contemporaneity of the Middle Proterozoic Duluth and Muskox intrusions and their apparently slightly older age than the Grenville orogeny. These contrast with the Sudbury irruptive which may have been intruded during the Hudsonian orogeny of late Lower Proterozoic age, although Fairbairn et al. (1960) consider the determined age of the irruptive is a minimum. Diabasic dykes of the Shield seem to differ widely in age as evidenced by the Lower Proterozoic Nipissing Diabase and the Middle Proterozoic Logan intrusives. Post-tectonic niobium-bearing alkaline and carbonatite bodies that cut Precambrian rocks are also of various ages; the Lackner Complex falls into the Middle Proterozoic, the Manitou Islands Complex into the Cambrian, and the Oka into the Cretaceous. The great age differences are surprising in view of the compositional and structural similarities of the complexes.

Figure 3 shows, with two exceptions only, potassium-argon ages on micas and does not include all of those reported in the literature. The exceptions are GSC 61-146, which gives a minimum age for the Lower Huronian, and sample 200 (Goldich et al., 1961), which gives a minimum age for the Knife Lake Group; both analyses are on whole rock samples which, however, contain a considerable percentage of sericite.

Problems of Interpretation of Potassium-Argon Ages

The reconnaissance study of the Shield has supplied rather satisfactory evidence that potassium-argon ages on micas are, on the whole, sufficiently accurate for dating main periods of orogeny. This is particularly well demonstrated over huge areas where remarkably consistent results have been obtained and where the cratons have evidently remained stable since the time of their last major orogeny. Besides, the ages obtained agree very well with the succession of events determined after many years of geological work. Other large areas, as already discussed, have been partly reworked by later orogenic events to give erratic dates before having become finally stabilized. In addition, a number of more local problems have been encountered; these are especially evident along boundaries between orogens of widely different ages. Because of the reconnaissance nature of our investigation we can do little more than point to such problems and offer tentative suggestions towards their solution. Local difference in the behaviour of biotite and muscovite, under the same environment, offers a particularly interesting field for further study. In the following, evidence is first given that indicates the general reliability of potassium-argon ages on micas; the local problems are then discussed.

As a general rule, especially in the large stabilized areas of the Shield, good agreement is found when K-Ar ages on micas are checked by other methods; moreover, the agreement is found in both young and old rocks of the Precambrian time-scale, as illustrated by the following examples. As reported by Wanless and Lowdon, (Lowdon, 1961, pp. 119-120), generally good checks were obtained between K-Ar and Pb-U, Pb-Th ages for coeval mica and uraninite and thorianite; most of these examples are from the Grenville province. In the western part of the Churchill province, Collins et al. (1954) reported a number of Pb^{207}/Pb^{206} ages on uraninites in the 1,740 to 1,850 m.y. range. These agree with the oldest pitchblendes of the region, and with the potassium-argon ages of the Hudsonian orogeny generally. Also, a large number of K-Ar ages on micas from the Precambrian of Minnesota and nearby parts of Ontario, mostly from the Archaean, have been checked by the Rb-Sr method by Goldich et al. (1961, pp. 26-30); differences were found to be less than 5 per cent in 30 of the 37 samples compared, and from 5 to 10 per cent in the remainder. Good agreement is also found between a K-Ar age of 2,455 m.y. (GSC 60-105) on muscovite and lead ratio ages of 2,550 m.y. on monazite and 2,450 m.y. on zircon (Mair et al. 1960); the muscovite is from Archaean basement rocks and the monazite and zircon are detrital minerals in unconformably overlying Lower Huronian sediments. Comparisons between K-Ar ages on biotite and muscovite coexisting in the same sample were discussed in the previous report (Wanless and Lowdon, in Lowdon, 1961, pp. 121-123). This work has been continued and the results to date are reported by Wanless and Lowdon, Part I of this report . Of the total of thirty-three such pairs, twenty-five are from the Precambrian Shield. Fifteen of these show discrepancies of less than 4 per cent, well within the limits of analytical error, and are regarded as concordant; seven show discrepancies between 5 and 10 per cent; and six show marked discordance in the range from 12 to 32 per cent. In each case, the biotites that give ages younger than coexisting muscovite are about equal in number to those in which the reverse is true. The pairs that give markedly discordant ages are discussed subsequently.

