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K-Ar AGES FOR HORNBLENDE FROM GRANITES AND GNEISSES AND FOR BASALTIC INTRUSIVES IN MINNESOTA

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ABSTRACT

K-Ar ages have been determined for hornblende concentrates from granitic intrusive and metamorphic rocks from the Minnesota River valley, northeastern Minnesota, and an adjacent area in Ontario, which were involved in the Algoman orogeny. Nine determinations giving ages ranging from 2570 to 2770 m.y. have an average of 2670 $\pm$ 30 m.y. This is significantly older than the age of about 2500 m.y. indicated by the Rb-Sr and K-Ar methods for biotite from these rocks. The age, however, agrees with the U-Pb ages of about 2700 m.y. for coexisting zircons. Mineral and whole-rock K-Ar ages for basic rocks that invaded the granitic and metamorphic rocks show two periods of intrusion in Minnesota--at 1600-1800 m.y. and at or before 2100 m.y.--in addition to the late Keweenawan igneous activity at about 1100 m.y.

INTRODUCTION

Precambrian rocks in Minnesota and adjacent areas record regional metamorphism and intrusion of granitic rocks which occurred during the Algoman and Penokean orogenies. After the granitic and metamorphic rocks cooled, there was an episode of large-scale fracturing accompanied by the intrusion of basaltic magma, generally in the form of dikes. The purpose of this study was to determine K-Ar ages for hornblende in rocks involved in the two orogenies, particularly the Algoman orogeny, and by use of the K-Ar method to determine the periods of intrusion of basaltic magma.

If igneous and metamorphic activity in Precambrian time was comparable to the tectonic activity associated with the Paleozoic and later orogenies (for example, the Appalachian, the Cordilleran, or the Alpine) it would be assumed that the Precambrian events took place over an interval of tens or possibly hundreds of millions of years. In an orogenic event extending through such a length of time, K-Ar ages for hornblende might be expected to record earlier events than would K-Ar ages for biotite, because the hornblende tends to retain its radiogenic argon during thermal metamorphism to a greater extent than does biotite (Hart, 1961; 1964; Hanson and Gast, 1967).

For the rocks involved in the Algoman orogeny, biotite Rb-Sr and K-Ar ages are between 2400 and 2600 m.y. (Goldich and others, 1961), and zircon U-Pb ages are about 2700 m.y. (Stern, 1964; Catanzaro, 1963; Davis and others, 1963; Anderson and Gast, 1964; and Anderson, 1964). The ages for the biotite from rocks involved in the Penokean orogeny range from 1600 to 1800 m.y. (Goldich and others, 1961). Goldich and others (1961) have described the geological relationships of the rock units dated in this study, and references to the older literature are given in that report. In this study, K-Ar ages were determined on hornblende concentrates from the Saganaga Granite, Giants Range Granite, Sacred Heart Granite, Northern Light Gneiss, hornblende schist from the Knife Lake Group, Morton Gneiss, and a hornblende-pyroxene gneiss at Granite Falls, all of which would be expected to give Algoman ages. Also, a K-Ar age was determined on hornblende from the Rockville Porphyritic Granite, which should give a Penokean age.

Radiometric dating of dike swarms in the Canadian Shield indicates that some of the swarms may be correlated over dis-

tances of hundreds of miles and that there are distinct periods of intrusion which may reflect large-scale fracturing of the continental crust (Leech, 1966; Burwash and others, 1963; Fahrig and Wanless, 1963; Payne and others, 1965; Van Schmus, 1965). As a preliminary study to ascertain whether the basaltic intrusive rocks in Minnesota are in accord with the patterns found in Canada, K-Ar ages were determined on whole-rock samples of three dikes near St. Cloud and one dike in Rainy Lake and on a hornblende concentrate from the Cedar Mountain Granophyre-Gabbro Complex in the Minnesota River valley.

ANALYTICAL METHODS

The analytical results are presented in Table 1.

Argon-40 was determined by using the mass spectrometer statically as a manometer without the use of isotopically enriched argon tracers.

The replicate standard deviation for argon is 2 percent. Replicate analyses of standard MIT biotite B3203 give an argon content of $4.01 \pm 0.03 \times 10^{-4}$ cc/gm,[1/] as compared to $3.877 \pm 0.01 \times 10^{-4}$ cc/gm reported by other laboratories.

The potassium content was determined by x-ray fluorescence (Rose, Adler, and Flanagan, 1962). The uncertainty (one standard deviation) in it is 1.5 percent of the total amount of potassium present. For potassium contents of less than 0.5 percent the uncertainty is larger.

