URANIUM, THORIUM, AND POTASSIUM CONTENT OF PRECAMBRIAN ROCKS, UPPER PENINSULA OF MICHIGAN AND NORTHERN WISCONSIN

SUPPLEMENT TO GJBX-48(76)

Uranium and Thorium Occurrences in Precambrian
Rocks, Upper Peninsula of Michigan and Northern
Wisconsin, With Thoughts on Other Possible Settings

Submitted to: Bendix Field Engineering Corporation
Grand Junction, Colorado

Contract Number: AE(05-1)-1651

Department of Geology and Geological Engineering
Michigan Technological University
Houghton, Michigan 49931

February 1977

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Principal Investigator

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INTRODUCTION

On April 30, 1976, I submitted the proposal for this contract modification, and July 29, well into the summer, the contract was signed. Thus, it was not possible to secure a research assistant until the fall. I received approval from ERDA on May 14, 1976, to purchase lead shielding for the gamma-ray spectrometer counting chamber. During the summer the chamber was manufactured and assembled with non-ERDA funds. In the fall we collected some additional samples, and between September and early January we established the procedures for counting and data reduction. In all, 54 samples were analyzed for U, Th, and K for the purpose of providing more extensive data on the abundance of these radioelements in the various bedrock formations of the study area.

The gamma ray counting chamber was designed and constructed by Jefferson Barstow. Preliminary information on design was provided by Drs. D.C. Noble and W.I. Rose, Jr., of this department. Dr. Noble also made numerous suggestions regarding improvements to the analytical procedures. About half of the lead was donated by the Department of Metallurgical Engineering, and the 400 channel TMC scintillation spectrometer was made available by the Department of Physics. All of the sample preparation and counting, and some of the collecting was done by Mrs. Carol Johnson, who served as Research Assistant. Dr. R.G. Schmidt provided the specific locations of the eleven samples of Archean granites and gneisses from western Gogebic County for which he had published earlier the potassium, uranium, and thorium abundances (Schmidt, 1976). Without all of this help and cooperation this work could not have been accomplished.

EQUIPMENT

The counting chamber is a cube, 22 inches to the side, with 4-inch

lead walls and a 14-inch cavity, and sits on a wooden table constructed of 4" x 4" lumber. The door is bricked with lead. The base has a round hole in which the 3" x 3" NaI crystal sits. The chamber contains 1½ tons of lead.

The counter is a 400 channel TMC scintillation spectrometer, connected to a teletype reader, producing both hard copy and punched tape. The tape is converted by an appropriate program into peak height/channel number plots.

PROCEDURE¹

Field samples are crushed to minus 0.2 inch, and about 300-gm splits are placed into cylindrical plastic containers (3½" x 1.4" high). On these the cover is taped shut with black electric tape. The containers are then numbered, weighed, and set aside for about two weeks.

Standards, some in triplicate, were prepared in the above manner, of material that also had been analyzed by neutron activation for U and Th at the Phoenix Memorial Laboratory of the University of Michigan, Ann Arbor. Some of these samples were analyzed also for K₂O by AA, using the fusion technique.

In view of the short time period for this contract and our lack of previous experience, and in order to assure the best counting statistics, we counted all samples for 1000 minutes (17 hours), and a few also for 400 minutes (6½ hours). Our experience now shows that 400 minutes is adequate.

We ran blanks (empty containers) from time to time to establish

¹ Johnson, Carol A., 1977, Procedure for gamma-ray spectrometry of rocks for U, Th, and K: Research report to be submitted, Dept. of Geol. and Geol. Engrg., M.T.U., Houghton.

background. We think that the few runs that showed higher background, may indicate inadequate ventilation and the leakage of gases from the building itself.

Our output for the three months was about 80 analyses.²

I tried several techniques for determining the elemental abundances from the output from replicate analyses of standards. All data was reduced to counts per minute per gram:

- 1) The technique of Bunker and Bush (1966), to measure directly the quantities of U and Th.
- 2) Measuring the area of the K^{40} , Bi^{214} , Tl^{208} peaks (minus backgrounds) on the c.p. 1000 min/channel number chart.
- 3) Measuring the height of these peaks.
- 4) Taking the highest count for the channel from the hard copy and subtracting the background.

The tests were made in the above sequence, with the hope that the first would be the best technique.³ Instead I found the first to be quite time-consuming, and the last technique to be as precise as the others, and much more rapid.