All of the above checks, mostly falling well within the limits of error, and whether obtained on mica pairs or by comparison of mica with uraninite-thorianite, zircon, or monazite, are thought to show that under normal conditions the K-Ar method gives at least the approximate age of crystallization of micas. In one of the above examples, however, a rather consistent discrepancy appears, even within the range of experimental error. This is the example in which mica ages were compared with uraninite and thorianite. These have been discussed by Robinson (in Lowdon, 1960, pp. 45-46) and by Wanless and Lowdon (in Lowdon, 1961, pp. 119-120). Selecting only those pairs that are from the Grenville province and confining our attention to those containing biotite, it is found that the biotites consistently give younger ages than associated uraninite or thorianite; the six biotite determinations average 927 m.y. and the seven determinations on associated uraninites and thorianites average 958 m.y., a difference of 31 m.y. The discrepancy between biotite and uraninite-thorianite compares with a similar difference between biotite and muscovite for the Grenville province as a whole. This shows in the histogram of Figure 3 where, within the range of 840 to 1,000 m.y. where most of the dates fall, thirty-one biotites average 910 m.y. and six muscovites average 950 m.y., a difference of 40 m.y. The younger apparent ages for biotite as compared with uraninite-thorianite on the one hand and with muscovite on the other could be explained either by loss of argon during the early stages of the cooling history of the rock or by assuming that the period of crystallization extended over a long time, of the order of 30 to 40 m.y. Although most of the biotites are beautifully clear and fresh, it is judged that the former explanation is the more probable, in which case it may be conjectured that the 30 to 40 m.y. figure gives some notion of the time required for the rocks of the Grenville province that are now at the surface, to cool down to the temperature at which argon was retained in biotite. ambiguous?

Possible loss of argon from biotite during cooling of the rock has not been detected in the older orogens, probably because the loss is masked by the increasingly greater analytical uncertainties which reach $\pm$ 90 m.y. in the Hudsonian and $\pm$ 125 m.y. in the Kenoran, so that the relatively small loss of argon is not of practical significance in the gross classification of most Precambrian rocks.

The difference in behaviour between biotite and muscovite becomes more apparent where discrepancies are greater than the analytical error. Such great differences are generally found near contacts between orogenic belts of widely different ages. At some such localities the determined age for biotite is younger than for muscovite while at other places it is older. In both cases, geological relationships indicate that the muscovite gives the more reliable age for the strongest and regionally most important event in the orogen in which it is found. Thus, several examples have been found in which the biotite of an older orogen close to a younger one reflects the younger event although the associated muscovite retains the old age. In some such cases the biotite has been recrystallized but in others the original biotite seems to have lost argon under conditions causing slight alteration or even under a very mild change in environment that caused no visible alteration. In contrast with this situation, the reverse age-relationship, in which the determined age for biotite is ∴ bi re-xlz much older than for muscovite, is found in high-grade gneisses of a younger orogen adjacent to an older one. This shows in rocks of the Grenville province close to the Grenville front where biotite is abnormally old while muscovite gives the usual age for the Grenville orogeny. In view of the apparent easy loss of argon from biotite under conditions of slight metamorphism on the one hand, its retention under conditions of high temperature and pressure on the other hand poses a problem for which no entirely satisfactory explanation is apparent. Examples illustrating both situations are given in the following.