The precision of a K-Ar age for a mineral is about 2 percent, because most of the ages are based on replicate analyses and because the half life of K^{40} is small compared to these ages. The uncertainty in the accuracy of the ages, however, may be 5 percent.

1/ Variations in isotopic abundances of strontium, calcium, and argon, and related topics, 1962, Department of Geology and Geophysics, MIT

Table 1--*K-Ar age determinations*

Map number	Field number	Sample analyzed[a/]	K wght. pct.	*Ar^{40} x10^4cc/gm	Air Ar^{40} pct.	Age[b/] m. y.
			Northeastern Minnesota			
			Hornblende Schist - Knife Lake Group			
1	IL-2	H	0.501	1.19	4	2650
			0.510	1.13	5	
				1.15	2	
			Giants Range Granite			
2	M5217	H	0.550	1.23	4	2660
			0.520	1.25	3	
3	M5219	B	6.95	6.57	7	1540
			7.02			
3	M5219	H	0.984	2.05	3	2500
			1.001[f/]			
			.990[f/]			
			Northern Light Gneiss			
4	M5274	H	0.545	1.28	4	2620
			0.590			
			Saganaga Granite			
5	M5275	H	0.460	0.98	8	2570
			0.458	1.01	4	
				1.00	6	
6	M5277	H	0.413	0.99	6	2770
			0.401	1.01	7	
			0.396[f/]			
			0.393[f/]			
			Minnesota River valley			
			Hornblende-Pyroxene Gneiss at Granite Falls			
7	M8185[e/]	H	0.883	2.16	2	2740
			0.884			
			Morton Quartz-Monzonite Gneiss			
8	M8318	H	1.01	2.22	4	2590
				2.23	1	

9	KA338[c/]	H	0.98 0.98 0.99	2.24 2.20	1 0	2630
			Sacred Heart Granite			
10	KA336[c/]	H	1.02 1.06	2.56 2.59	2	2760
			Central Minnesota			
			Rockville Porphyritic Granite			
11	RH-21	H	0.893 0.894	1.09 1.05	14 17	1800
			Basaltic Intrusives			
			Basalt Dikes in the vicinity of St. Cloud			
12	M8300	WR	0.776 0.770	0.555 0.568	25 6	1280
13	M8301	WR	2.00 1.96	1.73	2	1460
14	M8302	WR	0.568	0.550 0.552	8 10	1570
			Rainy Lake Dike			
15	M7052c M7052c[d/]	WR WR	0.455 0.656	0.71 0.96	6 1	2130 2040
			Cedar Mountain Granophyre-Gabbro Complex			
16	M8317	H	0.80 0.80	0.91	4	1750

* Radiogenic

[a/] H - hornblende
B - biotite
WR - whole rock

[b/] $e = 0.584 \times 10^{-10} yr^{-1}$
$= 4.72 \times 10^{-10} yr^{-1}$
$X^{40} = 0.0118$ atom percent of K

The analytical uncertainty in the ages is about 5 percent.

[c/] Analysts, H.H. Thomas and C.O. Ingamells, U.S. Geological Survey. Age reported in Thomas (1963).

[d/] Analysts, H.H. Thomas, R.F. Marvin, P. Elmore, U.S. Geological Survey.

[e/] Data from Hanson and Himmelberg (1967).

[f/] Analysts, H. Wiesmann and F. McDowell, Eidg. Tech. Hochschule, Zurich.