² Three months work period	= 12 weeks
Deduct 2 weeks for first group of samples to achieve equilibrium	-2
Total work period	= 10 weeks
10 weeks = 50 work days or 70 elapsed days	
No. of analyses of standards (19) and blanks (8)	25
No. of analyses of unknowns	54
Total no. of analyses	79

³We have learned that Bunker and Bush have stopped using this technique in favor of a rapid analysis technique.

PRECISION AND ACCURACY

I prepared standardization curves on log/log paper, and drew the best 45° line through the points, by eye, paying particular regard to the higher counts and analytical values. The detection limits for Bi²¹⁴ and Tl²⁰⁸ are near 2 ppm eU and 2 ppm eTh respectively.

I believe that the precision of this data is equal to or better than $\pm 20\%$ of the amount present, or 2 ppm, whichever is greater, for both eU and eTh.

RESULTS⁴

Data for the 54 additional samples analyzed are listed in Table 1, according to the stratigraphic position of the samples. In addition, this table shows the individual analyses reported as averages by Schmidt (1976), and average abundances as derived from the literature.

Estimates from the present data on U, Th, and K abundances in Precambrian formations in the study area appear in Table 2; Table 3 contains average data from various literature sources.

Results of our analyses are plotted on Plate 1 and Map 2. Note in particular that the McCaslin data are plotted in the lower portion of Plate 1. Some of the results also appear in Figures 1 to 5, which are up-dates of illustrations from my earlier report (Kalliokoski, 1976; see also Johnson, in Kalliokoski, 1976).

DISCUSSION OF DATA

As indicated in Table 1, many of the analyses represent "normal" rocks, but some are of radioactive material and of host rocks from

⁴For other U and Th analyses on Michigan rocks see Johnson, Carol A., Modes of occurrences of uranium and thorium in the Precambrian rocks of the Upper Peninsula of Michigan. M.S. thesis in preparation.

uranium showings. These show higher values which should not be considered as representative of the lithologic unit regionally. With this proviso, the new data supports the conclusions in my earlier report.

In particular, the data confirms the observation of Malan and Sterling (1969) that the Red River Porphyritic Quartz Monzonite has a considerably higher abundance of uranium than normal granites (Clark, Peterman, and Heier, 1966) and of Precambrian rocks in general (Farquharson, 1976; Fahrig and Eade, 1968; Shaw, 1967; Sterling and Malan, 1969). This is the most important finding of this study. It should be noted that rocks of the Bear geological province of Canada (Burwash and Cumming, 1976) and some pegmatites and microgranites from the Superior province in Manitoba and Ontario (Farquharson, 1976) show high values. It is noteworthy that the quartz monzonite shows a Th/U ratio generally below 3, perhaps denoting that the excess uranium occurs free of accessory minerals.

The data show that some of the older Archean granitoid rocks (+3.3 b.y.) contain higher U-Th abundances locally. The fact that the Th/U ratio is between 4 and 10 for most of these high values suggests that the cause of radioactivity may be in some accessory mineral.

CONCLUSIONS

1) Using a 1000-minute counting period and one chamber, one can achieve an analytical output of a sample a day. Using a 400-minute counting period, one can put in a sample at 8 a.m., remove it before 5 p.m., and put in another for the night run, thereby doubling output.

2) Estimates of the general U, Th, and K abundances can be made from the data in Table 1. However, the data points are not sufficiently closely spaced to allow for contouring these values on the geological base map.

Indeed at this time such a map could be misleading in its implied accuracy; anyone can draw their own contours on the map should they so desire, from the data in Table 2.

3) The Red River Quartz Monzonite facies of the Wolf River batholith of Wisconsin does contain higher than normal abundance of U as reported by Malan and Sterling (1969).

4) The data in Tables 2 and 3 suggest that the uranium content in the Lower Precambrian granites and gneisses may be on the high side of average values, but that other areas are known on the Canadian Shield where even higher values are common.

5) I interpret eTh/eU values in the range of 4 to about 10 to the presence of some syngenetic radioactive accessory minerals. I interpret a lower ratio to suggest the presence of supergene uranium. Uranium in excess of 10 ppm eU and with an eTh/eU ratio around 2 suggests to me the presence of supergene uranium at an abundance level probably not characteristic of the particular rock formation over more than a small area.