A biotite-muscovite pair in which a biotite date is 660 m.y. younger than associated muscovite is described by McGlynn (GSC 61-63, 1,755 m.y. on biotite; GSC 61-62, 2,415 m.y. on muscovite). This pair is from a body of Archaean granodiorite in the Slave province near the contact with unconformably overlying sediments of the Lower Proterozoic Snare Group of the Bear province. The Snare rocks were regionally folded and intruded by granite during the Hudsonian orogeny, but near the contact with the basement granodiorite they are only gently folded and only slightly metamorphosed. The granodiorite beneath the unconformity shows local crushing but generally does not appear to be much disturbed or otherwise altered. Yet, in spite of the unimpressive field evidence for deformation or heating, the original biotite was sufficiently recrystallized and chloritized to lose practically all of its argon at the time of the Hudsonian orogeny; recrystallization of biotite is evidenced by its occurrence in matted, randomly oriented, small crystals which, together with dark opaque material, appear to fill spaces formerly occupied by large biotite crystals (J.Y.H. Rimsaite, personal communication). The system was evidently open with respect to argon released from biotite but, under the same environment, the coexisting muscovite retained its argon to give the Archaean age. It is interesting to note also that muscovite, from another body of granodiorite in the same region and likewise overlain unconformably by Snare rocks, is considerably bent and broken but nevertheless gives the expected Archaean age of 2,460 m.y. (GSC 60-47), attesting to the ability of muscovite to withstand a fair amount of deformation without loss of argon. McGlynn is continuing his study of the region.

The same effect, while not demonstrated by biotite-muscovite pairs from a single sample, shows in the Archaean basement beneath Lower Huronian rocks of the Penokean fold belt. In the area from Quirke Lake westward, the Huronian rocks are but little metamorphosed and only gently folded. Muscovite from a pegmatitic segregation in the basement quartz monzonite gives an age of 2,455 m.y. (GSC 60-105) and this is thought to be the true age of crystallization for, as previously mentioned, it agrees with ages on detrital monazite and zircon from the overlying Huronian. Biotites from the same basement rocks, however, give much younger ages (GSC 59-42, 1,685 m.y.; GSC 61-145, 1,915 m.y.; and GSC 61-147, 1,520 m.y.). These erratic biotite ages in the Archaean rocks are thought to be due to a mild, marginal effect of the Hudsonian orogeny that deformed the nearby Huronian sediments. In the field it is difficult to find fresh biotite in the basement granitic rocks and gneisses for some miles north of the Huronian contact; but exceptionally, as in the samples dated, the biotite is quite fresh but nevertheless appears to have lost argon. In other samples collected but not submitted for dating, the biotite, in more or less the same environment, is considerably altered to chlorite, contains exsolved specks of dark material, or is locally crenulated. Such retrograde effects seem to be a consequence either of deformation accompanying gentle folding of the Huronian or of heating due to depth of burial or to intrusions of diabase and other basic rocks that commonly intrude the cover rocks. With a sufficiently large number of dates it might eventually be possible to draw an isograd at the outer limit of the abnormally young biotite dates.

Similarly, the biotite in Archaean basement rocks unconformably beneath gently folded rocks of the Cape Smith belt and of the northern part of the Labrador Trough, give anomalously young ages (GSC 60-122, 1,750 m.y.; GSC 61-178, 1,690 m.y.; and by Beall et al. (1960): sample B 4029, 1,660 m.y.; sample B 4028, 1,550 m.y., and sample B 4141, 1,770 m.y.). These contrast with the normal Archaean ages of the Superior province farther from the contact and reflect, more or less, the Hudsonian orogeny during which the unconformably overlying rocks were folded and intruded by sills of basic rocks. In at least the first two of the above samples, the apparently original biotite that crystallized during the Archaean is unaltered and seems to have lost argon under very slight heating or deformation. A different situation is found farther south where the rocks of the Labrador Trough are unfolded in a narrow strip adjacent to the Archaean basement, although they were involved in Hudsonian folding farther out. In this case the biotite of the basement retains the Archaean age (GSC 60-126, 2,440 m.y.; GSC 60-127, 2,505 m.y.; GSC 59-63, 2,365 m.y.; GSC 60-137, 2,425 m.y.; and by Beall et al. (1960): sample B 4139, 2,450 m.y.; and sample B 4138, 2,430 m.y.).