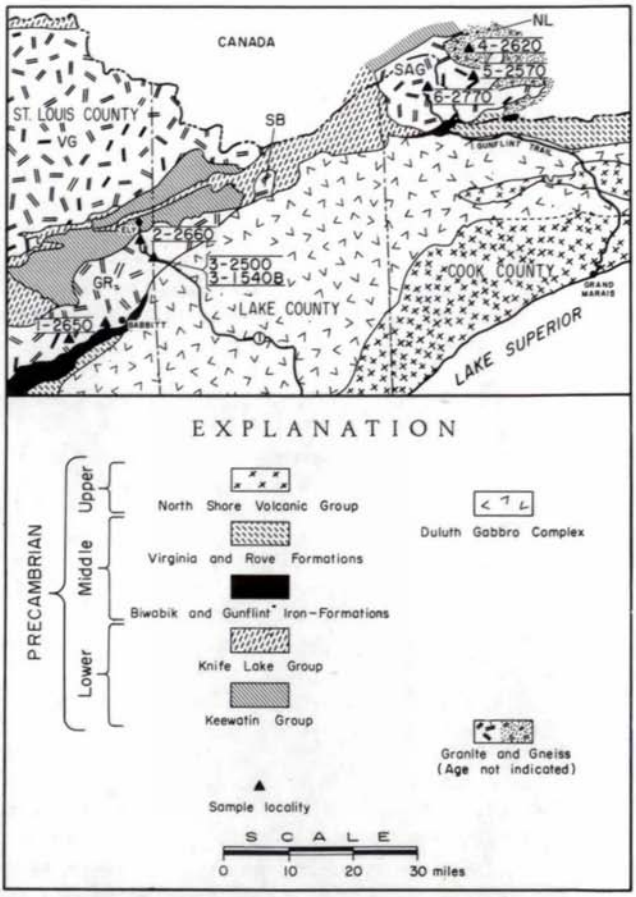


Figure 1--Generalized geologic map of northeastern Minnesota showing the location of samples and K-Ar ages in millions of years (modified from Goldich and others, 1961). *All ages are for hornblende except sample 3, which includes an age for biotite (B). Sample numbers refer to table 1. The granitic bodies are VG-Vermilion Granite, GR-Giants Range Granite, SB-Snowbank stock, SAG-Saganaga Granite, NL-Northern Light Gneiss.*

DISCUSSION OF AGES

Algoman granitic intrusive and metamorphic rocks

The granites and metamorphic rocks in northeastern Minnesota and adjacent areas in Ontario (fig. 1) that were involved in the Algoman orogeny give K-Ar and Rb-Sr biotite ages of 2400-2600 m.y. On the basis of these biotite ages it has been assumed that the Algoman orogeny reached its culmination 2500 m.y. ago (Goldich and others, 1961). U-Pb zircon ages for these rocks are discordant and give ages of 2600-2800 m.y., depending somewhat on the model used to explain the discordance (Anderson, 1964; Anderson and Gast, 1964; Davis and others, 1963).

Hornblendes from the Northern Light Gneiss, the Giants Range Granite, the Saganaga Granite, and from hornblende schist of the Knife Lake Group give ages ranging from 2500-2770 m.y. (fig. 1).

Sample M5219 from the Giants Range Granite, which was taken only 2.7 kilometers from the contact with the Duluth Gabbro Complex has a hornblende K-Ar age of 2500 m.y. Biotite from the same sample has an apparent K-Ar age of 1540 m.y., which indicates loss of radiogenic argon resulting from the thermal metamorphism associated with the intrusion of the Duluth Gabbro about 1100 m.y. ago. Comparison of these two ages with those from the Snowbank stock (Hanson and Gast, 1967) (fig. 2), which similarly was affected by the gabbro, suggests that the hornblende K-Ar ages on sample M5219 should be only slightly affected.

In southwestern Minnesota the Morton Quartz Monzonite Gneiss and the Montevideo Granite Gneiss of Lund (1956) are possibly 3500 m.y. old, as indicated by U-Pb zircon ages (Catanzaro, 1963; Stern, 1964), and were involved in a regional metamorphism during the Algoman orogeny. Hornblendes from the Morton Quartz Monzonite Gneiss, the Sacred Heart Granite, and the hornblende-pyroxene gneiss at Granite Falls give ages that range from 2590 to 2760 m.y. and average 2680 m.y. (fig. 3). The region also was affected by a thermal metamorphism at about 1800 m.y., which is reflected by the apparent biotite ages of 1800 m.y. from rocks that crop out between Granite Falls, Minnesota and Milbank, South Dakota (Goldich and others, 1961). Possibly this thermal event induced partial loss of radiogenic daughters from biotites in other parts of the Minnesota River valley as well, but apparently did not induce loss of argon from the hornblendes.