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TABLE 1

K, U, AND TH CONTENT OF PRECAMBRIAN ROCKS, MICHIGAN AND WISCONSIN

			Sp. No.	%K ₂ O	ppm eU	ppm eTh	Analyses Used in Table 2
Age Unknown	Upper Precambrian(?)	Jacobsville Sandstone, Military Hill - Sec. 34, T49N, R35W	76-200	1.3	<<2	<<2	*
-1.1 b.y.*	Upper Precambrian Rocks, Michigan	Nonesuch Shale, Black River Harbor, Michigan - Sec. 3, T49N, R46W	76-205	1.5	<2	7	*
		Felsite, Unnamed Formation - Sec. 29, T49N, R45W	76-206	3.6	3	21	*
		Chippewa Felsite, Copper Peak - Sec. 32, T49N, R46W	76-204	4	4	30	*
		Red Felsite, Bergland	760	6.5	8	36	*
		Flow-banded Felsite, Bergland	761	4	5	36	*
		Epidotized Felsite Porph., Bergland	762	3.4	6	36	*
		Quartz Fs. Porph., Bergland	763	4.2	4	25	*
		Andesitic Lava, Portage Lake Lava Series - Sec. 23, T48N, R47W	76-203	2	3	15	*
		Kallander Creek Formation - Sec. 1, T47N, R46W	76-202	1	<<2	4	*
		Siemens Creek Formation - Sec. 4, T47N, R45W	76-201	.9	<<2	2	*
		Bessemer Quartzite - Sec. 12, T47N, R47W	76-215	1.6	<<2	2	*
1.5 b.y.	Middle Precambrian Granitic Rocks, Wisconsin	Radioactive pegmatite, Anklaam rock pile #1	76-107	17	180	350	
		Radioactive pegmatite, Anklaam rock pile #1	76-107B	17	200	350	
		c.g. Bi Gr., Anklaam rock pile #2	76-108	13	110	170	
		Granite, Anklaam rock pile #3	76-109	8	35	65	*
		Aplite, 230' NE of Anklaam Pit #3	76-110	7.5	18	72	*
		Porphyritic Gr., 200' E of Anklaam pit #3	76-111	5.5	16	52	*
		f.g. gy BiGrGn, Radies Shaft	76-112	6.5	22	68	*
		Biotite peg., Radies Shaft	76-113	7	14	40	*
		Pink BiGr, Radies Shaft	76-114	6.5	22	68	*
		GyGrGn with reddened veinlets, Radies Shaft	76-115	6.5	28	92	
		c.g. pegmatitic Hb Gr., "Radies Farm"	76-116	5.5	11	38	*
		c.g. pink Gr., Marion ball park	76-117	6.5	11	31	*
		BiSchist schliere in Gr., "F & K Claims", E of rd.	76-118	5.2	28	35	
		Hb-Bi-Chl. Gr., "F & K Claims", E of rd.	76-119	5.2	18	31	*
		Hb Gr host to #118, "F & K Claims", E of rd.	76-120	5.2	19	25	*
		f.g. white Hb Gr., "F & K Claims", W of rd.	76-121	10	<2	3.5	*
		Radioactive peg., dump, "uranothor. locality", Tigerton Dells	76-122	15	90	350	
		Porph. Bi Gr, Ca 100' N of road, above loc., Tigerton Dells	76-123	6.5	12	58	*
-1.8-1.9 b.y.(?)	Middle Precambrian McCasin Formation, Wisconsin	Conglomerate, McCasin Fm., Carter Fire Tower	76-124	.4	2	46	*
		Quartzite with dissem. hem., McCasin Fm., Carter Fire Tower	76-125	<<.1	<<2	36	*
		Conglomerate, McCasin Fm., Carter Fire Tower	76-127	<<.1	<<2	36	*
1.9-2.0 b.y.	Middle Precambrian Rocks, Michigan	Tyler slate and gk., US-2 at 51, Ironwood Sec. 13, T46N, R2E	76-211	2.3	3	7	*
		Emperor volc. bx., Marinesco - Sec. 20/29, T47N, R43W	76-207	1.0	0	15	*
		Palms Quartzite, Radio Hill, Wakefield Sec. 10, T47N, R50W	76-209	.9	<<2	14	*
		Palms Quartzite, chortitized, Radio Hill, Wakefield Sec. 10, T47N, R50W	76-210	4	2	9	*
?1.5-2.4	Granite Erratics, near Iola, Wisc.	Boulder, near Iola, Wisconsin	76-103	.9	<2	6	
		Boulder, near Iola, Wisconsin	76-104	5.2	9	52	
		Boulder, near Iola, Wisconsin	76-106	5.2	3.5	20	
		Boulder, near Iola, Wisconsin	76-106a	5.2	90	36	
2.4	Altered Archean Metavolcanic Rock	Bi-chl. sch., E. of Montreal - Sec. 27, T47N R2E	76-214	1.5	<<2	3	*

