Preliminary investigations of radioelement distribution in an Archean granite gneiss from drill hole MG-CR-2A, Republic area, Michigan

by

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ABSTRACT

Analyses of an Archean granitic gneiss (probably the Compeau Creek Gneiss) from drill hole MG-CR-2A have yielded anomalously high contents of uranium (average for 18 samples is 14.4 ppm) and anomalously low Th/U ratios (average of the ratios for 18 samples is 0.86). Disequilibrium within the ^{238}U-decay chain suggests that some labile uranium may be present, but the high grade of metamorphism of the gneiss and the low Th/U ratios suggest that most of the uranium is stably bound. The data suggest that the Compeau Creek Gneiss is an unlikely source for uranium concentrated by low temperature processes; however the possibility exists that this unit could have been a source for uranium that was concentrated by mechanical or high temperature processes.

INTRODUCTION

Several recent articles have suggested that many uranium deposits may have granitic rocks as their ultimate source (Barbier, 1968; Rosholt and others, 1973, Von Backstrom, 1974; Stuckless and Nkomo, 1978; Fehn and others 1978; and Nkomo and others, 1978). In conjunction with the NURE Program, we have started to investigate granitic rocks as potential sources for uranium deposits within the Upper Peninsula of Michigan.

Potential source rocks for uraniferous Precambrian quartz-pebble conglomerates, such as those in Canada, north of the study area, are of particular interest. All the granitic rocks in the vicinity of the Iron River quadrangle for which geochronologic data are available are thought to be Archean (Van Schmus and Woolsey, 1975; Sims and Peterman, 1976). Dated granitic units within and adjacent to the Iron River quadrangle include the Presque Isle Granite (Puritan Quartz Monzonite), the granite near Thayer of Fritts (1969) (both in the western part of the state, figure 1), the gneiss at Watersmeet, and the granitic rocks of the southern complex (Van Hise and Bayley, 1897) of the Marquette district (in the vicinity of Republic, figure 1).

The rocks of the southern complex crop out in the eastern part of the Upper Peninsula where they have been subdivided into the Compeau Creek Gneiss (Gair and Thaden 1968) and the Bell Creek Gneiss (Cannon and Simmons, 1973). In places the Compeau Creek Gneiss intrudes the Bell Creek Gneiss (Cannon and Simmons, 1973), but Rb-Sr whole-rock studies have failed to demonstrate any age difference between the two units (Van Schmus and Woolsey, 1975).

The Bell Creek Gneiss consists mainly of coarse-grained granitic gneiss with abundant megacrysts of microcline as much as 4 to 5 cm long (Cannon and Simmons, 1973). Subordinate amounts of mafic gneiss form concordantly interlayered bands of weakly to moderately foliated mafic gneiss.

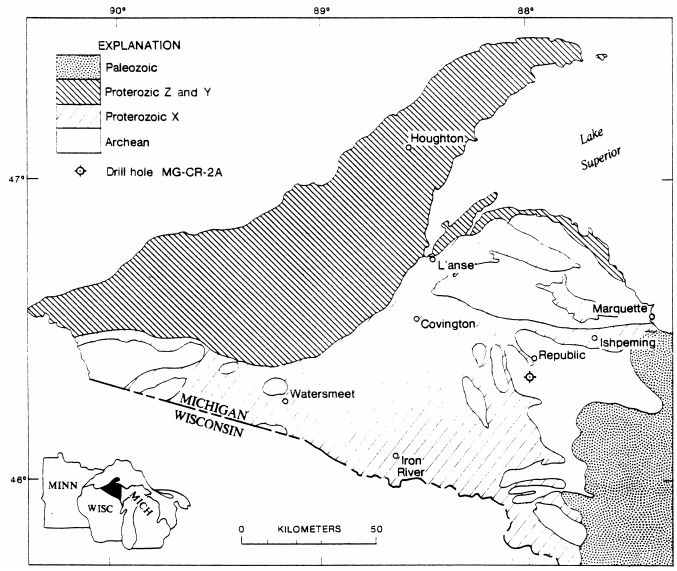

Figure 1.--Index map of the western upper Peninsula, Michigan showing the location of drill hole MG-CR-2A and generalized geology from Cannon and Gair (1970).

The Compeau Creek Gneiss is a more heterogeneous unit that ranges from tonalite to granite in composition and from massive to gneissic in structure (Cannon and Simmons, 1973). The Compeau Creek Gneiss is generally finer grained than the Bell Creek Gneiss and less granitic in composition.

Drill core analyzed in the current study was supplied by the Minnesota Geological Survey. The drill hole was located in the SW-1/4 of section 30, T 46 N, R 29 W, at latitude 46°21'08"N, and longitude 87°59'23"W (fig. 1). This location is on strike with and approximately 600 m beyond an area mapped as undivided Archean granitic rocks of the southern complex (Cannon and Klasner, 1976).