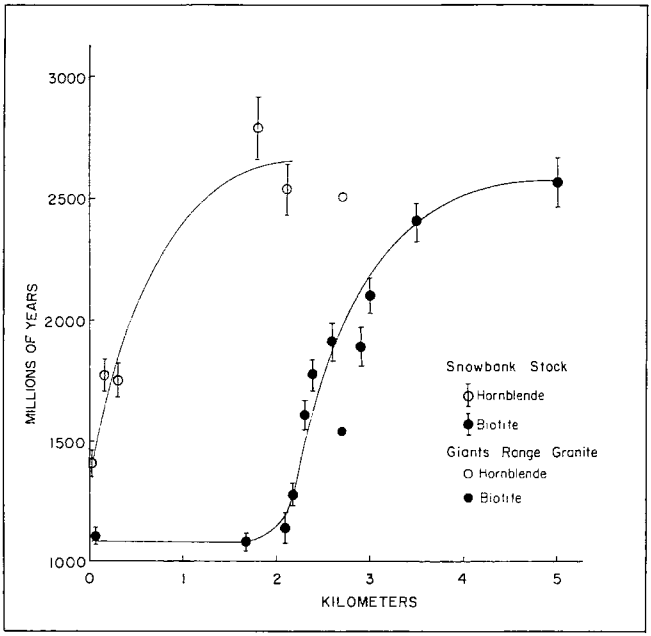


Figure 2--K-Ar ages for hornblende and biotite for the Snowbank stock and for sample M5219 from the Giants Range Granite plotted against the distance from the contact with the Duluth Gabbro Complex. *It can be seen that the biotite from the Giants Range Granite virtually fits the curve for the Snowbank stock biotites of the same grain size 0.3 - 0.8 mm diameter. This agreement suggests that the shape of the Duluth Gabbro and the dip of the basal contact were essentially the same over the two areas. Hanson and Gast, 1967, give a more comprehensive discussion of the problem.*

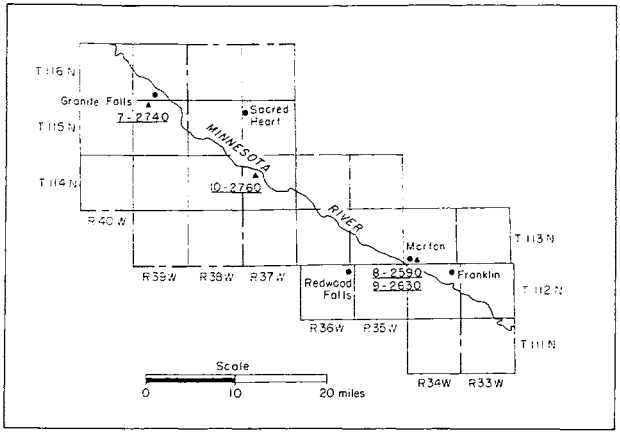


Figure 3--Map showing location of samples and K-Ar ages for hornblende in millions of years for granites and gneisses in the Minnesota River valley, southwestern Minnesota. *Sample numbers refer to table 1.*

The average age for the nine hornblendes involved in the Algoman orogeny (excluding M5219) is 2670 $\pm$ 30 m.y.; the range in age is from 2570 to 2760 m.y. (fig. 4). The hornblende K-Ar ages are as great or greater than the maximum biotite K-Ar ages and essentially equivalent to the zircon U-Pb ages for the rocks involved in the Algoman orogeny. The fact that associated biotite ages are lower may reflect heating over long periods of time at temperatures of about 300° C. during the later stages of the Algoman orogeny. The biotite ages may also show the effect of later thermal events as is the case in the Minnesota River valley.

Penokean Granitic Intrusive Rocks

A hornblende concentrate from the Rockville Porphyritic Granite of Woyski (1949) at Rockville gives a K-Ar age of 1800 m.y. (fig. 5). Although too much emphasis should not be placed on one mineral age, this age is older than the K-Ar age of 1650 m.y. for biotite from the same rock (Goldich and others, 1961), and is more comparable to the biotite ages (1750-1800 m.y.) of the older tonalites in east-central Minnesota.

Basaltic Intrusive Rocks

Except for the basaltic dikes near Granite Falls (Hanson and Himmelberg, in press; Goldich and others, 1961) and certain lamprophyres, it has been assumed that most of the dikes in Minnesota are of Keweenawan age (Grout and others, 1951, p. 1057). The Keweenawan intrusive rocks--in particular the Duluth Gabbro Complex--occur along the north shore of Lake Superior and give ages of about 1100 m.y. (Goldich and others, 1961; Silver and Green, 1963; and Faure, 1964).

Three samples of basalt dikes that cut the St. Cloud Red Granite and the Rockville Porphyritic Granite of Woyski (1949) in the vicinity of St. Cloud give K-Ar whole-rock ages of 1280, 1460, and 1570 m.y. These whole-rock ages may have been reduced, however, by low temperature diffusion of argon. Although it has been found that basaltic rocks on the order of millions of years old give reliable whole-rock K-Ar ages (McDougal, 1964; Dalrymple and Hirooka, 1965), older basaltic material on the order of hundreds to thousands of millions of years may give ages that are low, presumably because of low-temperature diffusion of argon (Burwash and others, 1963; McDougall and others, 1963; Leech, 1966). Assuming that the dikes in the vicinity of St. Cloud were intruded at the same time, it is concluded that they are between 1570 m.y., the oldest whole rock K-Ar age, and 1800 m.y., the age of the host rock.

