GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA

PAPER 82-12

ISOTOPIC AGE STUDIES AND TECTONIC INTERPRETATION OF SUPERIOR PROVINCE IN MANITOBA

INGO F. ERMANOVICS
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Available in Canada through

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Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Ontario, Canada K1A 0S9

and from

Geological Survey of Canada
601 Booth Street
Ottawa, Canada K1A 0E8

A deposit copy of this publication is also available
for reference in public libraries across Canada

Cat. No. M44-82/12E Canada: $4.00
ISBN 0-660-11403-8 Other countries: $4.80

Price subject to change without notice

Original manuscript submitted: 1980-02-01
Final approved for publication: 1982-10-08

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ISOTOPIC AGE STUDIES AND TECTONIC INTERPRETATION OF SUPERIOR PROVINCE IN MANITOBA

Abstract

Isotopic ages determined from U-Pb zircon, Rb-Sr whole-rock isochron, and K-Ar mineral data from Superior Province in Manitoba are tabulated and interpreted in relation to their distribution in subprovinces. Two episodes of igneous activity are separated in time by 300 Ma in all subprovinces at ca. 2900-3050 Ma (Wanipigowan Orogeny) and ca. 2660-2770 Ma (Laurentian Orogeny). K-Ar biotite ages are interpreted to be plutonic cooling ages and they show that blocking temperatures of argon in biotites south of Sachigo Subprovince were seemingly attained about 200-300 Ma after culmination of igneous activity 2700 Ma ago. Rb-Sr whole-rock and U-Pb zircon data of primary ages suggest that crustal growth during 2700-3000 Ma ago occurred without significant remelting of pre-existing rocks and that Superior Province responded to Laurentian tectonics as a unit.

However, some Rb-Sr whole-rock ages young southward from Pikwitonei Subprovince and K-Ar mineral ages young southward from southern Sachigo Subprovince. This seems to suggest that plutonic activity or cratonization or both proceeded from north to south in late Archean time. U-Pb zircon ages in the northern part of the Superior Province in the range 2700-2765 Ma as opposed to 2660-2730 Ma in the southern part may be cited in support of such a concept. Alternative hypotheses that may explain the younging trend to the south include loss of radiogenic daughters during deuteric mobilization at elevated but postconsolidation temperatures, isotopic rejuvenation, and plutonic cooling of epeirogenic proportions during late Archean time.

Young K-Ar ages were produced in Proterozoic time in Superior Province terrane north of northern Berens Subprovince as far as 350 km south of the Superior-Churchill boundary zone. Biotite ages with a median value of 2450 Ma in Berens are updated by proportionately greater amounts in the direction of the Churchill orogen and cluster in the range 1700-1800 Ma in the Superior-Churchill boundary zone. The cause of these younger ages in Sachigo Subprovince may have been regional uplift of Superior Province during Proterozoic time or isotopic rejuvenation related to tectonic activity along the Churchill-Superior boundary zone. Temperatures for this activity in Sachigo Subprovince are constrained by the blocking temperature of argon in biotite. In retrograde Pikwitonei (Churchill-Superior boundary zone) temperatures exceeded argon blocking temperatures in hornblendes.

Résumé

Les âges radiométriques déterminés selon les rapports U-Rb dans le zircon, Rb-Sr dans la roche entière et K-Ar dans les minéraux de la province du lac Supérieur au Manitoba sont mis sous forme de tableau et interprétés en fonction de leur répartition dans les sous-provinces. Deux épisodes d'activité ignée, séparés par 300 Ma, ont eu lieu dans toutes les sous-provinces il y a environ 2 900 à 3 050 Ma (orogénèse de Wanipigowan) et 2 660 à 2 770 Ma (orogénèse Laurentienne). Les âges provenant de la datation au K-Ar de la biotite représenteraient des périodes de refroidissement plutonique; ils indiquent que les températures de blocage de l'argon dans la biotite ont été atteintes environ 200 à 300 Ma après l'arrêt de l'activité ignée, il y a 2 700 Ma. Les âges primaires obtenus par la datation au Rb-Sr de la roche entière et à l'U-Pb du zircon laissent supposer que la formation de la croûte il y a 2 700 à 3 000 Ma a eu lieu sans refonte importante des roches existantes et que la province du lac Supérieur a répondu sous forme d'unité à la tectonique Laurentienne.

Toutefois, certains âges déterminés par la datation au Rb-Sr de la roche entière diminuent vers le sud à partir de la sous-province de Pikwitonei, tandis que les âges déterminés par datation au K-Ar des minéraux diminuent vers le sud à partir de la sous-province de Sachigo. Cette situation laisserait supposer que l'activité plutonique ou la cratonisation ou les deux à la fois ont eu lieu du nord vers le sud à la fin de l'Archéen. La datation à l'U-Pb du zircon donne des âges variant de 2 700 à 2 765 Ma dans la partie nord de la province du lac Supérieur, par rapport à 2 660 à 2 730 Ma dans la partie sud, ce qui semble appuyer l'hypothèse. D'autres hypothèses pourraient expliquer la réduction des âges en direction du sud, par exemple, la perte de produits radiogéniques lors de la mobilisation deutérique à des températures élevées, la post-consolidation, le rajeunissement isotopique et le refroidissement plutonique d'importance épirogénique durant l'Archéen tardif.

Des âges récents basés sur des rapports K-Ar ont été produits durant le Protérozoïque dans la province du lac Supérieur au nord de la sous-province de Berens septentrionale, jusqu'à 350 km au sud de la zone limite lac Supérieur-Churchill. La datation de la biotite donne un âge moyen de 2 450 Ma dans la sous-province de Berens; ce chiffre varie proportionnellement en direction de l'orogénèse de Churchill et 1 700 à 1 800 Ma dans la zone limite lac Supérieur-Churchill. Ces âges plus récents dans la sous-province de Sachigo pourraient être le résultat d'un soulèvement régional de la province du lac Supérieur au cours du Protérozoïque ou de rajeunissement isotopique lié à l'activité tectonique le long de la zone limite lac Supérieur-Churchill. Les températures liées à cette activité dans la sous-province de Sachigo seraient limitées par la température de blocage de l'argon dans la biotite. Dans le Pikwitonei (zone limite lac Supérieur-Churchill) où il y a eu métamorphisme régressif, les températures ont dépassé la température de blocage de l'argon dans les hornblendes.

INTRODUCTION

This report is a compilation and discussion of approximately 120 published and unpublished isotopic age determinations from 101 localities in the Superior Structural Province of Manitoba. The object is to trace the isotopic history of Archean rocks and to determine if it is possible to establish unique times of tectonic activity in various subprovinces.

This data inventory is also intended to highlight the types of age data in use for interpretation of Superior Province geology, leading to new directions for future isotopic studies. It is important that ages determined by all methods be rationalized as to whether they are primary (formational), metamorphic, or the result of plutonic cooling during epeirogeny to consider questions of timing of crustal processes.

The results of this study show that two major orogenic periods culminated ca. 2900-3050 Ma and 2660-2770 Ma ago. Determination of these times of orogeny is greatly influenced by interpretation of the geology, and limited by the paucity of data. Some of the Rb-Sr data, and all of the K-Ar data, however, do not support these times of orogeny. Instead, they seemingly reflect protracted tectonic activity during late Archean and early Proterozoic times. Rb-Sr and K-Ar systems appear to reflect sensitivities to PTX conditions, ambient within the rock mass, that defy definition. Where large areas of the Shield are characterized by such aberrant or geologically meaningless ages it may well be possible to rationalize such data to support hypotheses leading to slow unroofing and crustal cratonization.

The extent to which age determinations can be used to interpret tectonic history may be severely limited by metamorphism (Kalsbeek and Pidgeon, 1980; Krogh and Davis, 1973, 1975; Collerson and Fryer, 1978; Roddick and Compston, 1977; Barton et al., 1979; Nunes and Thurston, 1980; Brooks 1979, 1980; Field and Raheim, 1979a, b; Verpaelst et al., 1980; Brooks et al., 1972). It is likely that complete isotopic rehomogenization in metamorphic rocks is rarely attained except at very high grades (Collerson et al., 1982; Moorbath, 1975). Isotopic systems may become disturbed whenever mineral equilibrium is disturbed but direct correlation of these two functions is not possible. Variable metamorphism as shown by isograds within a succession is an additional complication. Increasing metamorphic grade toward margins of greenstone belts is common in Sachigo Subprovince (Weber and Scoates, 1978; Ayres, 1978) and English River-Uchi subprovinces (Ayres, 1978; McRitchie, 1971). Other belts exhibit mineral coarsening and increased structural complexity without attendant increase in grade.

It is likely that the early granitoids (generally metatonalites) were also affected by variable metamorphism, but this remains generally undetected except at very high grades, as for example at the orthopyroxene isograd defining Sachigo-Pikwitonei subprovinces (Weber and Scoates, 1978; Hubregtse, 1978). The origin of possible large scale migration of potassium in the early metatonalites during the Laurentian Orogeny (Ermanovics et al., 1979, Table 1) and the effect this may have on whole-rock isotope analysis also remains problematical.

Litho-tectonic domains in Manitoba have been defined as subprovinces (Douglas, 1973). These have been presented in cross-section (Ermanovics and Davison, 1976, Fig. 6) and are discussed in detail in McRitchie and Weber (1971), Bell (1971), Weber and Scoates (1978), Beakhouse (1977), and Ayres (1978). Boundaries between subprovinces may be abrupt or transitional and have been established on the basis of one or more criteria such as metamorphic grade (Pikwitonei: Bell, 1971; Hubregtse, 1980; Weber and Scoates, 1978), proportion of plutonic material, aeromagnetic patterns and faults (Berens and English River: Ayres, 1978; Beakhouse, 1977; Wilson, 1971), and faults and seismic profiles (Uchi and English River: Wilson, 1971; Hall and Hajnal, 1973).

The subprovinces may not be the sites of early tectonically independent domains. Metasediments of English River are thought to be facies equivalents of the dominantly volcanogenic successions of Uchi Subprovince (Ayres, 1978; McRitchie, 1971; Weber, 1971; Ermanovics, et al., 1979, p. 353). Supracrustal rocks of northern Sachigo have been traced to granulite facies assemblages in Pikwitonei (Weber and Scoates, 1978). However, the subsequent thermotectonic evolution, following initial orogenesis, appears to have shaped the present disposition of the subprovinces. Consequently, large scale, late stage orogenic adjustments or epeirogenic activity may be reflected in some of the K-Ar and to a lesser degree in the Rb-Sr whole-rock data.

The present summary study of isotopic ages seeks to rationalize the effects of metamorphism, present tectonic disposition of subprovinces and cooling history of the Archean in Manitoba.

Terminology

Common to all isotopic age determination methods is the assumption that the measured isotopic age of a sample reflects the time that has elapsed since the sampled rock or mineral became a closed system with respect to a particular radioactive parent-daughter pair. The radiogenic isotopes of Ar, Sr and Pb diffuse away from their original lattice sites at rates exponential to temperature (Dodson, 1973; Allsopp, 1977), and if mineralogical and isotopic equilibrium is maintained a primary or formational age for the rock or mineral may be assumed.

For igneous rocks any isotopic age other than the formational age may be considered to be an updated age. If during metamorphism complete isotopic rehomogenization occurs the isotopic system will yield a new or updated age which will reflect the formational age of the metamorphic rock. Incomplete rehomogenization as, for example, at low metamorphic grades is likely to lead to partial loss of daughter products and give rise to apparent ages that reflect neither the age of formation nor the time of the metamorphism (e.g. geologically meaningless ages, Field and Raheim, 1979b). Thus where updating is incomplete such isotopic ages may be said to be rejuvenated.

Stockwell (1982) has termed K-Ar mineral ages that are as much as 70 Ma younger than primary or formational rock ages epi-orogenic cooling ages. Where such ages are not readily assigned to orogeny he termed them rejuvenated ages. Epi-orogenic cooling ages for biotite must represent the time when biotite attained closure conditions (ca. 300°C, e.g. see reference in Mattinson, 1978) and by implication eventually reached near surface conditions that could lead to cratonization. The distinction between epi-orogenic cooling ages and rejuvenated ages is generally made on geological grounds (e.g. Hart, 1964; Wanless et al., 1970).

An observation arising from the present study is that K-Ar biotite ages are generally 200 to 300 Ma younger than ages of formation (primary or metamorphic) dating the close of the Laurentian Orogeny (2670 Ma, Stockwell, 1982) or 500-600 Ma younger than ages of formation dating from the Wanipigowan Orogeny (2900 Ma, Stockwell, 1982). One example, from the present study, of this generalization is demonstrated by a geologically coeval suite of metaplutonic, polydeformed, tonalites and gneisses on Lake Winnipeg and Wanipigow River. This suite yielded U-Pb zircon ages in the range 2900-3000 ± 10 Ma; a Rb-Sr whole-rock age of 2674 ± 136 Ma (possibly mildly rejuvenated during post Laurentian shearing); and a K-Ar biotite age of 2430 ± 52 Ma. The Rb-Sr age may be considered as a Wanipigowan age that was updated 200-300 Ma later to reflect reworking during the Laurentian Orogeny and hence is a formational-metamorphic age. The K-Ar age could represent an epi-orogenic cooling age dating from the closing of the Kenoran Orogeny (2510 Ma, Stockwell, 1982), however, neither geological evidence nor definitive formational ages for this orogeny have been established in Manitoba or elsewhere in Superior Province (K.D. Card, personal communication, 1982). Consequently, K-Ar biotite ages (and some hornblende ages) that are 200-300 Ma younger than the Laurentian are termed plutonic or tectonic cooling ages in this report, and probably include ages considered by Stockwell as dating the Kenoran Orogeny or to have resulted from epi-orogenic cooling. The term 'plutonic' includes metamorphism and igneous intrusion, as a convenience in this report. The concept of plutonic cooling ages is a useful one for the massive, unmetamorphosed, Laurentian granites (and the rocks they intrude) because they may indicate the time when slow unroofing or stress closure occurred in the crust of Superior Province following the Laurentian Orogeny. Plutonic cooling ages may also reflect regional updating during one or several episodes of rejuvenation following the Laurentian Orogeny.