ANALYTICAL PROCEDURES

Samples of NX core were taken at approximately 3 m intervals over a depth range of 9.4 to 60.4 m. Each sample (10 to 18 cm long) was cleaned and crushed to -32 mesh. Total weight for individual samples ranged from 1.5 to 3.0 kg. A sample weighing 80 to 100 g was split from the bulk sample and pulverized to -100 mesh. Approximately 600 g of the -32 mesh material was used for radium-equivalent uranium (Raell), thorium, and potassium analysis by sealed-can γ-ray spectrometry (Bunker and Bush, 1966, 1967). These results (table 1) are precise and accurate to ± (2 percent +0.1 ppm) for RaeU and Th (2σ) and to ± (2 percent + 600 ppm) for K (2σ). Approximately 7 to 8 g of the -100 mesh material was used for uranium analysis by delayed neutron,(Millard, 1976). Results for U (table 1) are precise within ± 4% (2 σ) except for samples 41 and 198 (±6%) and sample 171 (± 14%). Results for thorium by delayed neutron were very imprecise or unattainable because of the very low Th/U ratios (Th/U <2), therefore, no thorium values are reported for this technique.

TABLE 1.--Radiocelement data for drill-core samples from drill hole MG-CR-2A, Republic Area, Michigan

Sample number	U[1/] (ppm)	RaeU[2/] (ppm)	Th[2/] (ppm)	K[2/] (wt%)	Depth (m)
31	5.98	5.8	5.3	2.11	9.4
41	2.55	1.9	4.6	4.93	12.5
51	8.8	7.3	1.1	4.28	15.5
61	39.6	32.2	28.7	3.86	18.6
71	16.9	15.6	9.8	4.55	21.6
81	13.3	11.9	17.2	5.43	24.7
91	17.2	17.7	14.8	1.95	27.7
101	32.5	30.8	32.8	2.88	30.8
111	7.87	6.6	10.7	6.10	33.8
121	24.9	21.1	28.9	3.59	36.9
131	19.5	17.3	18.9	4.20	39.9
141	15.5	14.2	17.2	3.58	43.0
151	19.1	17.8	22.9	3.71	46.0
161	14.0	13.6	9.6	3.25	49.1
171	.76	0.74	0.8	1.61	52.1
181	5.82	6.4	1.9	2.87	55.2
191	10.3	9.4	1.4	2.98	58.1
198	3.84	2.8	0.87	3.40	60.4

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RESULTS AND DISCUSSION

Results for uranium, radium equivalent uranium, thorium and potassium are reported in table 1 and summarized in figures 2 and 3. Uranium content ranges from 0.76 to 39.6 ppm and averages 14.4 ppm. Both the average content and upper limit of the range are anomalously high by comparison with the typical numbers for granites (Rogers and Adams, 1969a). In contrast, thorium content ranges from 0.8 to 32.8 ppm and averages 12.4 ppm. These figures are low relative to the typical average thorium content in granites and the typical lower limit of the thorium range in granite (Rogers and Adams, 1969b).

The average Th/U ratio of 0.86 is anomalously low by comparison with the typical range of values for granitic rocks which is 3 to 5 (Rogers and Adams, 1969b). The range in values for the Th/U ratio of 0.13 to 1.36 (fig. 2) is small, and the maximum value is surprisingly low. The relative proportions of uranium, thorium, and potassium are shown on figure 3. None of the analyzed samples plot close to the area of typical proportions for average granites. All samples are high in uranium relative to thorium, and most are high in uranium relative to potassium. Approximately 2/3 of the samples cluster about a normal range of Th/K ratios, but the rest are low in thorium relative to potassium.

The comparison of uranium content with the uranium content determined from the radioactive daughter products of ^{238}U (RaeU) shows that secular equilibrium is not present for most of the analyzed samples (fig. 2). Stuckless and Ferreira (1976) have postulated that the secular disequilibrium within the ^{238}U-decay chain may indicate that uranium is labile and that it may be easily mobilized by near-surface processes. There is a suggestion in the data in this paper that uranium is currently being leached in the near-surface environment. The average trend in the RaeU/U ratio with depth is towards unity (fig. 2). There is also a weak tendency for the Th/U ratio to decrease with depth.

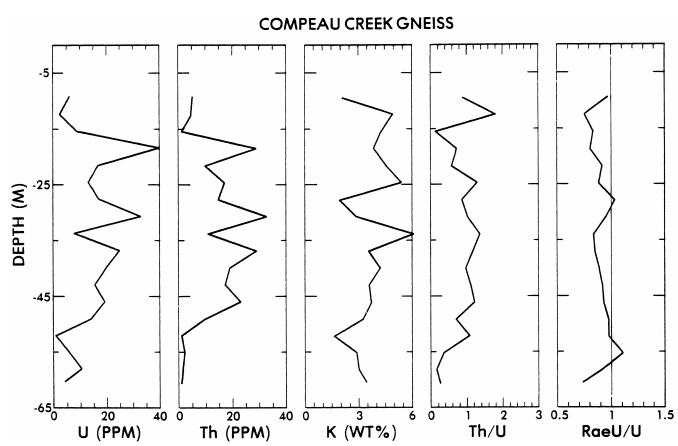

Figure 2.--Variation of radioelement contents and selected ratios as a function of depth in drill hole MG-CR-2A.