In the vicinity of Granite Falls, field relations show that mafic igneous rocks intruded gneisses during at least two separate periods. A hornblende K-Ar age from a tholeiitic diabase dike gives an age of 2080 m.y. Hornblendes from hornblende-andesite dikes give ages of about 1750 m.y. (Hanson and Himmelberg, in press). Hall (1899) may have been correct in assuming that there is a relationship between the time of intrusion of the basaltic dikes in the St. Cloud area and at least the hornblende-andesite dikes in the Granite Falls area; however, both sets of dikes are older than the

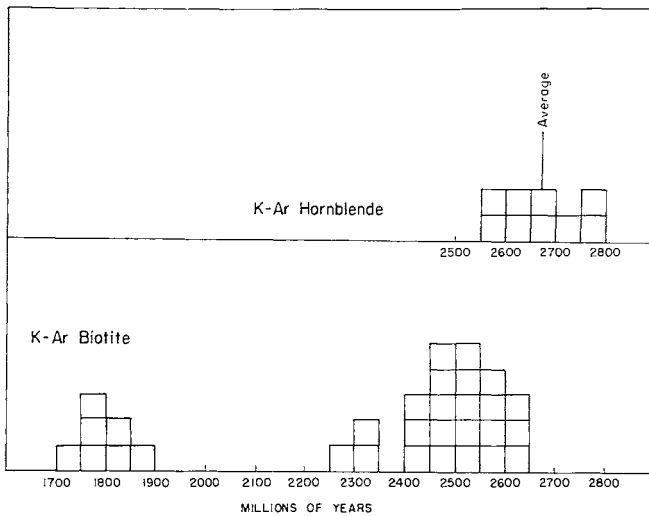


Figure 4--Histogram of K-Ar ages of hornblende and biotite concentrates from igneous and metamorphic rocks involved in the Algoman orogeny in Minnesota and Ontario. *The 1700-1800 m.y. old biotites are from the Montevideo-Granite Falls area, where the ages were lowered due to loss of radiogenic argon during a thermal event 1700-1800 m.y. ago. A K-Ar age for hornblende from this area was not lowered. The K-Ar ages for biotite are from Goldich and others (1961).*

Keweenawan intrusive rocks of the North Shore.

In the Minnesota River valley, about 40 miles southeast of Granite Falls, the roughly circular Cedar Mountain Granophyre-Gabbro complex, which has a maximum dimension of half a mile, intrudes the Morton Quartz Monzonite Gneiss. Hornblende from the complex gives a K-Ar age of 1750 m.y., which agrees with the previously

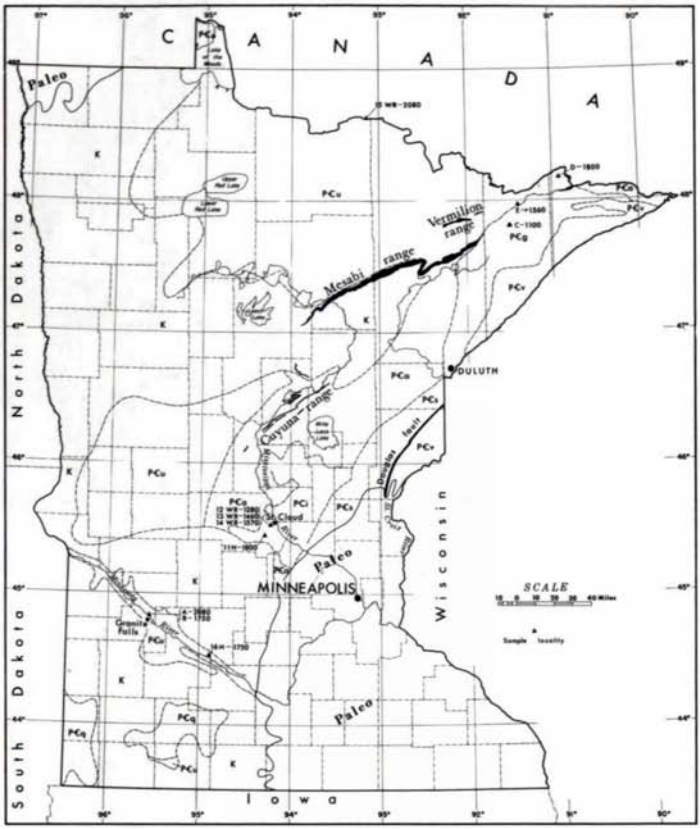
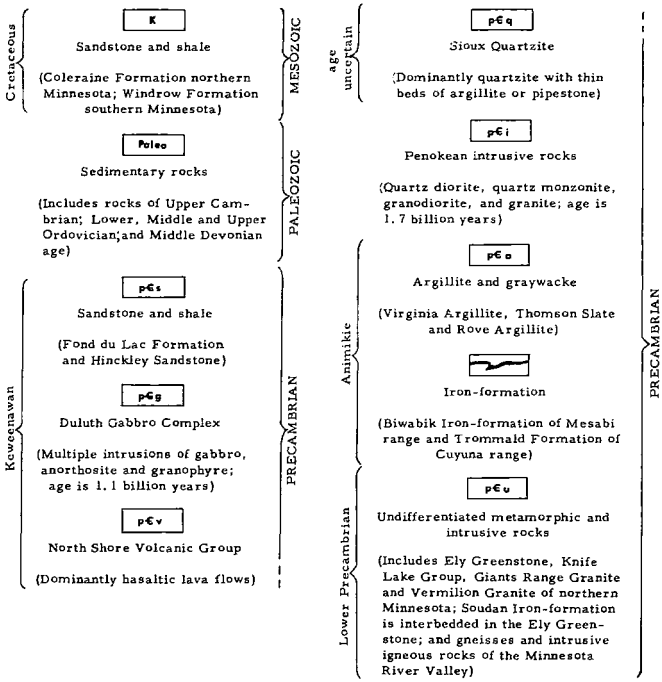