2.6 b.y.	Archean Gneisses and Granites, Western Gogebic County, Michigan (Schmidt, 1976)	Puritan Quartz Monzonite ^{1,2,3}	2399	5.0	6.2	46	*
		Puritan Quartz Monzonite	430	5.5	6.7	37	*
		Puritan Quartz Monzonite	527	5.7	4.5	37	*
		Van Buskirk Gneiss, neosome	2468	5.0	4.8	24	*
		Whiskers Creek Gneiss	617	2.8	4.3	18	*
		Whiskers Creek Gneiss	620	3.4	5.3	7.4	*
		Whiskers Creek Gneiss	665	2.8	4.5	8.7	*
		Whiskers Creek Gneiss	650	3.6	5.7	3.9	*
		Sunset Creek Intrusives					
		Pegmatite	665	3.9	4.4	2.1	*
		Granite	527	5.3	5.7	21	*
		Granite	665	6.0	4.3	22	*
Age Unknown	Archean Granites and Gneisses	f.g. pinkish aplite, Black River, Wisconsin	76-100	2.4	3	13	
		Bi-Q-Pc gneiss, Black River, Wisconsin	76-101	4.2	2	12	*
+3.3 b.y.	Archean Granites and Gneisses	Aplitic gn; N of Watersmeet	751	5	14	62	*
		Aplitic gn; N of Watersmeet	752	2.5	<2	18	*
		Aplitic gn; N of Watersmeet	753	3	<2	12	*
		Sheared gn; N of Watersmeet	754	5	15	80	*
		Sheared gn; N of Watersmeet	755	5.2	<2	7	*
		Presque Isle Gr.	756	5.3	8	10	*
		Presque Isle Gr.	757	6	9	70	*
		Presque Isle Gr.	758	.8	4	34	*
		Presque Isle Gr.	759	4.2	8	34	*
		Presque Isle Gr. Gneiss - Sec. 28, T47N, R43W	76-208	5	11	53	*

¹Rapid rock analyses performed by the U. S. Geological Survey

²Fused pellet fluorometric analyses by Joseph Budensky and Roosevelt Moore, U. S. Geological Survey

³Instrumental neutron activation analyses by Jesse J. Warr, Jr., Fred O. Simon, U. S. Geological Survey

*This and other ages from Van Schmus (1976).

Table 2

Probable Representative Contents of K, U, and Th in Precambrian Rocks,
Upper Peninsula of Michigan and northern Wisconsin

			No. of Sps.	%K ₂ O	ppm eU	ppm eTh
Upper Precambrian	(?)Upper Keweenawan Upper Keweenawan	Jacobsville Sandstone	1	1.3	<<2	<<2
		Nonesuch Formation	1	1.5	<2	7
	Middle Keweenawan	Unnamed Formation (felsite)	1	3.6	3	21
		Portage Lake Volcanics (andesite)	1	2	3	15
		Portage Lake Volcanics (felsite)	5	4	5	32
	Lower Keweenawan	Kallander Creek Formation	1	1	<<2	4
		Siemens Creek Formation	1	0.9	<<2	2
		Bessemer Quartzite	1	1.6	<<2	2
Middle Precambrian		Red River Quartz Monzonite	12	5.8	17	46
		McCaslin Formation	3	0.1	<2	40
		Tyler Formation	1	2.3	3	7
		Emperor Volcanic Breccia	1	1	0	15
		Palms Formation	2	2.5	<2	12
Lower Precambrian	Upper Archean	Granites and Gneisses (Schmidt, 1976)				
		Puritan Quartz Monzonite	3	5.4	5.8	40
		Van Buskirk Gneiss;				21
		Quartz Monz. neosome		5.0	4.8	24
		Whiskers Creek Gneiss	4	3.1	5.0	9.5
		Sunset Creek Intrusives	3	5.1	4.8	15
		Metavolcanic Rock		1.5	<<2	3
	Upper or Lower Archean	Biotite Quartz Plagioclase Gneiss, Wisconsin	1	4.2	2	12
	Lower Archean	Gneiss near Watersmeet	5	4	5	30
		Presque Isle Granite	5	4	8	40