Acknowledgments

The authors are indebted for constructive reviews obtained for an early version of this paper from J. Clark, K.D. Card, M.J. Frarey, J.B. Henderson, and W. Weber. J.C. Roddick reviewed a more recent form of the manuscript and provided some important conclusions that were incorporated in this paper. Several versions of the manuscript were reviewed by A. Davidson, whose help and continuous encouragement is gratefully acknowledged. A summary of this paper was presented at the 1980 Spring Meeting of the American Geophysical Union in Toronto. Responsibility for interpretation of the data and for any errors that may exist rests with the authors.

METHOD

Isotopic data, type of material analyzed, type of analysis, sample locality, source of information, and brief descriptive notes are presented in Table 1* for each age determination. The data were obtained mostly from published but also from unpublished works. The compilation includes 15 U-Pb zircon ages, 26 Rb-Sr ages, and 89 K-Ar mineral (primarily biotite and hornblende) ages. Seven U-Pb zircon ages and one Rb-Sr whole-rock age derived from terrane immediately east of the Manitoba-Ontario border are not listed in Table 1, but are identified throughout this work. All age determination calculations are based on the 25th IGC constants (Steiger and Jager, 1977).

Numbers for identification purposes were assigned to each sample locality and plotted on a metamorphic-lithologic map of Manitoba (Fig. 1). These numbers coincide with those appearing in figures and tables throughout this work. Data appearing on bar diagrams (Fig. 2, 3, 4) were plotted with decreasing relative latitude with respect to one another.

The map, Figure 1, was compiled from Weber and Scoates (1978), Ermanovics and Froese (1978) and from an early (May, 1979) manuscript version of the Geological Map of Manitoba (1980) provided by Manitoba Mineral Resources Division. Supracrustal rocks in Figure 1 appear in four metamorphic grade divisions: greenschist facies, lower amphibolite facies, upper amphibolite facies, and in Pikwitonei Subprovince amphibolite to granulite facies. In Sachigo Subprovince the designation of lower amphibolite facies includes upper greenschist and undivided amphibolite facies.

Three families of samples were considered and coded accordingly (Table 1, Fig. 2, 3, 4). These are plutonic, metasupracrustal (metasedimentary, metavolcanic, and amphibolite), and metaplutonic. Plutonic refers to massive, postkinematic granitoids exhibiting primary igneous textures. Metaplutonic includes metagranitoids, orthogneiss and gneissic migmatite whose composition varies from granitic to tonalitic. Leucosome in metaplutonic rocks may have developed during the emplacement of postkinematic intrusions.

RESULTS

K-Ar Age Determinations

K-Ar ages range from 1750 to 2700 Ma (Fig. 2). Two hornblende ages that average 3180 Ma represent an isolated and possibly aberrant age (29)[1]. Hornblende ages are older than biotite ages in hornblende-biotite pairs (Table 2, Fig. 2) and the differences in millions of years are as follows: Uchi 178; Berens 66, 119; Sachigo 14, 209, 298, 515, 604; retrogressed Pikwitonei 690. The exception to this rule occurs in granulite facies Pikwitonei where biotite ages are 300 Ma older than hornblende ages (Fig. 2). Both hornblende and biotite ages of plutonic rocks tend to be older than those obtained from their metasupracrustal country rocks. Metamorphosed plutonic rocks may be younger or older than either contiguous supracrustal or plutonic rocks. In spite of relative age differences no absolute age separations seem possible because of analytical age uncertainties.

Northern Berens and southern Sachigo subprovinces tend to yield older hornblende ages than southern Berens or Uchi (read hornblende ages of Figure 2 from analysis 88 downwards). North of locality 88 hornblende ages are much younger and are characterized by large age uncertainties (12, 18, 21, 77, 9).

Biotite ages of plutonic and metaplutonic rocks of central Berens (analyses 34 down to 40, Fig. 2) form a cluster in the range 2430-2500 Ma. This range becomes larger and younger southward. Age uncertainties of individual K-Ar age determinations are large and tend to overlap. Consequently these age trends may not be valid statistically.

To the north biotite ages become increasingly and drastically younger, and yield ages ranging from 1600 to 2200 Ma near the orthopyroxene isograd of Pikwitonei Subprovince. In Pikwitonei Subprovince this younging trend is broken; three biotite ages are older than nearby hornblendes and in the range 2600-2700 Ma and one, close to retrograde Pikwitonei, yields 2388 Ma (4). K Ar biotite and hornblende ages of all rock types in retrograde Pikwitonei Subprovince cluster in the range 1700-1800 Ma with a median value of 1750 Ma.

Rb-Sr Isochron Age Determinations

Whole-rock isochron ages range from 2424 to 2950 Ma (Fig. 3, Table 3). Ages from analyses 8a, 71, and the two older determinations of analysis 8b are errorchron calculations. Analysis 8b at 2803 ± 133 Ma, however, is an isochron age. Analysis 57 from Uchi is a whole-rock – mineral isochron age.

*See pages 17 to 22 for Table 1.

[1]Numbers in parentheses refer to identification numbers in all tables and figures.

Table 2. Paired age determinations (Ma)

Table 1 no.	K-Ar Biotite	K-Ar Hornblende	U-Pb zircon concordia intercept	Rb-Sr whole-rock isochron
6	1730	2420		
16	2113 ± 49		2712 ± 5	
26	2061 ± 48	2665 ± 63		
28	2153 ± 48	2668 ± 64	2703 ($^{207}Pb/^{206}Pb$)	
29		3170 ± 68	2895 ± 25	
		3188 ± 68		
30	2398 ± 52	2584 ± 63		
	2375 ± 51			
31	2466 ± 53	2480 ± 61	2804 ± 14	
34	2456 ± 53	2585 ± 63		
40	2504 ± 68	2570 ± 62		
47	2364 ± 66	2542 ± 62		
49	2430 ± 52			2674 ± 136
77	2592 ± 70	2355 ± 72		
		2300 ± 72		
86-87	1645			2455 ± 35
92	2010 ± 46		2757 ± 7	
93	2222 ± 91		2765 ± 18	
97	2375 ± 53	2673 ± 64		
101	2493 ± 72			2649 ± 130 2677 ± 160

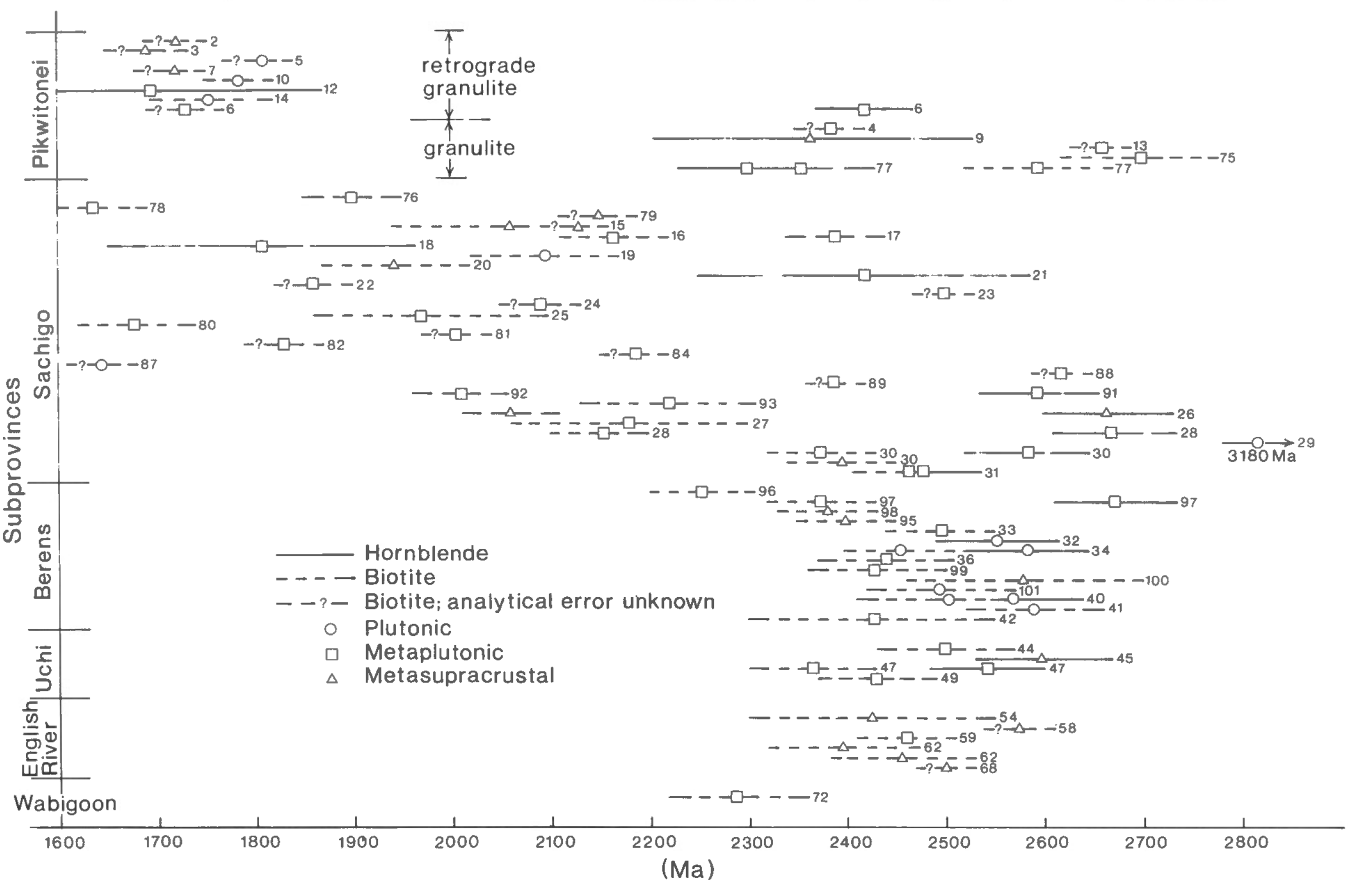

__Figure 2.__ K-Ar mineral ages. Analyses are arranged from north (top of diagram) to south with relative decreasing latitude with respect to the southern orthopyroxene isograd of Pikwitonei Subprovince, and the Churchill-Superior boundary zone.

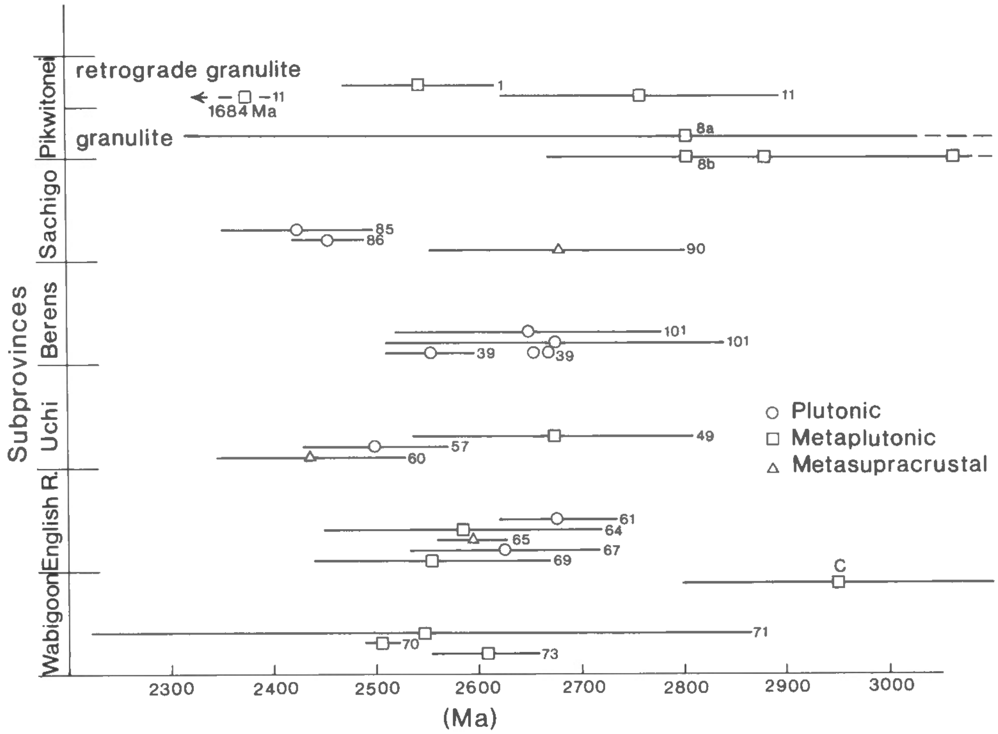

Figure 3. Rb-Sr whole-rock isochron ages. Analyses are arranged as in Figure 2. Analysis 'C' is from Tannis Lake area, Ontario, 4 km west of West Hawk Lake (Clark et al., 1981). Analyses 8a and the two older ages of 8b are errorchron calculations. Analysis 57 is a whole-rock mineral isochron age.

It is evident from Figure 3 that isochron ages of all rocks become younger from granulite facies Pikwitonei southward. This trend is essentially uniform and ranges from ca. 2800 Ma in Pikwitonei to 2500 Ma in Wabigoon. Ages of two plutonic bodies (85, 86) in Sachigo and of a phyllite (60) in Uchi fall well to the young side of this trend at ca. 2440 Ma. The isochron age of 2950 Ma was obtained from metatonalite near the English River – Wabigoon boundary (analysis C) and falls in the older range of U-Pb zircon ages (Fig. 4).

Analyses 8a and 8b represent metaplutonic rocks from both sides of the orthopyroxene isograd at Cauchon Lake (Weber and Loveridge, 1981). They were intended to test the hypothesis that enderbites from Pikwitonei are the high grade equivalents of metatonalites from the Gods Lake volcano-plutonic terrane of Sachigo Subprovince. Rb-Sr systematics of both plutonic terranes are highly disturbed and resulted in errorchrons rather than ages. Enderbite (8a) yielded 2803 ± 492 Ma ($^{87}Sr/^{86}Sr$ 0.7037 ± 0.0015; MSWD, 38.6); metatonalite (8b) yielded 2879 ± 193 Ma ($^{87}Sr/^{86}Sr$ 0.7009 ± 0.0008; MSWD, 4.3). Several calculations were made with the data from the metatonalite by omitting certain samples (Weber and Loveridge, 1981, Table 1, p. 117); one of these calculations determined an isochron of 2803 ± 133 Ma ($^{87}Sr/^{86}Sr$, 0.7011 ± 0.0005; MSWD, 1.7).