Figure 5--Generalized geologic map of Minnesota showing the location of samples and K-Ar ages in millions of years of basic intrusive rocks and a sample of Rockville Porphyry Granite (11-H). *H, hornblende; WR, whole rock. Sample A is for hornblende from a tholeiitic dike and B is the average hornblende age for hornblende-andesite dikes at Granite Falls, Minnesota. C is the age of the late Keweenawan intrusives and extrusives, D is a K-Ar age for biotite from a lamprophyre dike that cuts the Saganaga Granite (Goldich and others, 1961, KA 70), and E is a minimum Rb-Sr age for biotite from a lamprophyre dike that cuts metasedimentary rocks of the Knife Lake Group (Hanson and Gast, 1967, BC7601).*

EXPLANATION



determined K-Ar biotite age of 1750 m.y. (Goldich and others, 1961). It is probable that the Cedar Mountain Granophyre-Gabbro complex is nearly contemporaneous with the hornblende-andesite dikes near Granite Falls.

In the vicinity of Rainy Lake, mafic dikes as much as 200 feet thick cut granites and gneisses that are 2600 m.y. old (Goldich and others, 1961; Davis and others, 1963). Whole-rock K-Ar ages of 2130 m.y. and 2040 m.y. were obtained on the chilled margin of an 180-foot-thick dike on Fransen Island. If low-temperature diffusion took place, this is a minimum age.

A lamprophyre dike that cuts metasediments of the Knife Lake Group near Snowbank Lake, Minnesota, gives a Rb-Sr age for biotite of 1560 m.y. ($Rb^{87}\lambda\beta = 1.47 \times 10^{-11} years^{-1}$). Comparison of this age with those of the Snowbank stock, which were lowered by the thermal metamorphism associated with the intrusion of the Duluth Gabbro, would indicate that the lamprophyre dike is approximately 2600 m.y. old (Hanson and Gast, 1967). A lamprophyre dike cutting the Saganaga Granite gives a K-Ar age for biotite of 1800 m.y. (Goldich and others, 1961).

Considering the uncertainties in interpreting whole-rock K-Ar ages and the paucity of data, the periods of basaltic intrusion in Minnesota agree with those recognized in Canada at 2100-2400 m.y., 1700-2000 m.y., and 1000-1200 m.y. (Leech, 1966; Burwash and others, 1963; Fahrig and Wanless, 1963; Van Schmus, 1964; Payne and others, 1965; and Fairbairn and others, 1960).

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REFERENCES CITED

Anderson, D. H., 1964, Uranium-thorium-lead ages of zircons and model lead ages of feldspars from the Saganaga, Snowbank, and Giants Range Granite of northeastern Minnesota: Unpublished Ph. D. thesis, University of Minnesota, 128 p.

Anderson, D. H. and Gast, P. W., 1964, Uranium-lead zircon ages and lead isotope compositions in two Algoman granites of northern Minnesota (abs.): Geol. Soc. Am. Special Paper 82, p. 3,4.