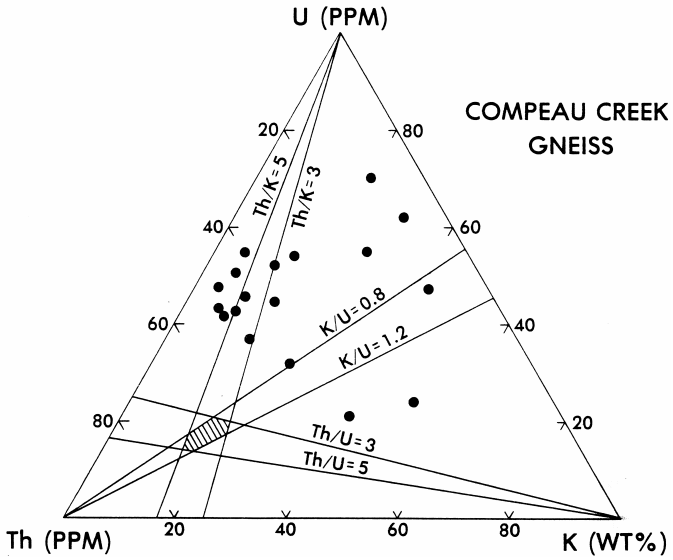

Figure 3.--Ternary diagram showing the relative abundances of U, Th, and K for samples from drill hole MG-CR-2A. The diagonally ruled field represents the greatest frequency of granites on a world-wide basis (Rogers and Adams, 1969a, b).

Although the decreasing Th/U ratio with depth could be due to mobilization of uranium in the upper portions of the drill hole, the trend could also be a function of the heterogeneous nature of the granite gneiss. The low potassium contents at 9.4 and 52.1 m depth (fig. 2) correspond to quartz-rich, microcline-poor samples, and the low potassium contents at 30.8 and 33.8 m depth correspond to layers of mafic segregates or xenoliths. The rest of the samples are fine-grained cataclastic to porphyroblastic, leucocratic gneisses. Biotite, muscovite, and garnet are common minor constituents. The only obvious radioactive phases are zircon and opaque metallic oxides that occur in biotite crystals,

The mineralogy, relative heterogeneity and textures of the analyzed samples suggest that M6-CR-2A was drilled in the Compeau Creek Gneiss rather than the Bell Creek Gneiss. Radioelement data also support this conclusion. Two analyses of the Bell Creek Gneiss have yielded U = 28.8 and 21.4 ppm, Th = 63.6 and 61.9 ppm, and Th/U =2.2 and 2.9 (Z. E. Peterman and M. R. Brock, written communications, 1979). The higher thorium contents and Th/U ratios are distinctly different from those obtained from drill hole MG-CR-2A.

CONCLUSIONS

On the basis of the data obtained thus far, we tentatively conclude that the Compeau Creek Gneiss is a possible source rock for uranium deposits, particularly of the quartz-pebble conglomerate or vein type. The high uranium contents and low Th/U ratios meet favorability criteria described by Nash (1979) for “fertile” granitic rocks in Washington and Idaho. These same criteria were initially present in the proposed source granite for uranium in sandstone near the Granite Mountains, Wyoming, but are now absent due to the relatively recent loss of uranium through low-temperature, near-surface leaching (Stuckless, 1979). The fact that the analyzed samples of the Compeau Creek Gneiss have both high uranium contents and very low Th/U ratios suggests that this unit has not lost any appreciable amount of labile uranium.

The RaeU/U ratios of less than 1 suggest that at least some of the uranium in the Compeau Creek Gneiss is labile (Stuckless and Ferreira, 1976), but it seems unlikely that large amounts of Teachable uranium are currently present. The Compeau Creek Gneiss was strongly metamorphosed in the late Archean, and the drill hole is located within the sillimanite zone of the early Proterozoic metamorphism. Dostal and Capedri (1978) have demonstrated that whole-rock uranium content decreases with increasing grade of metamorphism such that only firmly bound uranium remains after granulite metamorphism. If uranium was lost during metamorphism, the Compeau Creek Gneiss could have been a source for high temperature type deposits. However, it seems unlikely that the Th/U ratios were much lower initially than they are now, and hence a large uranium loss during metamorphism is unlikely. If most of the uranium in the Compeau Creek Gneiss is currently stably bound and if it has been stably bound since the late Archean, uranium could have been mechanically concentrated in the surrounding basins during the Archean and early Proterozoic. However, because much of the identifiable uranium is in zircon, the probability that the Compeau Creek Gneiss was a source for a uraninite-bearing quartz-pebble conglomerate seems low.

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