Initial $^{87}Sr/^{86}Sr$ ratios vary with tectono-thermal regimes (Table 3). Orthogneisses (49, 64, 73, 8b), post-kinematic granites (39, 61, 67, 101) and volcanics (65, 90) yield intercepts ranging from 0.6998 to 0.7024 with 80 per cent of values falling between 0.7001 to 0.7019. The two young post-kinematic plutons in Sachigo (85, 86) indicate higher intercepts of 0.7029 and 0.7078 respectively. All samples of the latter pluton (Magill Lake Pluton, 86) are highly radiogenic and two samples used in the regression yielded $^{87}Sr/^{86}Sr$ values of 18 (Clark and Cheung, 1980). In general, analyses of rocks that are associated with mixed compositions or granitic mobilizates (e.g. granite gneisses, layered migmatites, coarse grained porphyritic granitoid, 1, 11, 69, 70) tend to yield raised $^{87}Sr/^{86}Sr$ intercepts in the range 0.7038 to 0.715.

U-Pb Zircon Age Determinations

Comprehensive U-Pb data for infracrustal rocks in Manitoba are available only for Uchi and Sachigo sub provinces and these are insufficient to ascertain regional trends. Data from Favourable Lake (Sachigo Subprovince, T. Krogh, in Clark et al., 1981), from North Spirit Lake (Sachigo-Berens subprovinces, Nunes and Wood, 1980) and from Lac Seul area (English River Subprovince, Krogh et al., 1976) east of the Manitoba-Ontario border are included here (analyses A, N_1 to N_3 and K_1 to K_3, Fig. 4).

The U-Pb zircon data of Figure 4 fall into two groups. The older grouping comprises metatonalites and supracrustal rocks in the range 2895-3040 Ma (29, 46, 48, 53, A, and K_1, Fig. 4, Table 4). The younger grouping comprises mainly late granite and granodiorite in the range 2660-2770 Ma (16, 28, 43, 50, 51, 52, 55, 83, 92, 93, K_2, K_3, N_1, Fig. 4). Both include metasupracrustal rocks (29, 83, 55, N_2 and N_3, Fig. 4). Within the younger group of ages two subgroups are possible. In Sachigo Subprovince the range of 5 age determinations is 2700-2765 Ma and in Uchi-English River the range is 2660-2737 Ma.

It may be that the age spread given by the older group of rocks may not reflect a true range of formational ages; that some of these ages represent updating is a distinct possibility. Analysis 29 is from an altered amphibolite in Sachigo Subprovince. Analyses 46, 48 and 53 are from rocks that were deformed during late faulting along the shore of Lake Winnipeg in Uchi Subprovince. Analysis K_1, representing the oldest U-Pb zircon age, is from a compositionally uniform tonalite gneiss thought to have been emplaced prior to 3040 Ma ago (Krogh et al., 1976). Analysis 31 (2804 Ma) is from a compositionally mixed gneiss (early tonalite and later granitoid) and falls between the two groups of Figure 4. This sample exhibits highly discordant U-Pb systematics (Fig. 5, Table 4) and therefore may represent a mixed age.

Table 3. Rb-Sr whole-rock isochron ages arranged in order of increasing values of initial $^{87}Sr/^{86}Sr$ ratios

Table 1 no.	Age (Ma)	$^{87}Sr/^{86}Sr$	Remarks
67	2623 ± 91	0.6998 ± 0.0032	Post kinematic granite; English River
73	2608 ± 50	0.7001 ± 0.0014	Hybrid tonalite gneiss; Wabigoon
49	2674 ± 136	0.7010 ± 0.0006	Tonalitic ortho-gneiss; Uchi
8b	2803 ± 133	0.7011 ± 0.0005	Metatonalite, northern Sachigo
90	2680 ± 125	0.7014 ± 0.0009	Rhyolite and basalt; Sachigo
101	2649 ± 130	0.7014 ± 0.0016	Post kinematic granite; Berens
64	2584 ± 135	0.7014 ± 0.0021	Tonalitic ortho-gneiss; English River
65	2594 ± 35	0.7015 ± 0.0015	Metavolcanic; English River
61	2677 ± 55	0.7019 ± 0.0008	Post kinematic granite; English River
60	2437 ± 90	0.7022 ± 0.0009	Phyllite; Uchi
39	2557 ± 44	0.7024 ± 0.0010	Post kinematic granite; Berens
C	2950 ± 150	0.7025 ± 0.0014	Metatonalite; near English River – Wabigoon boundary
85	2424 ± 74	0.7029 ± 0.0001	Pre-Oxford Lake Group; Sachigo
11	2760 ± 135	0.7038 ± 0.0017	Migmatite; retro-grade Pikwitonei
69	2555 ± 113	0.7071 ± 0.0038	Late granitoid, English River
86	2455 ± 35	0.7078 ± 0.0043	Post-Oxford Lake Group; Sachigo
70	2504 ± 12	0.7087 ± 0.0015	Migmatite; Wabigoon
1	2545 ± 75	0.715 ± 0.002	Granitoid; retro-grade Pikwitonei

The younger group of metaplutonic rocks represent late-kinematic, homogeneous granites and granodiorites. Zircons from most of these rocks show significant lead loss and hence discordant ages. In this regard, metatonalites of the older grouping show less discordant U-Pb systematics. In all analyses the sequence $^{207}Pb/^{206}Pb$ $^{207}Pb/^{235}U$ $^{206}Pb/^{238}U$ indicates decreasing ages (Table 4).

A time of volcanic activity within the younger grouping is indicated from dacitic and rhyodacitic rocks at 2700 Ma (83, Hayes River Group in Sachigo Subprovince) and at 2732 ± 10 Ma in Uchi Subprovince (52). In each case the data are very discordant (and in the case of analysis 83, preliminary) and the felsic rocks represent only the upper members of their respective volcanic successions. Consequently, the age of some of the lower mafic members may yet be considerably older as determined elsewhere in western Superior Province (e.g. ca. 3000 Ma Nunes and Thurston, 1980; Nunes and Wood, 1980).

Analysis 55 (2690 Ma) is from a sample of meta-somatized paragneiss and the fresh, clear, small, euhedral zircons from this sample may reflect a time of metamorphism in Uchi. A similar zircon age of 2681 Ma (analysis K_2, Fig. 4) was obtained from a sample of pegmatite leucosome at Lac Seul in English River Subprovince and was also interpreted as a metamorphic age (Krogh et al., 1976).

INTERPRETATION

Wabigoon Subprovince

The Rb-Sr whole-rock age of 2950 ± 150 Ma (initial $^{87}Sr/^{86}Sr = 0.7028 \pm 0.0014$) from rocks north of Shoal Lake (Fig. 1 analysis C) was interpreted as having been updated during amphibolite facies metamorphism (Clark et al., 1981). "The somewhat high initial $^{87}Sr/^{86}Sr$ ratio of 0.7028 (Table 1) supports such resetting and could have been generated in about 150 Ma from an igneous body with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7008 and an average $^{87}Rb/^{86}Sr$ ratio of 1.0 comparable to that in the basement unit (Table 3)" (Clark et al., 1981, p. 99). On the basis of this argument the metatonalite may have a formational age of 3100 Ma.

Farquharson and Clark (1971) postulated that a major intrusive episode took place around 2600 Ma ago on the basis of analyses 73 and 69 (Fig. 3). In the present classification, analysis 69, a late granitoid phase within granodioritic gneisses, lies in English River Subprovince. They postulated yet a later period of intrusion 250 Ma ago (70, Fig. 3). Young ages derived from pegmatites (e.g. 71, Fig. 3) are interpreted by them as the result of open isotopic systems effected during intrusion of the Caddy Lake anatectic granite 2500 Ma ago (70). They point to the extreme enrichment of radiogenic ^{87}Sr as the cause of updating. More work is required to establish these younger plutons as representing major periods of intrusion. Farquharson and Clark (1971, p. 116) recognized the possibility that age determinations from their study area may be updated when they state, "...we suspect that later metamorphism may likewise have been responsible for slight open-system behaviour in the other units dated in this study". These include analyses 67, 70, 71 and 73.

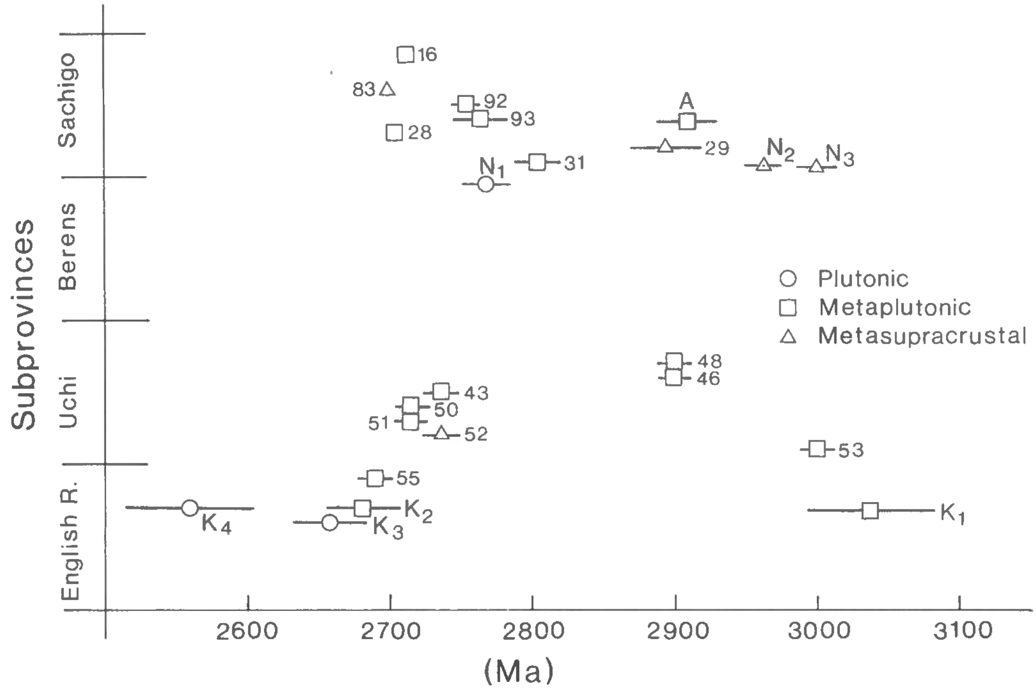

Figure 4. U-Pb zircon concordia intercept ages. Analyses are arranged as in Figure 2. Analysis A is from Favourable Lake, Ontario (Krogh and Davis, 1971; Hillary and Ayres, 1980). K-analyses are from Lac Seul area, Ontario (Krogh et al., 1976): K_1 = 3040 ± 40 Ma tonalite orthogneiss; K_2 = 2681 ± 20 Ma pegmatitic leucosome in paragneiss (age of metamorphism); K_3 = 2660 ± 20 Ma late or postorogenic granite; K_4 = 2560 ± 40 Ma late stage granitic pegmatite.

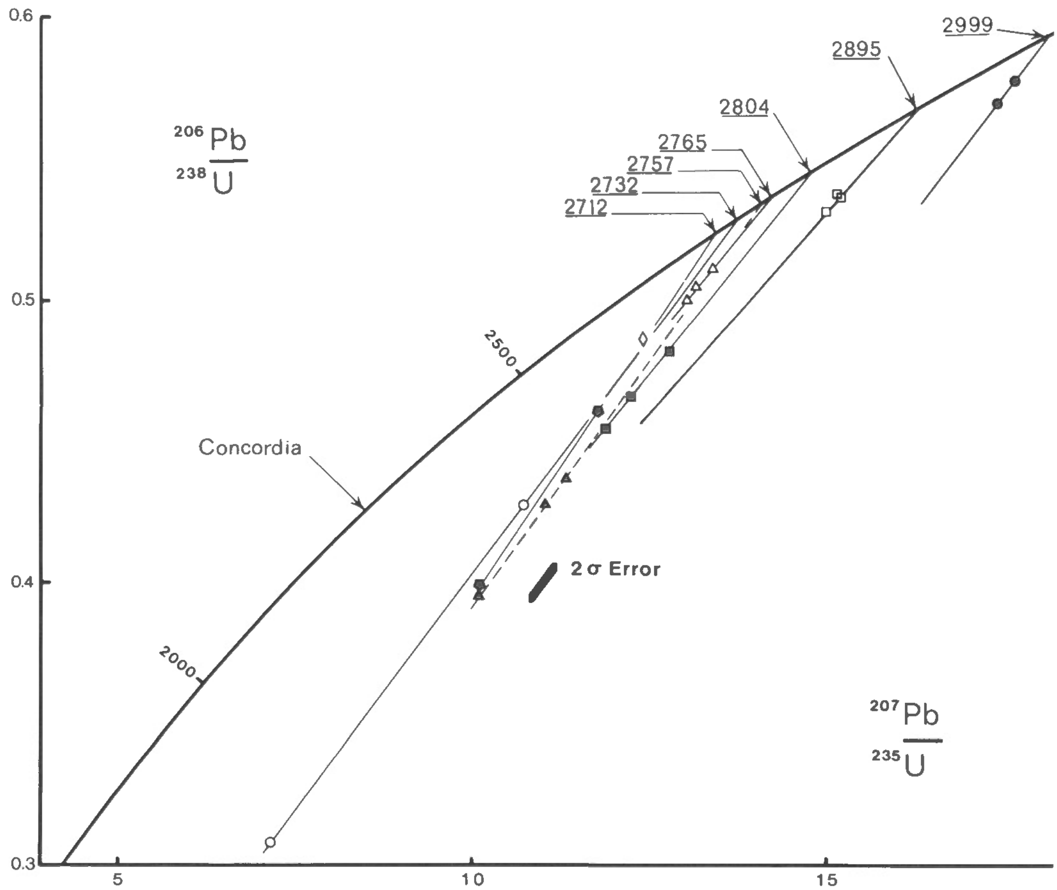

Figure 5. U-Pb zircon concordia intercepts. Date and symbols as in Table 4, (⬟ = 16, ○ = 52, ▲ = 92, △ = 93, ■ = 31, □ = 29); closed circles represent analysis 53 (Table 1) obtained from Krogh et al. (1974, and personal communication, 1979); ◇ = analysis 28 and is a $^{207}Pb/^{206}Pb$ age of 2703 Ma.