Table 3

Average Content of K, U, and Th in Granitic Rocks

%K ₂ O	ppm eU	ppm eTh	
4.3	4.7	20	Average silicic igneous rock (Clark et. al., 1966)
2.6	2.6	9	Average granodiorite (Clark et. al., 1966)
2.6	2.4	10	Average Canadian Shield (Shaw, 1967)
	8	36	Bear Province (Burwash and Cummings, 1976)
4.7	4.5	36	Pink Granodiorite (Farquharson, 1976)
4	1.8	30.7	Porphyritic Granodiorite (Farquharson, 1976)
5	14.7	46	Pegmatite/microgranite (Farquharson, 1976)
5	16	30	Caddy Lake Quartz Monzonite (Farquharson, 1976)

Sp. No.	% eK ₂ O	eU(ppm)	eTh(ppm)
76 - 100	2.4	3	13
76 - 101	4.2	2	12

Figure IV-5 - Outcrops of Precambrian gneiss overlain by sandstone on Black River, near Withie, Clark County.

Figure IV-6 - Outcrop maps of Fred Anklam farm occurrence, near Big Falls (Loc. W-1).

Sp. No.	% K_2O	eU(ppm)	eTh(ppm)	Location
76-107	20	180	350	
-107B	20	200	350	
-108	13	110	170	
-109	8	35	65	
-110	7.5	18	72	230' NE of 109
-111	5.5	16	52	150' E of 109

Figure IV-10 - Outcrop maps of uranium showings on Radies farm near Big Falls; a Radies Shaft (Loc. W-12); B, "Radies farm" (Loc. W-4).

Sp. No.	%eK ₂ O	eU(ppm)	eTh(ppm)
76-112	6.5	22	68
-113	7.0	14	40
-114	6.5	22	68
-115	6.5	28	92
-116	5.5	11	38

FIGURE 3

Figure IV-11 - Outcrop maps of uranium occurrences on "F and K Claims" (Loc. W-3); a, east of road; b, west of road.

Sp. No.	%eK ₂ O	eU(ppm)	eTh(ppm)
76-118	5.2	28	35
-119	5.2	18	31
-120	5.2	19	25
-121	10.0	< 2	3.5

FIGURE 4

Figure IV-13 - Outcrop map of uranothorite locality, Sec. 10/15, Tigerton Dells (Loc. W-7).

Sp. No.	% eK ₂ O	eU(ppm)	eTh(ppm)	Location
76 - 122	15	90	350	
- 123	6.5	12	58	about 300' S of 122

RADIOACTIVE OCCURRENCES

76-200 ← Sample number
180 ← eU in ppm

L E G E N D

Formations or units designated by predominant lithology

PALEOZOIC

- ISO Ordovician Limestone

UPPER PRECAMBRIAN OR CAMBRIAN

stj	cobaville Sandstone
UPPER PRECAMBRIAN (KEWEENAWAN)	
stf	Freda Sandstone
ns	Nonesuch Shale
ch	Copper Harbor Conglomerate
syk	Syenodiorite
fk	Felsite; felsite porphyry
ak	Andesite
dk	Keeweenawan diabase
bsk	Basalt
bsp	Portage Lake Lava Series
lss	South Range Lava Series
nk	Keeweenawan quartzite

MIDDLE PRECAMBRIAN

- | Iron River - Crystal Falls
Menominee Area	
ts	Stambaugh and Fortune Lakes Sates
gh	Huagwah Graywacke
tr	Riverston Iron Formation
cs	Quinn Creek Sandstone
gh	Baldwin Greenstone
ghm	Michiganite Graywacke
th	Hemlock felsic volcanics
gh	Hemlock Greenstone
gs	Goodrich Quartzite
lv	Vulcan Iron Formation
qt	Felch Formation (quartzite)
dt	Redwilde Dolomite
qs	Sturgeon Quartzite
cf	Fern Creek Formation