Another sample of loss of argon from biotite, in a different setting but fundamentally the same, is found in the Preissac-Lacorne batholith which lies within the Superior province some distance from its borders. The geology of the area has been studied by Dawson (1953) and the age determinations have been discussed by Snelling (in press). Four biotites from granodiorite of the batholith average 2,407 m.y. (GSC 59-69, -72, -73, -74) and all give younger ages than three muscovites from granodiorite and associated pegmatite which average 2,635 m.y. (GSC 59-66, -68, -70), a difference of 228 m.y. All the micas are primary and all are fresh except for one biotite which is much altered to chlorite. The pegmatites, which cut the batholith, are actually the youngest rocks although the K-Ar ages erroneously give the reverse relationship. As in examples described in previous paragraphs the muscovite is thought to give the true age of crystallization of the batholith and pegmatite. As this age is older than the prevalent ages for the general region and for the Superior province as a whole, it is possible that the batholith has undergone a later mild form of deformation or heating that was too weak to affect the argon in muscovite but caused argon to escape from biotite. Evidence for the later period of deformation is found in two ages in the wall-rock, one on biotite at 2,455 m.y. (GSC 59-71) and the other on muscovite at 2,395 m.y. (GSC 60-106). These two ages are regarded as concordant because the difference of 60 m.y. is within the limits assigned to analytical error. The average age of the two wall-rock micas is 2,425 m.y., which agrees with that of the biotites (2,407 m.y.) within the more competent batholith and dates the period of later deformation.

Turning our attention now to cases where apparent ages on biotite are much older than on associated muscovite, we find the best example in the Grenville province close to the Grenville front. Again it appears that the muscovite gives a more reliable age for the main orogeny for it agrees with ages found throughout the body of the province. This is illustrated by a biotite-muscovite pair from orthogneiss, 1 1/2 miles southeast of the front, in which biotite gives an age of 1,270 m.y. (GSC 60-108) and muscovite gives 960 m.y. (GSC 61-162). No entirely satisfactory explanation can be given for the old biotite age. If it represents an old biotite which survived the apparently high temperature conditions that prevailed during the Grenville orogeny when the associated muscovite was formed, it is difficult to understand why its argon was not driven off when, as in examples discussed previously, argon can be lost from biotite under much milder conditions.

The problem also involves a consideration of the effect of the Grenville orogeny on rocks on the Superior side of the front where biotite, in contrast, gives an abnormally young age. This shows in a sample of granodiorite 3/4 mile northwest of the front, in which biotite gives an age of 1,840 m.y. (GSC 60-107) whereas the normal age for rocks of the Superior province is in the neighbourhood of 2,500 m.y. The abnormally young biotite age is readily accounted for by loss of argon due to proximity to the Grenville orogen. It seems probable, however, that the two opposing phenomena—that of abnormally old ages on one side of the front and abnormally young ones on the other—are inter-related and that it should be possible to account for both phenomena by a single hypothesis. A suggested explanation for both phenomena is that of argon diffusion, probably along crystal interfaces, from the older province to the younger. That is to say, the argon released from the old biotite on the Superior side of the front might have migrated down the concentration gradient into the Grenville province. There, filling available interspaces in a closed or partly closed system and, when reaching a concentration equal to that within the biotite, it would prevent further escape of argon from the old biotite. This is offered as a possible explanation for the retention of argon even at a relatively high temperature.

However, it is not at all certain that the biotite of the Grenville province is really as old as indicated (1,270 m.y.) because the geological setting is such that it may have crystallized during the Grenville orogeny at about the same time as the associated muscovite (960 m.y.). This is suggested by the field observation that the metamorphic change from gneisses on the Grenville side of the front, to low-grade greenstone and slate on the Superior side, is sharply defined at this locality and does not take place gradually over the width of 2 miles or more in which the biotite dates are abnormal. That is, the orthogneiss of the sample under discussion has a typical Grenville appearance both in structure and in grade of metamorphism. Therefore, as an alternative to the proposition that the biotite is old and survived the effects of the Grenville orogeny, it seems reasonable to suppose that it crystallized during the Grenville orogeny at about the same time as the associated muscovite. If so, the abnormally old biotite date requires some other explanation and it may be conjectured that the argon, which is presumed to have migrated from the Superior side of the front, was added to the biotite on the Grenville side and that this took place at an elevated temperature during the early stages of the cooling history of the rock. An objection is the apparent difficulty of adding excess argon to the space lattice of biotite. This is part of a problem being investigated experimentally under the direction of L.G. Berry at Queen's University in cooperation with the Geological Survey.