Table 4. Zircon Data[1]

Sample no.	Size (µm)	U (ppm)	*Pb (ppm)	$^{206}Pb/^{204}Pb$ (measured)	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	Concordia intercept age (Ma)	K-Ar ages (Ma)	Figure 5 symbols	Table 1 no.
EE-75-072	-105-+74 NM	469.7	251.1	11332	2440	2583	2703	2712 ± 5	m 1961 ± 46	⬢	16
	-105-+74 M	559.6	260.7	7420	2163	2445	2692		b 2113 ± 49		
EE-74-BLI-4A	-64-+44	162.4	57.77	4731	1720	2130	2553	2732 ± 10		○	52
	-44	114.0	58.7	4601	2290	2500	2676				
EE-74-364	-149-+130	433.5	226.7	3971	2335	2550	2725	2757 ± 7	b 2010 ± 46	▲	92
	-64-+44 NM	478.5	245.5	5882	2293	2525	2720				
	-64-+44 M	570.2	269.5	6601	2143	2444	2706				
EE-74-372	-149-+130 NM	221.5	133.4	11594	2660	2710	2746	2765 ± 18	b 2222 ± 91	△	93
	-74-+64	321.9	191.6	6598	2630	2691	2737				
	-44	433.0	259.4	9609	2610	2682	2737				
EE-74-273	-149-+130 NM	933.1	460.5	7407	2465	2620	2747	2804 ± 14	h 2480 ± 61	■	31
	-130-+74	1023.1	496.5	7075	2413	2595	2742		b 2466 ± 53		
	-74-+64	997.0	513.1	8184	2533	2663	2763				
EE-74-001	+105 NM	254.9	158.7	4663	2769	2830	2873	2895 ± 25	h 3170 ± 68	□	29
	+105 M	250.8	157.4	9351	2750	2816	2864		h 3188 ± 68		
	-62-+44	222.5	154.6	356	2778	2827	2862				
EE-72-A1	-74	395.3	226.6		2550	2636	2703		h 2668 ± 64	◆	28
									b 2153 ± 48		

[1] Data this work only * = radiogenic b = biotite m = muscovite h = hornblende NM = non magnetic M = magnetic

One K-Ar biotite age (72, Fig. 2) indicates that the blocking temperature of Ar was attained 2300 Ma ago. The young age, although tenuous evidence, is nevertheless thought to be in keeping with the relatively young Rb-Sr results because similar proportional differences between Rb-Sr and K-Ar ages are seen in paired analyses elsewhere in this study (Table 2, e.g. 49, 101).

A difference of 650 Ma exists between the oldest and youngest age. The time that elapsed from a period of plutonism 2500-2600 Ma ago to the youngest recorded age is 200-300 Ma.

English River Subprovince

U-Pb zircon ages (Fig. 4) show evidence of plutonic activity at 3040 Ma and granitic intrusion 2660-2681 Ma ago. The older age was derived from zircons showing more than one stage of growth and hence this tonalite gneiss may have been derived from a rock older than 3040 Ma (Krogh et al., 1976).

Rb-Sr ages of plutonic and metaplutonic rocks range from 2550 to 2680 Ma (Fig. 3). Although these ages cannot be distinguished from one another because all error limits overlap, this range is nevertheless older by 50 Ma and longer by 30 Ma than that of Wabigoon. If the zircon ages from Lac Seul (Krogh et al., 1976) also apply to English River Subprovince in Manitoba then the Rb-Sr ages may have been updated from an original age of ca. 2700 Ma (analysis K_2, Fig. 4) if a common time for their emplacement is assumed. Analysis 69 (2550 Ma) was interpreted as a possible updated age (Farquharson and Clark, 1971). The zircon age of analysis 55 (Fig. 4) was interpreted as a metamorphic age at 2690 Ma (Krogh et al., 1974). The plutons are metamorphosed and hence it is likely that their Rb-Sr whole-rock ages may be slightly updated.

Argon in most biotites passed through blocking temperatures 2400 to 2500 Ma ago (Fig. 2). This seemingly extends the isotopic record from 3040 to 2400 Ma (about 640 Ma, as in Wabigoon Subprovince). The interval from the earliest plutonic activity to a period of major intrusion and volcanic activity at 2700 Ma is 300-350 Ma. The interval from this igneous episode to the end of the range of K-Ar ages is again about 300 Ma.

Supracrustal rocks appear to show a greater degree of open system behaviour than plutonic and metaplutonic rocks. An amphibolite schist from Bird River volcanics (65) yielded a Rb-Sr whole-rock age of 2594 Ma and was interpreted as updated (minimum depositional age, Turek and Peterman, 1971).

Uchi Subprovince

U-Pb zircon ages show that an early period of plutonic activity occurrred 2900 to 3000 Ma ago and that a later period of volcanism and granitic intrusion occurred 2715 to 2735 Ma ago (Fig. 4). Analysis 53 (2999 Ma) is from a highly deformed, porphyroclastic orthogneiss. Zircons from this rock contained cloudy cores and hence the age may be a mixed (updated) one. A K-Ar biotite determination from this rock yielded an age of 2430 Ma (49, Fig. 2). Analyses 48 and 46 (2900 Ma) are from a leucocratic gneiss of uncertain origin and although the age of 2900 Ma was interpreted as a metamorphic age (Krogh et al., 1974), this requires verification.

Rb-Sr whole-rock ages are considerably younger. An age of 2674 Ma (analysis 49, Fig. 3) was obtained from a sample that yielded the 2900 Ma zircon age. "The $^{87}Sr/^{86}Sr$ initial (..of analysis 49..) is compatible with direct derivation of these rocks from the mantle but, in light of their low Rb/Sr ratios, does not preclude a period of crustal residence in the order of a few hundred million years"

(Ermanovics, 1980, p. 213). The 2500 Ma age (57, Fig. 3) of the Ross River pluton (a whole-rock – mineral isochron age) and the 2437 Ma age of a phyllite were interpreted to be updated and metamorphic ages, respectively (Turek and Peterman, 1968, 1971). Since a young time of metamorphism has not been established it may be best to view both ages as rejuvenated ages in response to unspecified causes.

Two K-Ar hornblende ages are 2597 and 2542 Ma and biotite ages range from 2502 to 2364 Ma (Fig. 2). Total time from the first recorded plutonic activity (53, Fig. 4) to final Ar retention in biotite was thus ca. 635 Ma (2999-2364 Ma); this range in time is practically identical to that recorded for Wabigoon and English River. The time of earliest plutonic activity (53) to the time of Laurentian igneous activity (43, 50, 51, 52, Fig. 4) is about 260 to 290 Ma. Blocking temperatures of argon in biotites of both episodes were attained 200 to 350 Ma later following the Laurentian culmination ca. 2700 Ma ago.

Berens Subprovince

This subprovince consists almost entirely of plutonic rocks; they are characterized by a small range of isotopic ages. Rb-Sr whole-rock ages based on four analyses of two plutons (39, 101) cluster in the range 2649-2677 Ma. A fifth analysis from the Horseshoe Lake granite (39) gave an age of 2557 Ma. This age is considered to be updated in light of two Rb-Sr calculations of the border phase of the body (2655 and 2670 Ma, Ermanovics and Loveridge, 1980) and an unpublished discordant U-Pb zircon age of 2715 Ma (T.E. Krogh, personal communication, 1973, analysis 72-52; discussed in Krogh et al., 1975, p. 623). Although this U-Pb zircon age requires corroboration, it suggests that Rb-Sr whole-rock isochron ages of late kinematic granitoids elsewhere in the subprovince may be updated by 35 to 65 Ma or even by 150 Ma, judging from analysis (39). This granite (39) intrudes volcanic rocks at Horseshoe Lake and hence the zircon provides a minimum age of 2715 Ma for the amphibolite facies supracrustal rocks at Horseshoe Lake. A quartz diorite (analysis N_1, Fig. 4) of the MacDowell Lake pluton that intrudes the supracrustal rocks of North Spirit Lake, yielded a U-Pb zircon age of 2768 Ma (Nunes and Wood, 1980) and thus confirms the age of plutonism in Berens.

K-Ar ages within 10 km south of the Sachigo-Berens boundary (96, 97, 98, 95) define a younger range of ages than those in the main part of the Berens Subprovince. Typical for the subprovince are hornblende ages (32, 34, 40, Fig. 2) in the range 2553-2585 Ma. Biotite ages (33, 34, 36, 99, 101, 40, 41, 42, 101) are in the range 2431-2592 Ma with a median value of close to 2500 Ma. In the northern margin of the subprovince biotite ages range from 2253 to 2400 Ma.

Paired analyses of biotite and hornblende from the same rock (34, 40) show biotite to be about 70 to 130 Ma younger than hornblende in central Berens. A similar analysis (97) from rocks in the northern part of Berens indicates that biotite is nearly 300 Ma younger than the hornblende age. The younger ages herald the beginning of progressive and pronounced isotopic rejuvenation northward across the Sachigo Subprovince (see below).

Thus in the main body of Berens Subprovince hornblendes in plutonic and metaplutonic rocks passed through argon blocking temperatures ca. 2553 to 2585 Ma ago (32, 34, 40) and biotites ca. 2431 to 2592 Ma ago (33, 34, 36, 40, 41, 99, 101). Considering the U-Pb zircon age 2715 Ma as a reference age for the time of crystallization of late kinematic Berens batholiths, the length of plutonic cooling based on biotite is ca. 120 to 280 Ma or ca. 180 to 340 Ma if the U-Pb zircon age of 2768 Ma from the MacDowell Lake pluton is used as a reference age.

Sachigo Subprovince

Meagre evidence suggests at least two Archean volcano-plutonic episodes and seemingly protracted plutonism. An early episode is suggested by four U-Pb zircon ages in the range 2900-3013 Ma (Fig. 4). These include amphibolite (29, 2895 Ma), metatonalite (A, 2910 Ma, Favourable Lake, Ontario), tuff-breccia (N_3, 3013 Ma, North Spirit Lake, Ontario) and a granitoid clast from conglomerate (N_2, 2975 Ma, North Spirit Lake).

A second episode is supported by U-Pb zircon ages of granodiorites that lie unconformably beneath Island Lake series (92, 93, ca. 2760 Ma) and beneath Cross Lake Group (16, ca. 2710 Ma) and by a tonalite that intrudes Island Lake Group (28, 2703 Ma). Yet a third period of post-kinematic tectonic activity is suggested by isochron ages 2424 Ma and 2455 Ma (85, 86, Fig. 3; Clark and Cheung, 1980), provided that these may be considered to be primary ages.

Some of the evidence suggests volcanic activity in Sachigo Subprovince in the range 2700-2770 Ma. Supracrustal rocks in Sachigo have been divided traditionally into a lower, dominantly volcanic succession (Hayes River Group) and an unconformably overlying succession of dominantly sedimentary rocks (Oxford Lake Group and Island Lake series). However, there are areas where the distinction cannot be made (e.g. at Cross Lake, Fig. 1; Hubregtse, 1980) and consequently supracrustal deposits cannot be readily assigned to one group of rocks or the other (cf. U-Pb zircon ages of granitoids intruding supracrustal rocks; 16, 28, 83, 92, 93, Table 1).

The possibility that supracrustal rocks of pre-2765-Ma age exist is demonstrated at Cauchon Lake (Fig. 1). Here, a 2803 ± 133 Ma old metatonalite (8b, Fig. 3, Rb-Sr whole-rock isochron) suggests at best a minimum age for the amphibolite facies metavolcanic rocks it intrudes since the age determined for the metatonalite itself may be a metamorphic age that was subsequently updated. The Rb-Sr whole-rock system for this metatonalite is highly disturbed (Weber and Loveridge, 1981). The volcanic succession at Cauchon Lake may therefore be much older than the volcanics transgressed by the orthopyroxene isograd at Cross Lake where a maximum age for the succession is 2712 Ma (16). Hillary and Ayres (1980) infer pre-2910 Ma old volcanics from amphibolite inclusions in the old tonalite at Favourable Lake in Sachigo Subprovince just east of the Ontario-Manitoba border. Although sparse, the evidence from Cauchon Lake and amphibolite analysis 29 from Stevenson Lake in Sachigo (U-Pb zircon age ca. 2900 Ma) suggest that volcanism did occur prior to 2900 Ma.

Biotite K-Ar ages show progressive rejuvenation from northern Berens to the orthopyroxene isograd of Pikwitonei Subprovince. They vary from the median value of 2500 Ma in central Berens to 1600-1700 Ma in northern Sachigo (Fig. 2). Although analytical uncertainties of individual analyses overlap, hornblende K-Ar ages in southern Sachigo initially increase in age with respect to hornblende ages in Berens from a range of 2553-2585 Ma to a range of 2585-2673 Ma (26, 28, 30, 80, 91, 97). Where biotite ages are available from rocks of this older group of hornblende ages, they are in the range 2061-2375 Ma. Two K-Ar analyses (29, 31, Fig. 2) do not follow these groupings in southern Sachigo. Biotite and hornblende of analysis 31 (Fig. 2) are nearly identical with values of 2466 and 2480 Ma (U-Pb zircon age of 2804 Ma, Fig. 4). Analysis 29 of the amphibolite that yielded the anomalous hornblende ages of 3170 Ma and 3188 Ma (shown as 3180 Ma in Fig. 2) nevertheless has an old U-Pb zircon age of 2895 Ma (Fig. 4).

The younger K-Ar ages of biotites discussed so far for the southern subprovinces appear to show cooling times that are younger than times of plutonic crystallization by about 200-300 Ma. In Sachigo Subprovince, however, biotite ages become progressively younger northward, and far exceed this plutonic cooling interval of 200-300 Ma. Because this progressive updating of K-Ar ages is in the direction of the Churchill Province (Churchill orogen) these may be rejuvenated ages or epeirogenic ages resulting from tectonic activity related to the Hudsonian Orogeny of adjacent Churchill Province. Stockwell (1982, Fig. 7) has traced such younger K-Ar ages from the Nelson Front of the Churchill Province 180 km southward (Cross Lake Subprovince) into the Superior Province. The present work shows that this younging extends 350 km into Superior Province to northern Berens Subprovince.