Burwash, R. A., Baadsgaard, H., Campbell, F. A., Cumming, G. L., and Folinsbee, R. E., 1963, Potassium-argon dates of diabase dyke systems, District of Mackenzie, N.W.T.: Trans. Can. Inst. Mining Met., v. 66, p. 303-307.

Catanzaro, E. J., 1963, Zircon ages in southwestern Minnesota: Jour. Geophys. Res., v. 68, p. 2045-2048.

Dalyrymple, G. B., and Hirooka, K., 1965, Variation of potassium-argon and calculated age in a late Cenozoic basalt: Jour. Geophys. Res., v. 70, p. 5291-5296.

Davis, G. L., Tilton, G. R., Aldrich, L. T., Hart, S. R., Steiger, R. H., and Kouvo, O., 1963, The ages of rocks and minerals: in Annual Report of the Director of the Geophysical Laboratory, 1962-63, p. 218-229.

Fahrig, W. F. and Wanless, R. K., 1963, Age and significance of diabase dyke swarms of the Canadian Shield: Nature, v. 200, p. 934-937.

Fairbairn, H. W., Hurley, P. M., and Pinson, W. H., 1960, Mineral and rock ages at Sudbury-Blind River, Ontario: Proc. Geol. Assoc. Canada, v. 12, p. 41-66.

Faure, G., 1964, The age of the Duluth Gabbro complex and the Endion sill by the whole rock Rb-Sr method: in Twelfth Annual Prog. Rept. for 1964, No. 1381-12, p. 255-257. Dept. of Geology and Geophysics, Massachusetts Institute of Technology, Cambridge.

Goldich, S. S., Nier, A. O., Baadsgaard, H., Hoffman, J. H., and Krueger, H. W., 1961, The Precambrian geology and geochronology of Minnesota: Minn. Geol. Survey Bull. 41, 193 p.

Grout, F. F., Gruner, J. W., Schwartz, G. M., and Thiel, G. A., 1951, Precambrian stratigraphy of Minnesota: Geol. Soc. Am. Bull., v. 62, p. 1017-78.

Hall, C. W., 1899, The gneisses, gabbro-schists, and associated rocks of southwestern Minnesota: U.S. Geol. Survey Bull. 157, 116 p.

Hanson, G. N. and Gast, P. W., 1967, Kinetic studies in contact metamorphic zones: Geochim. Cosmochim. Acta, v. 31, no. 7, p. 119-153.

Hanson, G. N. and Himmelberg, G. R., 1967, Ages of mafic dikes near Granite Falls, Minnesota: Geol. Soc. Am. Bull., v. 78 (in press).

Hart, S. R., 1961, The use of hornblendes and pyroxenes for K-Ar dating: Jour. Geophys. Res., v. 66, p. 2995-3001.

Hart, S. R., 1964, The petrology and isotopic mineral-age relations of a contact zone in the Front Range, Colorado: Jour. Geol., v. 72, p. 493-535.

Leech, A. P., 1966, Potassium-argon dates of basic intrusive rocks of the District of Mackenzie, N.W.T.: Can. Jour. Earth Sciences, v. 3, p. 389-412.

Lund, E. A., 1956, Igneous and metamorphic rocks of the Minnesota River valley: Geol. Soc. Am. Bull., v. 67, p. 1475-1490.

McDougall, I., 1964, Potassium-argon ages from lavas of the Hawaiian Islands: Geol. Soc. Am. Bull., v. 75, p. 107-128.

McDougall, I., Compston, W., and Hawkes, D. D., 1963, Leakage of radiogenic argon and strontium from minerals in Proterozoic dolerites from British Guiana: Nature, v. 198, p. 564-567.

Payne, A. V., Baadsgaard, H., Burwash, R. A., Cumming, G. L., Evans, C. R., and Folinsbee, R. E., 1965, A line of evidence supporting continental drift: Reprinted from the Upper Mantle Symposium New Delhi 1964 of the International Union of Geological Sciences, p. 83-93.

Rose, H. J., Adler, I., and Flanagan, F. J., 1962, Use of La_2O_3 as a heavy absorber in the x-ray fluorescence analysis of silicate rocks: U.S. Geol. Survey Prof. Paper 450-B, p. 80-82.

Silver, L. T. and Green, J. C., 1963, Zircon ages for middle Keweenawan rocks of the Lake Superior Region (abs.): Trans. Am. Geophys. Union, v. 44, no. 1, p. 107.