The anomalous age relationships are not just local phenomena but seem to be characteristic of the Grenville front generally. This is indicated by samples from the Grenville province close to the front at several other places. The anomalous relationship shows in a sample of migmatite from which biotite gives 1,125 m.y. (GSC 60-139) and coexisting muscovite gives 980 m.y. (GSC 60-138). One other muscovite close to the front also gives the expected Grenville age of 930 m.y. (GSC 61-198) but a nearby biotite gives 1,645 m.y. (GSC 60-140). Three other biotites give old ages: one from schist at 1,680 and 1,705 m.y. (GSC 59-80); one from paragneiss at 1,395 m.y. (GSC 61-159); and the third from granite at 1,170 m.y. (GSC 61-158). On the Superior side of the front an additional sample of biotite, from quartz syenite, gives an abnormally young age of 2,205 m.y. (GSC 59-79).

Another pair in which the apparent age of biotite is much older than muscovite is found in paragneiss in the western part of the Superior province where the rocks seem to have been reworked during the Hudsonian orogeny (see GSC 61-124, biotite 2,135 m.y.; and GSC 61-125, muscovite 1,680 m.y.). It is possible that the geological setting is similar to that along the Grenville front and that, there too, argon may either have been prevented from escaping or may have been added to the biotite.

The reconnaissance study of potassium-argon ages in the Shield is being continued and it is expected that this work will soon be supplemented by rubidium-strontium age determinations.

TOPLEY INTRUSIONS

by H. W. Tipper

The Topley Intrusions of central British Columbia were described by Armstrong (1949, pp. 92-97) and, for lack of evidence to the contrary, were considered as one intrusive complex with granitic, dioritic, and syenitic phases. The stratigraphic relations were imperfectly known but the Topley Intrusions were considered to be post-Permian and pre-Upper Triassic although the possibility of several periods of intrusion was not ignored. Later work by the writer (Tipper, 1955) produced evidence that the granitic phase was post-Upper Triassic and pre-early Middle Jurassic. The granitic rocks intruded Upper Triassic strata, and boulders of these granites occur in Middle Jurassic conglomerates. Middle Jurassic arkose also occurs near the present outcrop area of the granites. The age of the Topley Intrusions is now considered as very late Triassic or, more probably, Lower Jurassic.

As the granites are stratigraphically better dated than most granitic masses in British Columbia, this presented an opportunity to check the stratigraphic relations against an absolute age determined on the contained biotite and to check the relative ages of the different phases of the Topley Intrusions. The biotites in four samples, two from the granite phase and two from the diorite phase, were analyzed, and the resulting information is summarized below.

Age Determination Number	Phase of Topley Intrusions	Age
GSC 61-34	diorite	63 m.y.
GSC 61-35	diorite	178 m.y.
GSC 61-36	granite	138 m.y.
GSC 61-37	granite	154 m.y.

The spread of ages seems at first unusual for a group of igneous rocks considered to be one unit, but the stratigraphic facts relative to the Topley Intrusions, the regional geology, and local conditions pertinent to each specimen permit a reasonable interpretation and explanation of these seemingly anomalous ages. Each specimen and age obtained will be briefly discussed.