A case may be made for an episode of K-Ar updating or epeirogeny in Sachigo in addition to the hypothesis of thermal events related to Hudsonian Orogeny in Churchill Province. The evidence and an estimate of the time of this activity in Sachigo Subprovince is afforded by the Molson dykes which are reported to be metamorphosed in northern Sachigo (Hubregtse, 1978). K-Ar ages in southern Sachigo, where dykes are not metamorphosed, suggest an age of magnetization in the range 1800-2000 Ma (Ermanovics and Fahrig, 1975). Another line of evidence to the time of updating may be the K-Ar ages themselves. Of the twenty-two K-Ar ages younger than 2350 Ma in Sachigo nearly 70 per cent of the analyses fall in the range 1900-2200 Ma.

The effects of possible rejuvenation on U-Pb zircon or Rb-Sr whole-rock ages in Sachigo are difficult to evaluate. For plutonic rocks only two Rb-Sr whole-rock ages are available and these seem inordinately young when compared to U-Pb zircon ages of other plutons in the subprovince. These younger plutons are the Bayly Lake Pluton (85, 2424 ± 74 Ma) and the Magill Lake Pluton (86, 2455 ± 35 Ma). The latter is a foliated granite and has a K-Ar biotite age of 1645 Ma. Clark and Cheung (1980) interpret the Rb-Sr ages as primary ages on the basis of the collinear nature of their data.

Pikwitonei Subprovince

This subprovince contains a southern granulite facies and a northern amphibolite facies that was retrograded from granulite grade. The northern terrane (retrograde Pikwitonei) is the Churchill-Superior boundary zone (Wabowden subprovince of Bell, 1971). The zone is bounded by the Thompson belt in the northwest.

Neither the age of the plutonic rocks nor the age of granulite metamorphism is established in Pikwitonei. The errorchron calculation for enderbite (8a, Fig. 3) north of Cauchon Lake yielded 2803 ± 492 Ma. Weber and Loveridge (1981) suggested that the cause of the isotopic disturbance may have been the granulite metamorphism, and that the enderbite was updated from rocks whose pre-existing age was 2900-3000 Ma. An alternative explanation is that 2900-3000 Ma represents an age of granulite facies metamorphism and that updating was caused during plutonic activity in Sachigo 2700-2765 Ma ago or during possibly two thermal disturbances in Proterozoic time that clearly rejuvenated rocks in adjacent terranes. Analysis 8b (2803 ± 133 Ma and errorchrons of 2879 ± 193 Ma and 3066 ± 317 Ma) of metatonalite just south of the orthopyroxene isograde at Cauchon Lake also shows highly erratic Rb-Sr whole-rock systematics and may have been subjected to the same thermal disturbances as the enderbite. Whether or not the ages reflect emplacement, metamorphism, rejuvenated emplacement ages, or even rejuvenated metamorphic ages is not amenable to analysis given the present data. Hubregste (1978, 1980) has described a complex series of events locally in Pikwitonei that include two metamorphisms in Archean time ranging from amphibolite to granulite grade and one in Proterozoic time locally attaining amphibolite grade.

K-Ar hornblende ages in Pikwitonei are younger than K-Ar biotite ages, the reverse of what is normally found. In addition, the biotite ages are the oldest of any in Manitoba (ca. 2700 Ma). A paired analysis (77, Fig. 2) indicates a biotite age of about 2600 Ma and two hornblende ages of 2300 and 2355 Ma. Hornblende ages younger than biotite ages may reflect low K-content in hornblendes or excess argon in biotite and their apparent resistance to rejuvenation, a function of sluggish diffusion rates in originally anhydrous, granulite facies rocks (Chopin and Maluski, 1980; Pankhurst et al., 1973).

If 2900 to 3000 Ma (8a and 8b) is viewed as the approximate time of high grade metamorphism or plutonism in granulite Pikwitonei Subprovince and if the hornblende ages (6, 9, 77, Fig. 2) in the range 2300 to 2400 Ma are resolved as plutonic cooling rather than as rejuvenated ages, the time to attain argon blocking temperatures in hornblende was 500 to 600 Ma. This time interval is in keeping with that observed for the southern subprovinces using biotite and suggests that Pikwitonei granulites have experienced deep if not prolonged burial, at least as long as rocks in other subprovinces.

The retrograde granulite terrane yields Rb-Sr whole-rock ages of 2760 Ma, 2445 Ma, 1684 Ma and a median K-Ar age of 1750 Ma. The Rb-Sr ages are proof of Archean rocks in the Superior-Churchill boundary zone. Rationalization of Archean ages from the boundary zone seems futile in the light of the fact that tectonic activity (real or apparent) in the adjacent Thompson lineament may have occurred at times throughout a span of nearly 550 Ma from ca. 2050 to 1500 Ma (Brooks and Theyer, 1981). It is likely that all ages of Archean rocks in this terrane were rejuvenated in early Proterozoic time.*

K-Ar data define the retrograde granulite terrane (Churchill-Superior boundary zone) by a relatively neat cluster of ages in the range 1700-1800 Ma (Fig. 2). Hence the K-Ar ages may be viewed as the time that retrograde Pikwitonei stabilized to conditions corresponding to argon blocking temperatures following 'Hudsonian Orogeny'(?). If, as in the southern subprovinces, 200-300 Ma is a reasonably period for plutonic cooling, then it seems possible to extrapolate to a major plutonic or tectonic culmination 2000-2100 Ma ago in northern Pikwitonei Subprovince that produced retrograde metamorphism in the granulites. However, possible protracted tectonic activity related to plate collision may have controlled the age pattern in this area.

DISCUSSION

Few ages of formation of supracrustal rocks are available in Manitoba. Minimum ages for volcanism may be inferred from contiguous granite-greenstone assemblages, but even here some metamorphosed intrusive rocks must represent minimum ages for igneous intrusion. Late volcanism in Uchi, Berens, Sachigo, and in English River subprovinces, probably occurred 2700-2730 Ma ago. U-Pb zircon age measurements obtained directly from volcanic rocks in western Ontario (Uchi and Sachigo subprovinces) indicate volcanic activity in the range 3013-2739 Ma (Uchi-Confederation Lakes, Nunes and Thurston, 1980; North Spirit Lake, Nunes and Wood, 1980). Evidence for early volcano-plutonic episodes (pre-2900 Ma) is inferred from ages of

* See also Cumming, O.L., Eckstrand, O.R., and Peredery, W.V., 1982: Geochronologic interpretation of Pb isotope ratios in nickel sulfides of the Thompson Belt, Manitoba: Canadian Journal of Earth Sciences, v. 19, p. 2306-2324. Pb isotope data have prompted these workers to postulate primary and secondary isotopic events at 2320 Ma, 2015 Ma, 1620 Ma, 1620 Ma and 1125 Ma ago.

metaplutonic rocks in all subprovinces except Berens. Rocks of earlier orogenies are also present in Berens (Ermanovics et al., 1979), but so far no attempt has been made to date them.

U-Pb zircon data suggest that ages of crystallization of late- to post-kinematic granitoids are about the same in Sachigo (16, 28, 92, 93), Berens (72-52, T.E. Krogh, personal communication, 1973; Nunes and Wood, 1980; N_1 in Fig. 4) and Uchi (43, 50, 51) defined by a narrow interval in the range 2705 to 2770 Ma. However, the data from Lac Seul in Ontario extend this range to 2660 Ma in English River Subprovince and permit a two-fold subdivision in the range. The older subdivision of five analyses in Sachigo yields 2700-2765 Ma; the younger subdivision of seven analyses in Uchi and English River yields 2660-2737 Ma (Fig. 4). These subdivisions may indicate older, late kinematic plutonism in the northwestern part of Superior Province. The morphology of the zircons was not studied even though it was known that K-Ar ages of Laurentian granites in greenschist facies were 500-600 Ma younger than U-Pb ages (e.g. analyses 92 and 93). Although the U-Pb zircon data are generally highly discordant (Fig. 5) they lie on chords to the origin and show no multistage events. Thus any rejuvenation of the U-Pb decay system is likely to have been minimal and if operative is most likely to have affected primary zircon ages from Sachigo rather than zircons from the southern subprovinces. Thus any absolute age difference of late kinematic Laurentian plutonism between northern and southern Superior Province may yet be slightly greater than the present data seem to suggest by virtue of possible mild rejuvenation of zircon ages in Sachigo.

Rb-Sr whole-rock isochron ages from similar late-kinematic rocks yield a best estimate of primary ages in the range 2623 to 2677 Ma (39, 61, 67, 101 'plutonic' rocks, Fig. 3) that is indistinguishable in Berens, Uchi and English River subprovinces. The nature of the plutonic activity that may have given rise to problematically young Rb-Sr whole-rock ages (ca. 2500 Ma or less) needs to be determined in Sachigo (85, 86, Clark and Cheung, 1980), in Berens (39, Ermanovics and Loveridge, 1980) and in Wabigon (70, 71, Farquharson and Clark, 1971).

An important result arising from the present study is the observation that 200-300 Ma separates two igneous episodes (Wanipigowan-Laurentian) in all subprovinces except Pikwitonei. In addition, another 200-300 Ma separates the last volcano-plutonic episode (Laurentian) from the time of K-Ar cooling in all subprovinces except Sachigo. This distinct interval may be real or apparent. It is possible that the ages reflect sampling biases in that field workers may have tended to collect tectonic end members. Such end members may include the oldest and youngest rocks, but not the mixed lithologies from an area.

Inspection of the Rb-Sr ages of plutonic and meta-plutonic rocks of Figure 3 shows a decrease in whole-rock ages from an age of 2800 Ma (probably a minimum) in Sachigo-Pikwitonei to 2500 Ma in Wabigoon. Although additional sampling is required to prove it, a similar trend, but in a younger range, is demonstrated by the K-Ar horn-blende ages (Fig. 2) extending from southern Sachigo south-ward to Uchi Subprovince (ca. 2670 to 2430 Ma). Similarly, K-Ar biotite ages appear to reflect the hornblende trend, but in yet a younger range which extends from central Berens to Wabigoon (ca. 2500 to 2300 Ma). If Protrozoic rejuvenation in Sachigo Subprovince had not occurrred, it is interesting to speculate that K-Ar ages would today still show an aging trend northward to Pikwitonei.

Plutonic Cooling Ages and Isotopic Rejuvenation

Biotites will record a K-Ar age when temperatures drop below closure conditions shortly following orogenic culmination (ca. 70 Ma, epi-orogenic cooling, Stockwell, 1982) or much later (200-300 Ma, this work) following plutonic culminations. The latter may be interpreted as plutonic cooling ages of postkinematic Laurentian granites and reworked Wanipigowan gneisses. These ages may have been produced during regional uplift and thus they imply prolonged crustal residence at temperatures above ca. 300° (e.g. see references in Mattinson, 1978, Fig. 8).

The crust in northwestern Superior Province may have intersected the blocking temperature isograd more than once in Archean time following the Laurentian Orogeny. However, even if repeated intersections had occurred, only the last one would be recorded as the K-Ar age. Thus, in some geological settings plutonic cooling ages could also be rejuvenated ages.

Whereas plutonic cooling ages may actually reflect the time that regional uplift (epeirogeny) occurred, updating that results from mild isotopic rejuvenation rarely indicates the time that rejuvenation occurred, either in the K-Ar system or in any other decay system (e.g. Field and Raheim, 1979a, b; Kalsbeek and Pidgeon, 1980). Blocking temperatures (MacIntyre et al., 1967) are not independent functions. Exponential loss of radiogenic daughters decelerating near the respective blocking temperature, hydrous or anhydrous rock conditions, solid solution in minerals, as well as uplift rates may all conspire to produce partial updating in isotopic systems (e.g. Foland, 1979; Chopin and Maluski, 1980). However, where large areas of crust yield similar K-Ar ages the cause of isotopic closure must have been similar. Closure conditions are probably dated by such ages. Where large areas of crust yield erratic or unidirectional trends of updated ages as in Sachigo the cause may be several diachronous events and therefore primary K-Ar ages are unlikely to be distinguished from partially reset or completely reset ages (e.g. Berger et al., 1979).

Whatever the tectonic style may have been to cause the younger K-Ar ages in Sachigo, temperatures that accompanied the tectonics or epeirogeny were in the range between argon blocking temperatures of biotite and hornblende. Resetting of hornblende and some biotite ages from 'Archean' values appears to have been spotty or incomplete judging from adjacent analyses (e.g. 18 to 24). Consequently, Sachigo Subprovince may have attained K-Ar closure conditions at the end of the Archean as did the southern subprovinces. Closure conditions in K-Ar systems in retrograde Pikwitonei appear to have been well uniformly attained at least to argon blocking temperatures in hornblende (12) and closure conditions in Rb-Sr whole-rock systems (11).

Rb-Sr isotope systematics that lead to apparent ages with respect to U-Pb ages may be understood but not readily quantified (e.g. Baadsgaard and van Breemen, 1970). Empirical evidence shows generally that rocks with isochron ages that are characterized by large analytical uncertainties also show high Rb/Sr ratios, high values of radiogenic Sr or raised $^{87}Sr/^{86}Sr$ initial ratios (Farquharson and Clark, 1971; Kalsbeek and Pidgeon, 1980; Clark and Cheung, 1980). Consequently, such rocks may have been subject to transfer of mass, leading to disturbed systems and ultimately to updated ages. The extent to which mass transfer has occurred, whether on the atomic, molecular, mineral or whole-rock scale, is a decision that must rest on petrological or regional field observations.

A concept based on plutonic cooling and postconsolidation closure conditions may be envisaged in Rb-Sr systems where evidence shows that similar rocks yield similar whole-rock isochron ages younger than U-Pb zircon ages for a large domain or subprovince. Kamineni and Dugal (in press) have demonstrated that alteration in granitic rocks generally occurs near fractures. Altered rocks were found to be depleted in Sr and Ca, and enriched in Mg and ferrous iron. 'Grey granites' of the Eye-Dashwa Lakes pluton of Ontario, considered by them to be unaltered, contain 800-1000 ppm Sr, whereas 'pink granites', shown to be altered, contain as little as 200-300 ppm Sr. The physical characteristics of this alteration, and hence inferred transfer of mass from the rock system leading to updated Rb-Sr ages are such as to probably remain undetected in the field during routine sampling of rocks for isotopic age determinations. Detailed analysis of rock alteration to a depth of 1000 m showed that 80 per cent of the near surface rock volume of the Eye-Dashwa Lakes pluton may have been subject to this type of mass transfer.