LOWER PRECAMBRIAN

gr	Granite
gn	Granitic to dioritic gneiss
hs	Metasediments of Solberg Schist and
Six Mile Lake Amphibolite
ake	East Branch Arkose
gs	Dinosaur Greenstone

gkm	Michiganite Graywacke
ib	Bijik Iron Formation
pmp	Clarksburg mafic pyroclastics
lg	Greenwood Iron Formation
sm	Michiganite Slate
qg	Goodrich Quartzite
in	Negaunee Iron Formation
ss	Samo Slate
qa	Ajibik Quartzite
sw	Wawa Siltst.
dk	Kona Dolomite
qm	Mesnard Quartzite
ce	Enchantment Lake Formation

gr	Granite
gn	Granitic to dioritic gneiss
sy	Syenite
gd	Granodiorite
di	Diorite
h	Hornblende schist and amphibolite
gb	Gabbro
db	Diabase
u	Ultramafic rocks
fak	Felsic agglomerate of Kitchi Schist
fcm	Felsic porphyry of Mona Schist
ftm	Felsic tuff of Mona Schist
mtm	Mafic tuff of Mona Schist
gm	Basaltic greestone of Mona Schist

SYMBOLS

- Geologic context
- Fault
- Keweenaw dike, projected mainly on the basis of negative magnetic expression
- Mainly native copper producing horizon, conglomerate or amygdaloid. Length indicates extent of mining along strike. Size of circle indicates past production in follow.
- > 1 billion pounds Cu
0.1 - 1 billion pounds Cu
1 - 100 million pounds Cu
- QUINCY MINE
ATLANTIC MINE
KINGSTON CONGLOMERATE
- ▲* Moderate native copper producer: conglomerate, amygdaloid or fissure type 1 million to 100 million pounds Cu
- ▲* Minor native copper producer; conglomerate, amygdaloid or fissure type < 1 million mining Cu
- △ Native copper prospect with surface and/or underground workings - no recorded production.
- X Native copper occurrences
- Precious metals prospect - retarded production.
- X Cu
X Au? Nonferrous metal prospect or occurrence, other than native copper.
- Native metal prospect or occurrence, probable of mineral not verified.

ABBREVIATIONS

Ag	Silver	Mo	Molybdenum
Au	Gold	Ni	Nickel
Cu	Copper	Pb	Lead

Notes:

- * Indicates fissure-type deposit
- † White Pine deposit principally chalcocite

PRELIMINARY GEOLOGIC MAP OF GREEN BAY SHEET EXPLANATION

CENOZOIC Qal Quaternary alluvium
PALEOZOIC Pz Paleozoic sedimentary rocks, undifferentiated
PRECAMBRIAN

Age	Wausau Area	Lohrville- Redgranite Area	Wolf River Batholith
Uncertain, possibly younger than 1450-1500 m.y.	lg mg mv	Leucogranite Metagabbro Mylonite (various ages, but some younger than 1450-1500 m.y.)	
1450-1500 m.y.	ng qsy sy spg hg	Mineral granite Quartz syenite Lamprophyre Syenite and nepheline syenite Stevens Point gray granite Hogarty hornblende granite	rgm Red River porphyritic quartz monzonite wrgm Wolf River hornblende granite and quartz monzonite wqgm Waupaca quartz monzonite

Uncertain, possibly 1450-1500 m.y.	g kqm ibc	Aplite Kalinke quartz monzonite Intrusive breccia complex	
Uncertain, possibly between 1450-1500 and 1640-1670 m.y.	qt	Quartzite	

1640-1670 m.y.	ghg gm lv	Granite Heights granite Quartz monzonite Felsic volcanic and volcaniclastic rocks	g Granite
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Uncertain, possibly 1640-1670 m.y.	di t mv	Diorite and quartz diorite Trachyte Nafic volcanic rocks	
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Uncertain, equal to or older than 1900 m.y.	gn	Gneiss	
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Lithologic units of uncertain age designation	gu m sch	Granite to quartz, diorite and equivalent gneiss, undifferentiated Metamorphosed mafic rocks Schist	an Anorthosite (intruded by granitic rocks of the Wolf River batholith)
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Symbols

Contact, dashed where approximate or inferred
Fault, dashed where approximate or inferred
Shear zone, mylonite

Samples dated by Rb-Sr whole rock methods
1450-1500 m.y.
1640-1670 m.y.

RADIOACTIVE OCCURRENCES

J. KALLIOKOSKI, 1977
E.R.D.A. Cont. E (05-1)-1651

76-200 ← Sample number
180 ← eu in ppm

Compiled by L.G. Medaris, Jr. and J.L. Anderson

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