Stern, T. W., 1964, Isotopic ages of zircon and allanite from the Minnesota River valley and LaSal Mountains, Utah (abs.): Trans. Am. Geophys. Union, v. 45, p. 116.

Thomas, H. A., 1963, Isotopic ages on coexisting hornblende, mica, and feldspar (abs.): Trans. Am. Geophys. Union, v. 44, p. 110.

Van Schmus, R., 1965, The geochronology of the Blind River--Bruce Mines area, Ontario, Canada: Jour. Geol., v. 73, p. 755-780.

Woyski, Margaret S., 1949, Intrusives of central Minnesota: Geol. Soc. Am. Bull., v. 60, p. 999-1016.

APPENDIX

Sample Locations

1. IL-2 is hornblende schist, a metamorphosed phase of the Knife Lake Group, from road cut on west side St. Louis county road 21, north-central part sec. 6, T. 60 N., R. 13 W., Minnesota (collected by P. K. Sims).

2. M5217 is from the Giants Range Granite, first large outcrop south of the Ely Greenstone on State Highway 1. About 700' south of line between section 2 and 11 on west line of section 11, T. 62 N., R. 12 W., St. Louis Co., Minnesota.

3. M5219 is from the Giants Range Granite on State Highway 1, on the line dividing sections 25 and 36, T. 62 N., R. 12 W., St. Louis Co., Minnesota.

4. M5274 is from the Northern Light Gneiss, Savage Bay, Northern Light Lake, lat. 48° 15.6' N, long. 90° 42.8' W, Thunder Bay District, Ontario (collected by D. H. Anderson).

5. M5275 is from the Saganaga Granite in Northern Light Lake, immediately south of Nelson Bay, lat. 48° 13.4' N, long. 90° 41.8' W, Thunder Bay District, Ontario (collected by D. H. Anderson).

6. M5277 is from the Saganaga Granite on southern end of eastern branch of bay connecting Sea Gull Lake and Saganaga Lake, lat. 48° 10.0' N, long. 90° 52.6' W, Cook County, Minnesota (collected by D. H. Anderson).

7. M8185 is from a hornblende-pyroxene gneiss near Granite Falls, SE1/4 NW1/4 sec. 4, T. 115 N., R. 39 W., Yellow Medicine County, Minnesota (collected by G. R. Himmelberg).

8. M8318 is from an abandoned quarry in Morton Quartz-Monzonite Gneiss west of Railroad Spur NW corner, SW1/4 sec. 32, T. 113 N., R. 34 W., Renville County, Minnesota.

9. KA338 Same location as M8318 (collected by S. S. Goldich).

10. KA336 is from Sacred Heart Granite consisting of pegmatitic hornblende and red potassium feldspar on SW corner sec. 8, T. 114 N., R. 37 W., Redwood County, Minnesota (collected by S. S. Goldich).

11. RH-21 from the Rockville Porphyritic Granite, quarry one-half mile south of Rockville, SE1/4 NW1/4 sec. 16, T. 123 N., R. 29 W., Stearns County, Minnesota (collected by R. K. Hogberg).

12. M8300 is from a four-foot fine-grained basaltic dike which strikes N. 70° E., has a vertical dip, and cuts the St. Cloud Red Granite in a quarry 1 1/2 miles south of the junction of Highways 23 and 52, in the southwest part of St. Cloud, NE1/4 SW1/4 sec. 20, T. 124 N., R. 28 W., Stearns County, Minnesota.

13. M8301 is from a fine-grained porphyritic basalt dike which cuts the St. Cloud Red Granite in a quarry near the center of the west line of section 20, T. 124 N., R. 28 W., Stearns County, Minnesota. The dike is poorly exposed and only a part of one contact can be seen.

14. M8302 is from a six-foot fine-grained basaltic dike which cuts the Rockville Porphyritic Granite in a quarry 4 1/2 miles east of Rockville and immediately north of Highway 23, Stearns County, Minnesota. The dike strikes N. 35° E.

15. M7052c consists of two pieces from the chilled border on the SW edge of the dike on Fransen Island, which is the third island NW of Stop Island, lat. 48° 37.5' N, long. 93° 15' W. About 1/2 mile south of the International Boundary, Koochiching County, Minnesota. The dike is 180 feet thick and strikes N. 40° W.

16. M8317 is from the granophyre-gabbro of the Cedar Mountain Complex on the northwest edge on top of the annular outcrop in the SE1/4 NE1/4 sec. 15, T. 112 N., R. 34 W., about 1 mile south of Franklin, Redwood County, Minnesota.