Pore waters obtained from one borehole of the Eye-Dashwa Lakes pluton yielded Sr values of up to 103 ppm at depths below 500 metres, as compared to 0.35 ppm obtained from near surface pore waters (Kamineni and Dugal, 1982; Frape and Fritz, 1982). Waters below 500 metres are considered to be ancient waters that occupy fractures formed during the first 100 to 200 million years of cooling of the pluton (Kamineni and Stone, personal communication, 1982). These data suggest a mechanism for whole-rock open system behaviour during the postconsolidation, deuteric stages of plutonic cooling. Sr, primarily in association with Ca or in solution, is flushed from the rock mass and may equilibrate with the altered wall rock and a large variety of fracture filling materials (Frape and Fritz, 1982; Kamineni and Dugal, in press). Loss of Sr daughters from the whole-rock Rb-Sr decay system by this mechanism can be envisaged to occur in the mesozone where plutonic rocks cool during regional stresses at relatively elevated temperatures. Similar losses of Sr are likely to occur in a hydrous epizone of the crust during metamorphism where fractures in granitoids are reactivated and where fracture-filling materials are rejuvenated.

CONCLUSIONS

Evolution of the continental Archean crust in Superior Province in Manitoba since ca. 3100 Ma ago was episodic and seemingly continuous. Two episodes of igneous activity are separated in time by 200-300 Ma in all subprovinces at ca. 2660-2770 Ma (Laurentian Orogeny, Stockwell, 1982) and ca. 2900-3050 Ma (Wanipigowan Orogeny, Stockwell, 1982). K-Ar biotite ages show that blocking temperatures of argon in biotites south of Sachigo Subprovince were attained yet 200-300 Ma later, following the Laurentian Orogeny.

Evidence for volcanic activity during the younger episode is obtained from sparse direct U-Pb measurements in zircons from felsic rocks that represent upper members in their respective supracrustal successions. Evidence for the older volcanic activity is mainly inferred from as yet undated supracrustal remnants occurring as inclusions in old orthogneisses.

The low initial $^{87}Sr/^{86}Sr$ ratios for most of the data and undetected inherited components in zircons suggest that plutonic crustal growth between 3100 and 2700 Ma ago occurred without significant remelting of pre-existing crust. Closure conditions in the K-Ar hornblende system (ca. 500°C) occurred about 2550 to 2650 Ma ago and in the K-Ar biotite systems (ca. 300°C) about 2400 to 2550 Ma ago. Within these broad ranges of ages the Superior Province in Manitoba appears to have responded to tectonic conditions as a single unit since the Laurentian Orogeny.

Although analytical uncertainties of individual analyses are large, the Rb-Sr whole-rock ages of plutonic and metaplutonic rocks appear to young southward from Pikwitonei and K-Ar mineral ages appear to young southward from the Sachigo-Berens boundary area. The U-Pb zircon data of the Laurentian episode seem to support sequential magma formation (and by inference attendant metamorphism) during a period of 110 Ma. The Rb-Sr and K-Ar age trends thus seem to show that plutonic cooling or cratonization or both proceeded from north to south in late Archean time.

However, it has also been argued in this work that all isotopic systems are amenable to updating. In the case of the Rb-Sr data, post consolidation, late stage deuteric activity may have modified primary ages. Such activity may follow emplacement of magma or may be interpreted to occur during protracted crustal residence at temperatures above the argon blocking temperature in biotite. Sequential regional uplift from north to south could thus produce the Rb-Sr age pattern.

No evidence was found to suggest that argon closure conditions in biotites and hornblendes were attained more than once in Archean time following the Laurentian. K-Ar hornblende ages are similar to some Rb-Sr whole-rock ages and this suggests gradual crustal cooling to closure conditions in biotites.

The blocking conditions leading to Rb-Sr and K-Ar ages younger than 2700 Ma in Berens and the terrane southward may have been the enigmatic Kenoran Orogeny (Stockwell, 1982) ca. 2500 Ma ago. In this hypotheis the centre of Kenoran activity, representing metamorphism only, lies somewhere in the southern part of the Shield. The Rb-Sr whole-rock ages of granitoids in Wabigoon (70, 71, 73, Fig. 3) in the range 2500-2600 Ma and a U-Pb zircon age of late pegmatite of 2568 Ma in English River Subprovince (Krogh et al., 1976) may be cited in support of such a concept. Thus, whereas rocks in the northern part of western Superior Province are only mildly thermally disturbed, they actually become reworked at higher temperatures in the southern part of the province.

The parallel to this hypothesis may be seen more clearly in terrane north of Berens where, during Proterozoic time, orogenic activity in Churchill Province may have effected regional uplift or rejuvenation in Superior Province. Rejuvenation in response to temperature or temperature-related uplift rates occurs first in K-Ar biotite, then in K-Ar hornblende, and then in Rb-Sr whole-rock systems. Nearer the source of heat (Churchill-Superior boundary zone or Churchill orogen) isotopic ages may actually reflect prograde metamorphism and the production of granitic melts in retrograde Pikwitonei.

Possible episodes of isotopic setting or resetting during late Archean time in Sachigo and Pikwitonei subprovinces, are now masked by rejuvenation that occurred in Proterozoic time. Older K-Ar hornblende ages persist northward partly into Sachigo, but their contiguous biotite ages are drastically updated (Fig. 2) as far as 350 km south from the Thompson lineament (Fig. 1). Biotite ages with a median value of 2450 Ma in Berens are updated by proportionately greater amounts in the direction of the Churchill Province and cluster in the range 1700-1800 Ma in retrograde Pikwitonei Subprovince. The cause of this updating in Superior Province probably resulted from rejuvenation during Hudsonian Orogeny. Crust nearer the orogen was subjected to more heat for longer periods of time than in southern Sachigo.

Meagre evidence suggests a possible thermal event or disturbance of K-Ar biotite systems in Sachigo Subprovince 1900-2200 Ma ago that may predate Hudsonian effects.

Nearly seventy per cent of the K-Ar ages younger than 2350 Ma fall in this range. This thermal disturbance may have coincided with intrusion of the Molson dykes whose age of magnetization was estimated to be 2000-2100 Ma (Ermanovics and Fahrig, 1975). In northern Sachigo the Molson dykes are metamorphosed and this may have occurred 2000-2100 Ma ago. Sachigo Subprovince may therefore have been subjected to rejuvenation in Kenoran times, again possibly 1900-2200 Ma ago, and yet again in late Aphebian time. K-Ar ages progressively younging toward Churchill Province may have had several diachronous causes related to continental collision (Gibb, 1968; Weber, 1980; Fountain and Salisbury, 1981; Stockwell, 1982; Gibb and Thomas, 1976) that may include both isotopic rejuvenation and crustal uplift. Temperatures that may have accompanied Proterozoic tectonics in Sachigo Subprovince appear to have approached the argon blocking temperature in hornblendes, whereas in retrograde Pikwitonei temperatures exceeded this value.

Isotopic rejuvenation in northern Berens, Sachigo and Pikwitonei is thus likely related to thermal and tectonic disturbances sited north of Pikwitonei during early and middle Aphebian times. In Manitoba this disturbance has affected the northern two-fifths of the Superior Province.

The age of plutonism and granulite facies metamorphism remains unknown in Pikwitonei Subprovince. The age inferred for plutonism is 2900-3000 Ma (Weber and Loveridge, 1981). Cognizance must be taken of the reality of several thermal events or disturbances that may have updated the ages of crystallization in that subprovince. In addition, the rocks may have had a protracted crustal residence time since they may not have been exhumed to near surface conditions until the Proterozoic.

The Sachigo-Berens boundary area marks the place where the effects of plutonic cooling during Archean time and rejuvenation during Proterozoic time overlap.

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Table 1. Isotopic age determinations in the Superior Province of Manitoba

Identification	Reference	Location	Concentrate	%K	$^{40}Ar/^{40}K$	$\%^{40}Ar$	Age (Ma)	Remarks
1. DDH-1,2,3	(17)	19 km west of Gillam near Gull Rapids; see Fig. 5 in Ref. (17)	Rb-Sr whole-rock isochron	Intercept=0.715 ± 0.002			2545 ± 75	Samples obtained from 3 boreholes; granitic mobilizates in supra-crustal rocks; retrograde Pikwitonei.
2. GSC 60-82	(3)	North of Split Lake 56°15'25"N 96°05'10"W	Biotite with minor hornblende	7.52	0.1624	99	1722	Hornblende-biotite paragneiss; veined by fine grained granite.
3. GSC 60-81	(3)	Northwest of Assean Lake; 56°13'05"N 96°31'05"W	Clean, dark brown biotite with rare quartz	7.77	0.1627	97	1690	Granitized augen paragneiss possibly derived from Assean Lake group.
4. GSC 60-83	(3)	North shore of Dafoe Lake; 55°45'00"N 96°12'40"W	Fresh, reddish brown biotite; a few fragments of quartz and hornblende	7.43	0.2889	98	2388	Hypersthene granite; green grey, granoblastic with scattered crystals of biotite; also present are quartz, micro-cline, orthoclase, (?) andesine, myrmekite and hypersthene.
5. B3810	(2)	Partridge Crop Lake 55°39'N, 97°20'W; see Fig. 2 in Ref. (2)	Biotite	3.69	0.181	-	1812	1 m thick pegmatite cutting mafic gneiss.
6. AK256	(4)	Thicket Portage 55°19'N 97°40'W	Hornblende	1.47	0.296	-	2420	Pyroxene - hornblende gneiss; pre-Assean Lake group.
AK192	(4)	As above	Biotite	7.20	0.169	-	1730	Biotite gneiss; pre-Assean Lake group.
7. GSC 61-121	(6)	Wintering Lake 55°23'55"N 97°54'50"W	Clean biotite	7.66	0.1671	99	1720	Paragneiss; quartz-oligoclase-biotite gneiss interlayered with hornblende gneiss.
8a. Proj. 184A	(26)	Area north and northwest of Cauchon Lake; see Fig. 1 in Ref. (26)	Rb-Sr whole-rock errorchron	Intercept=0.7037 ± 0.0015			2803 ± 492 (MSWD=38.6)	Enderbites from Pikwitonei collected over large area.
8b. Proj. 184B	(26)	Southwest end of Cauchon Lake; see Fig. 1 in Ref. (26)	Rb-Sr whole-rock isochron	Intercept=0.7011 ± 0.0005			2803 ± 133 (MSWD=1.7)	Metatonalite from Sachigo near Pikwitonei orthopyroxene isograd; samples 1-4 and 6.
			Errorchron	Intercept=0.7009 ± 0.0008			2879 ± 193 (MSWD=4.3)	Samples 1-6 (all samples).
			Errorchron	Intercept=0.7004 ± 0.0011			3066 ± 317 (MSWD=3.2)	Samples 1-5.
9. GSC 65-98	(9)	West of south shore of Sipiwesk Lake 54°56'45"N 98°06'22"W	Dark green hornblende	1.50	0.2841	97	2365 ± 165	Amphibolite; layer in a granulite gneiss comprising andesine, hornblende, augite, magnetite and hypersthene.
10. GSC 63-105	(7)	Island in Setting Lake 54°57'N 98°39'W	Orange-brown biotite with sparse inclusions of zircon and quartz	7.75	0.1774	100	1787 ± 60	Granite; oligoclase-microcline-quartz stock; part of a chain of stocks parallel to Superior-Churchill boundary zone.
11. Fig. 4	(20)	Setting Lake; see Fig. 2 in Ref. (20)	Rb-Sr whole-rock isochron	Intercept=0.7038 ± 0.0017			2760 ± 135	Layered migmatite gneisses; retrogressed Pikwitonei granulites.
	(20	As above	As above	Intercept=0.7125			1684	As above.
12. GSC 64-82	(8)	On railway bend 1.5 km north of Resting Lake 54°52'15"N 98°44'00"W	Blue-green to brown hornblende	0.82	0.1633	96	1695 ± 170	Quartz monzodiorite; horn-blende + biotite; may be similar to #10.
13. GSC 64-81	(8)	3 km northeast of Little Manitou Rapids, Nelson River 54°49'N, 98°02'W	Brown biotite with 2% total chlorite	8.05	0.3534	99	2661	Granulite facies gneiss; oligo-clase, quartz, untwinned felds-par (orthoclase?), biotite, hornblende and orthopyroxene.
14. GSC 64-80	(8)	East shore of Conlin Lake 54°44'N, 98°30'W	Olive-brown biotite; 30% of biotite is partly altered to epidote	7.76	0.1692	99	1755 ± 60	Granite; massive.

First number on left in column under "Identification" refers to sample locality in Figure 1 and in tables and figures throughout this work. Numbers in "Reference" column are as follows:

(1) Lowdon, 1960
(2) Moore et al., 1960
(3) Lowdon, 1961
(4) Burwash et al., 1962
(5) Leech et al., 1963
(6) Lowdon et al., 1963
(7) Wanless et al., 1965
(8) Wanless et al., 1966
(9) Wanless et al., 1967
(10) Turek and Peterman, 1968
(11) Wanless et al., 1968
(12) Farquharson and Clark, 1971
(13) Penner and Clark, 1971
(14) Turek and Peterman, 1971
(15) Wanless et al., 1972
(16) Wanless et al., 1973
(17) Clark, 1974
(18) Krogh et al., 1974
(19) Farquharson, 1975
(20) Cranstone and Turek, 1976
(21) Wanless et al., 1978
(22) Clark and Cheung, 1980
(23) Wanless et al., 1979
(24) Ermanovics and Loveridge, 1980
(25) Ermanovics, 1980
(26) Weber and Loveridge, 1981
(W) Data this work

Rb-Sr age calculations are based on ^{87}Rb decay constant = $1.42 \times 10^{-11} yr^{-1}$
K-Ar and U-Pb age calculations are based on 25th IGC constants (Steiger and Jäger, 1977)

Table 1 (cont.)