GSC 61-34

This specimen, although more correctly described as a granodiorite, was obtained from the dioritic phase of the Topley Intrusions. It differs from the dioritic phase by a lower mafic mineral content and a lack of any obvious foliation. Although this specimen occurred within a belt that is typical of the dioritic phase, there is no field evidence to suggest that it is anything but a part of the Topley Intrusions. However, the age determined for this specimen, 63 m.y., suggests that: (1) the result is low due to argon loss or some subsequent metamorphic event; or (2) the intrusion sampled is of Paleocene age and hence not part of the Topley Intrusions as defined. There is no field or laboratory evidence that strongly supports the first possibility and in fact the mineralogical character of the biotite is counter to it.

Tertiary granitic rocks are known in various parts of central and northern British Columbia, but the presence of Tertiary intrusions in the Topley area itself has not previously been suggested. On Nadina Mountain, about 75 miles west of the Topley area, a granite stock intrudes Upper Cretaceous sediments (Lang, 1930); in McConnell Creek area (Lord, 1948, pp. 41-43) about 140 miles north, the Kastberg Intrusions are believed to be post-Paleocene; and elsewhere, various stocks have been thought to be Tertiary for one reason or another. South of the Topley area there are several small stocks intruding Middle Jurassic rocks, and in the absence of evidence to the contrary, these too may be Tertiary. There is no compelling reason why a Tertiary stock could not have intruded the Topley complex itself, and the writer suggests the K-Ar age of 63 m.y. as evidence of this.

GSC 61-35

This specimen was collected from the dioritic phase of the Topley Intrusions and closely resembles the granodiorite described by Armstrong from Grizzly Mountain, just south of the locality of this specimen (Armstrong, 1949, p. 95). This granodiorite body appears to be uniform, free from inclusions, fresh, unsheared, and not intruded by later dykes. There is no reason to suggest from field or laboratory evidence that the biotite age obtained would not be that of the time of intrusion. This age, 178 m.y., corresponds to the accepted stratigraphic age for the Topley Intrusions. However, the stratigraphic evidence for a Lower Jurassic age does not apply to this phase of the intrusions, and one of the purposes of this investigation was to determine whether or not the granite and diorite phases were emplaced contemporaneously. This is a strong probability in the light of the 178-m.y. date of the diorite and the stratigraphic evidence of the age of the granite.

GSC 61-36 and GSC 61-37

Two specimens of coarse pink granite, similar to those described by Armstrong (1949, p. 93), were collected from the granite phase. These granites intrude Upper Triassic (Norian) rocks, and boulders lithologically identical to them occur in Middle Jurassic (Bajocian) rocks. A Lower Jurassic age is considered most probable.

The age of the biotites from these granites, 138 m.y. and 154 m.y., would suggest ages of intrusion of Upper Jurassic and Middle Jurassic respectively. Neither of these corroborates the stratigraphic evidence. Assuming the stratigraphic evidence to be correctly interpreted, it follows that the age determined for the biotites does not reflect the true age of intrusion of the granites. The granite batholith from which these specimens were collected has been cut by many dykes of volcanic origin, shear zones are common throughout, and chloritization of the biotite has occurred. In addition, as previously suggested, younger stocks may have intruded these granites. Any or all of these factors may have caused loss of argon and so caused low biotite ages.

One other age, 163 m.y., for biotites from the Topley Intrusions has been published (Baadsgaard et al., 1961). This sample was collected from near Fort Fraser and most probably was from the granite phase. Although slightly older than the two ages here recorded, it is still younger than Lower Jurassic. For the same reasons stated previously the writer believes that this does not correctly indicate the age of intrusion.

Conclusions

One age determination supports the stratigraphic evidence, namely that the Topley Intrusions were emplaced in Lower Jurassic time. Reasons were presented why the other ages do not corroborate the evidence, but at the same time do not invalidate the Lower Jurassic age. There is a strong suggestion that the granite and diorite phases are contemporaneous.

In the absence of stratigraphic evidence the K-Ar ages of the Topley Intrusions would probably have been interpreted to mean that its various phases were emplaced at rather widely separated times. This points to the need for great caution in drawing conclusions about Cordilleran events from K-Ar dates alone. The geological events may be much older than the K-Ar dates suggest.

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