Identification		Reference	Location	Concentrate	%K	$^{40}Ar/^{40}K$	$\%^{40}Ar$	Age (Ma)	Remarks
15.	GSC 60-84	(3)	Island near NW shore of Cross Lake, 54°39'15"N 97°58'00"W	Unaltered biotite	7.28	0.2236	96	2060 ± 125	Paragneiss, garnetiferous, minor sillimanite.
	GSC 61-125	(6)	As above	Very impure concentrate of muscovite	6.41	0.1619	97	1685	As above.
	GSC 61-124	(6)	As above	Fresh biotite; minor quartz and opaques	7.28	0.2366	97	2131	As above.
16.	EE-75-072	Proj. 310 (W)	Cross Lake; below unconformity 54°38'45"N 97°48'45"W	Zircon	U-Pb concordia intercept			2712 ± 5	Metatonalite; fresh muscovite, biotite and feldspar; muscovite graphically intergrown with quartz and feldspar; sample 24 m from Cross Lake unconformity.
	GSC 78-190	(23)	As above	Muscovite	7.97	0.2018	99.2	1961 ± 46	As above.
	GSC 78-189	(23)	As above	Green-brown biotite	7.92	0.2288	99.7	2113 ± 49	As above.
17.	GSC 78-188	(23)	Cross Lake 54°39'N 97°48'30"W	Green biotite	7.82	0.2812	99.6	2389 ± 52	As above but only trace of muscovite; 12 m from unconformity.
18.	GSC 65-96	(9)	1.5 km north of Minago River 54°32'38"N, 98°35'13"W	Green hornblende with less than 5% chlorite	0.96	0.1806	96	1807 ± 165	Orthogneiss; alternating layers of plagioclase and hornblende.
19.	GSC 63-101	(7)	West end of Cross Lake, 54°32'N 98°09'W	Clean, olive-brown biotite	8.25	0.2304	100	2097 ± 70	Granite porphyry.
20.	GSC 63-102	(7)	West end of Cross Lake, 54°36'N 98°01'W	Impure muscovite (40% intergrown with altered brown biotite) with carbonate, quartz and feldspar.	6.24	0.1730	100	1759 ± 60	Paragneiss; oligoclase, microcline, quartz, biotite, muscovite.
	GSC 63-103	(7)	As above	Brown biotite, with 2% chlorite	8.05	0.2029	100	1943 ± 70	As above.
21.	GSC 64-83	(8)	Large island in the east-central part of Kiskitto Lake 54°16'00"N 98°30'45"W	Blue-green to pale yellow hornblende; trace of mica, quartz and K-feldspar	1.30	0.2963	98	2421 ± 170	Hornblende forms the interstices between labradorite crystals of football size; see Ermanovics and Davision, 1976 (Fig. 5, p. 341).
22.	AK 207	(4)	Cross Lake 54°36'N 97°56'W	Biotite	7.58	0.189		1860	Granodiorite; post-Cross Lake Group.
23.	AK 206	(4)	Cross Lake 54°38'N 97°47'W	Biotite	7.59	0.315		2500	Biotite gneiss; pre-Cross Lake Group.
24.	AK 213	(4)	Cross Lake 54°35'N 97°45'W	Biotite	6.81	0.229		2090	Tonalite; a cobble from Cross Lake Group conglomerate; compare to #16 and #17.
25.	GSC 61-127	(6)	11 km south of Robinson Portage; 54°15'N, 96°16'W	Green-grey biotite	7.94	0.2075	100	1970 ± 125	Grandiorite gneiss; 15% microcline.
26.	GSC 76-203	(21)	9.5 km south of Norway House 53°53'45"N, 97°49'W	Unaltered dark green hornblende with <2% biotite	0.825	0.3543	98.8	2665 ± 63	Amphibolite; medium grained, granoblastic; inclusion in foliated gneissic hybrid granodiorite.
	GSC 76-202	(21)	As above	Unaltered green biotite	7.70	0.2238	99.6	2061 ± 48	As above.
27.	GSC 60-85	(3)	Kettle Island on Playgreen Lake, 53°45'40"N 97°55'30"W	Green to brown biotite	7.80	0.2463	92	2181 ± 125	Granodiorite to granite; weakly foliated and altered.
28.	EE-72-A1	Proj. 141 (W)	North shore of Ponask Lake 53°52'15"N 96°20'01"W	Zircon	$^{207}Pb/^{206}Pb$		age	2703	Metatonalite; layered and lineated; intrudes Ponask Lake metasedimentary rocks, compare to #92, 93 and 16.
	GSC 76-208	(21)	As above	Light brown biotite	7.69	0.2353	99.6	2153 ± 48	As above.
	GSC 76-209	(21)	As above	Pleochroic olive to dark green hornblende	0.870	0.3437	98.7	2668 ± 64	As above.
29.	EE-74-001	Proj. 246 (W)	Chain of islands, Stevenson Lake 53°54'N 96°00'W	Zircon	U-Pb concordia intercept			2895 ± 25	Biotite-hornblende amphibolite intruded by pink granite veins.
	GSC 78-184	(23)	As above	Pleochroic light brown to green	0.335	0.4916	99.2	3170 ± 68	As above.
	GSC 78-184	(23)	As above	Hornblende	0.335	0.4974	99.2	3188 ± 68	Duplicate analysis of above.
30.	GSC 78-177	(23)	Bigstone Lake 53°43'29"N 95°49'10"W	Green-brown biotite	7.54	0.2913	99.8	2398 ± 52	Paragneiss; quartzofeldspathic gneiss relict in orthogneiss below; may derive from Bigstone Lake volcanics.
	GSC 78-178	(23)	As above	Light greenish brown biotite	7.74	0.2862	99.8	2375 ± 51	Tonalite gneiss with abundant granitic mobilizate; relationship to Bigstone Lake supracrustal rocks not known.

Table 1 (cont.)

Identification		Reference	Location	Concentrate	%K	$^{40}Ar/^{40}K$	$\%^{40}Ar$	Age (Ma)	Remarks
	GSC 78-179	(23)	As in no. 30	Pleochroic brown to green hornblende	1.22	0.3342	99.8	2584 ± 63	As above.
31.	GSC 78-180	(23)	Bigstone Lake 53°43'40"N 95°49'40"W	Zircon	U-Pb concordia intercept 2804 ± 14				Orthogneiss; layered tonalite gneiss with younger metasomatic lenses; thought to be remobilized basement to Bigstone Lake volcanics.
			As above	Green-brown biotite	7.67	0.3065	99.8	2466 ± 53	As above.
	GSC 78-181	(23)	As above	Pleochroic brown to green hornblende	0.943	0.3097	99.4	2480 ± 61	As above.
32.	GSC 76-206	(21)	West shore of Gunisao Lake 53°31'25"N 96°23'W	Unaltered blue-green hornblende	0.614	0.3267	99.3	2553 ± 61	Diorite; coarse grained, massive; cogenetic with #33 and granite.
33.	GSC 76-207	(21)	Southeast shore of Gunisao Lake 53°32'N, 96°11'45"W	Light greenish biotite with <2% chlorite	7.88	0.3117	99.8	2489 ± 55	Granodiorite; foliated, porphyritic plagioclase; hybrid rock with mafic schlieren; border phase of granite.
34.	GSC 76-205	(21)	Belanger River 53°26'40"N 96°43'40"W	Unaltered blue-green hornblende <2% biotite	0.768	0.3345	99.5	2585 ± 63	Granodiorite; grey medium grained, weakly foliated.
	GSC 76-204	(21)	As above	Unaltered light green biotite	7.64	0.3041	98.9	2456 ± 53	As above.
36.	GSC 72-76	(16)	26 km NNW of Weaver Lake 52°58'35"N 96°40'W	Brown-green biotite <2% chlorite	7.64	0.3238	99	2441 ± 70	Quartz monzodiorite; coarse grained, white oligoclase (68%), microcline (9%), quartz (6%), biotite (16%), foliated, heterogeneous rock.
39.	Proj. 119	(24)	Horseshoe Lake 52°12'N, 95°54'W	Rb-Sr whole-rock isochron	Intercept=0.7024 ± 0.0010			2557 ± 44 (MSWD=0.66)	Composite sample of granite and granodiorite; stock is typical of Berens Subprovince granites; completely surrounded by and intrudes Horseshoe Lake metavolcanic rocks.
			As above	Muscovite-rich rock	Assuming intercept 0.702			2655 2670	Two muscovite-bearing border phase samples of the stock; see also #101.
40.	GSC 72-72	(16)	Horseshoe Lake 52°11'10"N 95°52'20"W	Nonpleochroic fresh hornblende with ~5% biotite	1.02	0.3308	99	2570 ± 62	Quartz diorite (9% quartz) massive, medium grained; andesine (51%), hornblende (18%); interpreted as subvolcanic to porphyritic dacites at Horseshoe Lake.
	GSC 72-73	(16)	As above	Brown-green biotite with <2% hornblende	7.32	0.3151	99	2504 ± 68	As above.
41.	GSC 70-76	(15)	Sasaginnigak Lake 51°35'N, 95°35'W	Yellow-olive biotite with ~13% chlorite	7.72	0.3361	99	2592 ± 70	Granodiorite; coarse grained, massive to weakly foliated; constitutes main rock type (late orogenic) in Berens Subprovince, and is the cause of high aeromagnetic signatures in granitic terrane.
42.	GSC 60-87	(3)	East shore of Aikens Lake 51°11'40"N 95°18'W	Olive-brown biotite with 5% chlorite, quartz and opaques	7.19	0.2977	95	2427 ± 125	Granodiorite; microcline phenocrysts and chloritized biotite.
43.	72-46	(18)	West shore of Obukowin Lake 51°05'N, 95°13'W	Zircon	U-Pb concordia intercept			2737 ± 10	Tonalite; see #44.
44.	GSC 72-74	(16)	East shore of Lake 6.5 km north of Wallace Lake 51°05'40"N 95°22'35"W	Unaltered light green biotite	8.00	0.3146	99.4	2502 ± 72	Tonalite; augen foliation, epidotized plagioclase; supercedes GSC 60-88 (2670 Ma, Lowdon, 1961, SH-22-59).
45.	GSC 72-71	(16)	6.5 km NE of Wallace Lake 51°03'40"N 95°21'40"W	Clean, olive green to blue-green hornblende with 2% biotite	0.973	0.3374	99	2597 ± 70	Amphibolite gneiss; host rock as for #43, and #44.
46.	72-37	(18)	East shore of Lake Winnipeg, 51°27'N 96°33'W	Zircon	U-Pb concordia intercept			2900 ± 10	Quartzofeldspathic gneiss; like #48 but with garnet and coarser grained; locally granitized.
47.	GSC 72-69	(16)	5 km NW of Shallow Lake 51°22'30"N 96°17'00"W	Brown to blue-green hornblende, trace of biotite	0.789	0.3240	98	2542 ± 62	Tonalite; medium grained, weakly foliated, mesocratic, (25% biotite + hornblende).
	GSC 72-70	(16)	As above	Light green biotite with 6% chlorite	7.04	0.2839	98	2364 ± 66	As above.
48.	72-4	(18)	First rapids on Rice River 51°21'N 96°24'W	Zircon	U-Pb concordia intercept			2900 ± 10	Quartzofeldspathic gneiss; granoblastic with horizontal mullion structure; rock may have been leucocratic dacite. May be intruded by #53.

Table 1 (cont.)

	Identification	Reference	Location	Concentrate	%K	$^{40}Ar/^{40}K$	$\%^{40}Ar$	Age (Ma)	Remarks
49.	Project 121	(25)	From Lake Winnipeg to #48 51°16'50"N 96°20'45"W	Rb-Sr whole-rock isochron	Intercept=0.7010 ± 0.0006			2674 ± 136 (MSWD=0.84)	Metatonalite orthogneiss; includes interfolded rocks as described for #46, #48 and #53.
	GSC 78-186	(23)	As above	Light brown biotite + 3% chlorite	7.18	0.2983	99.9	2430 ± 52	Metatonalite; identical to #53.
50.	72-1	(18)	Island east of Deer Island 51°18'30"N 96°28'30"W	Zircon	U-Pb concordia intercept			2715 ± 10	Granodiorite; gneissic, augen texture, intrudes (?) volcanic rocks in lit-par-lit fashion; layers 0.6-1.2 m thick.
51.	72-39	(18)	3 km east of Black Island 51°15'N 96°19'W	Zircon	U-Pb concordia intercept			2715 ± 10	Granodiorite - granite; medium grained, foliated; dyke 90 x 6 m cutting earlier gneissose structures of #46, and #48.
52.	EE-74-BLI-4A	Proj. 239 (W)	Southeast side of Black Island 51°16'14"N 96°23'28"W	Zircon	U-Pb concordia intercept			2732 ± 10	Rhyodacite breccia of the Black Island succession.
53.	72-40	(18)	5 km west of Hole River Settlement 51°11'08"N 96°21'15"W	Zircon with pitted surfaces	U-Pb concordia intercept			2999 ± 10	Metatonalite; schistose, porphyritic with recrystallized chlorite + biotite + quartz + epidote + muscovite; kink folded matrix; blue quartz segregations; may intrude #46 and #48.
54.	GSC 61-128	(6)	Manigotagan Settlement 51°06'40"N 96°18'54"W	Brown biotite with chlorite and quartz	7.62	0.2964	100	2422 ± 125	Metasedimentary schist; with muscovite, biotite, chlorite and garnet; compare with #60 and #57.
	GSC 61-129	(6)	As above	Impure muscovite with chlorite and biotite	6.29	0.3009	100	2442 ± 125	As above.
55.	72-38	(18)	6.5 km south of Manigotagan Settlement 51°04'10"N 98°18'W	Zircon	U-Pb concordia intercept			2690 ± 10	Paragneiss and orthogneiss; part of English River Gneiss Belt; this may be a metamorphic zircon age.
56.	Fig. 3	(10)	Bissett and surroundings 51°01'22"N 95°40'42"W	Rb-Sr isochron sericite and fuchsite	Intercept=0.6997 ± 0.0028			2662 ± 185	Gold-bearing quartz veins with sericite and fuchsite gangue; veins cut tonalite (#57 and #59) and the San Antonio Formation.
57.	Fig. 2	(14)	Pluton 16 km SSE of Bissett 55°58'N 95°30'W	Rb-Sr, whole-rock biotite and plagioclase isochron	Intercept=0.7016 ± 0.0012			2501 ± 70	Ross River Pluton; granodiorite-tonalite as #59; interpreted to be a metamorphic age; compare with #59 and metamorphic age of phyllites #60; sample collected from a zone of deformation (W. Weber, pers. comm 1980).
58.	00-68-224	(14)	NW shore of Caribou Lake 50°56'19"N 95°40'20"W	Rb-Sr biotite age				2574	Paragneiss of the English River Subprovince, interpreted by Turek and Peterman (1971) as having been updated during 2500 Ma metamorphism. See #57.
59.	GSC 60-89	(3)	South shore of Faraway Lake 50°55'N 95°26'05"W	Brown biotite with 5% chlorite	7.60	0.3049	99	2459 ± 52	Granodiorite-tonalite; massive, chloritized biotite, zoned andesine. This is the Ross River Pluton described in detail by Paulus and Turnock (1971). Age supercedes GSC-60-89 (SH-21-59) 2670 Ma in Lowdon, 1961 (Wanless, pers. comm., 1980).
60.	Fig. 4	(10)	Long Lake 50°51'31"N 95°23'12"W and north of Bissett 51°02'56"N, 95°41'37"W	Rb-Sr whole-rock isochron	Intercept=0.7022 ± 0.0009			2437 ± 90	Phyllites of the Rice Lake Group; mineralized veins #56 give minimum age of group; 2437 Ma is metamorphic age.
61.	Fig. 3	(14)	Pluton at Black Lake, 50°40'25"N 95°22'56"W	Rb-Sr whole-rock isochron	Intercept=0.7019 ± 0.0008			2677 ± 55	Granite cuts paragneiss of #62; age is minimum for age of intrusion for quartz monzonite and of metamorphism of paragneiss compare with metamorphic U-Pb zircon age of 2690 Ma, #55.
62.	GSC 60-90	(3)	East end of Black Lake, 50°38'45"N 95°18'W	Unaltered red-brown biotite	8.09	0.3036	99	2454 ± 70	Paragneiss; rerun of GSC 60-90 Lowdon, 1961, SH-20-59.
	02-68-514	(14)	As above	Unaltered biotite	7.74	0.2907	99.7	2396 ± 78	Collected by W. Weber from same outcrop as GSC 60-90.
63.	02-68-514	(14)	Black Lake 50°38'45"N 95°18'00"W	Rb-Sr biotite age				2477	Paragneiss; as #62.
64.	Fig. 3	(13)	9.5 km NW of Bird Lake, 50°29'30"N 95°29'09"W	Rb-Sr whole-rock isochron	Intercept=0.7014 ± 0.0021			2584 ± 135	Tonalite-granodiorite; grey and gneissic.

Table 1 (cont.)

Identification		Reference	Location	Concentrate	%K	$^{40}Ar/^{40}K$	$\%^{40}Ar$	Age (Ma)	Remarks
65.	Fig. 4	(13)	5 km SW of Bird Lake, 50°26'14"N 95°25'12"W	Rb-Sr whole-rock isochron	Intercept=0.7015 ± 0.0015			2594 ± 35	Metavolcanic rocks (Bird River Volcanics) from area of garnet-amphibolite schists; age is interpreted as a minimum for deposition of volcanic and sedimentary rocks.
66.	GSC 59-41	(1)	Whiteshell River 50°21'N, 95°21'30"W	Unaltered lepidolite	7.43	0.3059	87	2464 ± 125	Pegmatite dyke; complex.
67.	Fig. 2	(19)	Lac du Bonnet 50°18'36"N 95°48'30"W	Rb-Sr whole-rock isochron	Intercept=0.6998 ± 0.0032			2623 ± 91	Granite; (Lac du Bonnet Granite) pink, medium grained, massive; intrudes tonalite #64 and Bird River Volcanics #65.
68.	AK 170	(4)	Stoney Mountain No. 1 (borehole) 50°03'N, 97°16"W	Biotite	6.87	0.314		2500	Biotite gneiss.
69.	Fig. 4	(12)	16 km west of Whiteshell Lake	Rb-Sr whole-rock isochron	Intercept=0.7071 ± 0.0038			2555 ± 113	Granodiorite; porphyritic microcline, coarse grained; appears to be a massive phase within the Whiteshell granodiorite gneisses.
70.	Fig. 5	(12)	Between Caddy Lake and West Hawk Lake	Rb-Sr whole-rock isochron	Intercept=0.7087 ± 0.0015			2504 ± 12	Granite gneiss (Caddy Lake quartz monzonite); grey garnetiferous gneiss and massive granite.
71.	Fig. 3	(12)	5 km east of Caddy Lake	Rb-Sr whole-rock isochron	Intercept=0.7009 ± 0.0031			2548 ± 320	Granodiorite; grey and pink, gneissic; porphyritic margin of the Rennie Batholith.
72.	GSC 66-107	(11)	North of Falcon Lake, 49°45'N 95°15'20"W	Olive-green biotite- with <3% hornblende	8.02	0.2680	100	2289 ± 70	Granite stock; folaited.
73.	Fig. 2	(12)	McMunn and East Braintree settlements	Rb-Sr whole-rock isochron	Intercept=0.7001 ± 0.0014			2608 ± 50	Granodiorite; pink and gneissic; hybrid mass comprising layered rock mixed with massive granitic rocks.
74.	GSC 70-78	(15)	On Fox River 55°58'30"N 93°39'W	Buff biotite with 5% free chlorite and 5% opaque inclusions	6.70	0.1685	99	1729 ± 55	Paragneiss; dark grey hornblende - biotite, plagioclase gneiss.
75.	GSC 66-108	(11)	Southeast shore of small oval lake, 1.2 km southwest of High Hill River 55°45'15"N 94°57'00"W	Clean, olive-green biotite; trace of hornblende	6.65	0.3623	100	2695 ± 80	Granite; coarse grained, foliated, dark grey; hornblende (15%), pyroxene (3%), blue quartz eyes (33%), augen microcline (25%), plagioclase (17%); (charnockite?).
76.	GSC 72-77	(16)	Bigstone River 55°37'25"N 95°04'15"W	Impure green biotite with 28% chlorite	7.28	0.1955	99	1899 ± 55	Granite; weakly gneissic; plagioclase (42%), quartz (33%), microcline (20%), biotite (4%) chlorite (1%).
77.	GSC 72-79	(16)	Northeast end of Stupart Lake 55°39'00"N 93°59'30"W	Dark green biotite with 3% hornblende	7.54	0.3363	99.5	2592 ± 70	Granodioritic gneiss; oligoclase (50%), quartz (25%), hornblende (12%), biotite (12%).
	GSC 72-80	(16)	As above	Clean, dark green hornblende with 3% mica	1.31	0.2742	99	2355 ± 72	As above.
		(16)	As above	As above	1.31	0.2630	99	2300 ± 72	As above.
78.	GSC 72-78	(16)	20 km west of southern end of Stupart Lake 55°32'08"N 94°40'25"W	Impure, light green biotite with 23% chlorite	7.02	0.1546	99	1635 ± 50	Granite; medium grained, orange-grey, locally gneissic; oligoclase (32%), perthite (32%) quartz (32%) biotite (3%), pyroxene chlorite, muscovite.
79.	GSC 61-126	(6)	South shore of island in Atik (Utik) Lake; 55°15'18"N 96°00'00"W	Brown biotite; chlorite/biotite 0.14	7.26	0.2405	100	2151	Cordierite schist.
80.	GSC 66-109	(11)	1.5 km north of Red Cross Lake on Red Sucker River 55°05'N, 92°45'W	Olive-green biotite; total chlorite is 20%	7.28	0.1609	99	1678 ± 55	Granodiorite gneiss; plagioclase (54%) quartz (40%), biotite + microcline + pyroxene + sericite + chlorite.
81.	GSC 62-100	(5)	East shore of Seller Lake; 55°02'00"N 94°27'40"W	Biotite: 70% clean green, 10% brown, 20% chloritic and epidotic; chlorite/biotite 0.18	7.30	0.2138	100	2006	Granite; weakly gneissic, grey, medium grained.
82.	GSC 60-96	(3)	Southeast arm of Rieder Lake, Ontario 54°54'N 91°50'W	Green-grey biotite; trace epidote, and quartz inclusions	7.94	0.1842	95	1830	Gneiss; biotite, quartz, feldspar.

Table 1 (cont.)

Identification	Reference	Location	Concentrate	%K	$^{40}Ar/^{40}K$	$\%^{40}Ar$	Age (Ma)	Remarks
83. in Weber and Scoates, 1978	Catanzaro pers. comm., 1977	West end Knee Lake 54°53'N, 95°05'W	Zircon	Discordant U-Pb age; preliminary			2700	Metadacite of the Hayes River Group; compare to #16, #92 and #93.
84. B 3808	(2)	South shore Oxford Lake 54°48'N, 95°35'W	Biotite	7.10	0.247		2183	Gneissic granite; intrudes Hayes River Group and Oxford Lake Group.
	(2)	As above	Biotite	7.10	0.2488		2194	As above.
85. MF-559	K-Ar1393 Wanless unpublished	5 km west of Gods River community on north shore of Gods Lake 54°52'N 94°10'W	Clean lepidolite	7.43	0.2972	100	2425	Lepidolite from pegmatite; part of lithium pegmatite belt crossing the Superior Province.
Fig. 4 p. 564	(22)	Northwest shore of Gods Lake 54°47'N 94°25'W	Rb-Sr whole-rock isochron	Intercept=0.7029 ± 0.0001			2424 ± 74	Bayly Lake Pluton; granodiorite; massive, porphyritic; intrudes Hayes River Group; compare with #86 and #87, and pre-Oxford Lake Group granitoids #16, #92 and #93.
86. Fig. 5 p. 565	(22)	Magill Lake; west of Gods Lake; 54°47'N, 94°55'W	Rb-Sr whole-rock isochron	Intercept=0.7078 ± 0.0043			2455 ± 35	Magill Lake Pluton; weakly foliated, medium grained to pegmatitic; intrudes Oxford Lake Group; compare to #85.
87. B 3809	(2)	Magill Lake 54°45'N, 94°55'W	Biotite	1.98	0.156		1645	As above.
88. AK 208	(4)	Gods Lake 54°38'N, 94°16'W	Biotite	7.46	0.343		2620	Granodiorite; 'quartz-eye'; pre-Oxford Lake Group.
89. AK 205	(4)	Gods Lake 54°32'N, 94°30'W	Biotite	7.25	0.289		2390	Granodiorite; gneissic; post-Oxford Lake Group.
90. Fig. 3 p. 564	(22)	Goose Lake 54°16'N, 94°40'W	Rb-Sr whole-rock isochron	Intercept=0.7014 ± 0.0009			2680 ± 125	Fragmental rhyolite tuff(?) and metabasalt possibly of Hayes River Group. Without basalt samples data yield an errorchron of 2441 ± 182 Ma ($^{87}Sr/^{86}Sr$=0.7056 ± 0.0018).
91. GSC 78-185	(23)	Island Lake 53°58'13"N 94°54'05"W	Pleochroic light green to light brown hornblende with trace of chlorite	0.390	0.3265	98.9	2595 ± 62	Cataclastic quartzofeldspathic gneiss; green, epidotic; adjacent to supracrustal rocks.
92. GSC 78-182	(23)	Northwestern shore of Island Lake 53°57'45"N 94°46'35"W	Zircon	U-Pb concordia intercept			2757 ± 7	Granodiorite-tonalite; boulders from base of Island Lake series, possibly derived from unconformably underlying granitoid #93.
		As above	Light brown biotite + 10% chlorite	6.74	0.2101	99.9	2010 ± 46	As above.
93. GSC 78-183	(23)	Island Lake 53°58'00"N 94°39'30"W	Zircon	U-Pb concordia intercept			2765 ± 18	Granodiorite-tonalite; unconformably underlies Island Lake series conglomerate #92.
	K-Ar-2504 (W)		Greenish biotite + 3% chlorite	7.48	0.2481	99.9	2222 ± 91	As above.
95. GSC 78-192	(23)	Azure Lake 53°05'31"N 94°39'45"W	Pale brown biotite	8.20	0.2836	99.8	2400 ± 53	Paragneiss; granoblastic biotite - feldspar- quartz rock.
96. GSC 78-193	(23)	Azure Lake 53°05'31"N 94°39'15"W	Brown to greenish brown biotite with 2% chlorite	7.54	0.2540	99.6	2253 ± 50	Orthogneiss or metasomatized paragneiss #95; leucocratic.
97. GSC 78-194	(23)	Warrington Lake 53°00'50"N 94°52'20"W	Light brown biotite	7.34	0.2783	99.8	2375 ± 53	Orthogneiss; mafic biotite - hornblende plagioclase gneiss.
GSC 78-195	(23)	As above	Pleochroic brown to green hornblende	0.695	0.3448	99.5	2673 ± 64	As above.
98. GSC 78-191	(23)	North shore of Warrington Lake 53°00'50"N 94°53'W	Light brown biotite + 2% chlorite	7.69	0.2797	99.8	2382 ± 53	Leucocratic layered gneiss adjacent to supracrustal rocks.
99. GSC 70-77	(15)	Island near NW shore of Charron Lake, 52°46'15"N 95°14'W	Clean green-brown biotite	8.04	0.2985	99	2431 ± 70	Tonalite gneiss; cataclastic; 6 m from pseudotachyte occurrence, Ermanovics, et al., (1972).
100. GSC 60-86	(3)	NE shore of Charron Lake, 52°45'N 95°13'W	Clean biotite with quartz and zircon inclusions	7.91	0.3337	98	2582 ± 125	Paragneiss; inclusion in tonalite, 915 m from #99, where 2431 Ma could be an updated age due to cataclastic metamorphism.
101. GSC 72-75 Project 120	(16)	Apisko Lake, 52°32'20"N 95°22'30"W	Green-brown biotite with 15% chlorite	7.62	0.3127	99.4	2493 ± 72	Granite, pink, massive medium grained, leucocratic (4% chloritized biotite). Typical granite of Berens Subprovince.
	(25)	As above	Rb-Sr whole-rock isochron	Intercept=0.7010 ± 0.0020			2677 ± 160	As above (MSWD=1.14).
				Intercept=0.7014 ± 0.0016			2649 ± 130 (MSWD=1.01)	As above, plus cogenetic granodiorite phase. Intrudes grey gneissic granodiorite.