J KAU: Earth Sci., vol. 4, pp. 161-170 (1411 A.H./1991 A.D.)

Uranium and Thorium Enrichment in Haql Granite in Midyan Region Northwest of Saudi Arabia

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ABSTRACT. Thirty-four radiometric anomalies with high contents of U ahd Th were identified in an area east of Jabal Az-Zuhd in the Midyan Region, northwest of Saudi Arabia. These anomalies occur in Haql granite and associated aplites and pegmatites, mostly near its contact with a porphyritic mass of the younger Midyan granite. Fracturing, silicification and hematitization are common features in Haql granite. Uranophane was identified at one of the anomalous localities. High mobilization of U within the studied rocks was indicated by wide scatter in eU/U, Th/U and K/U ratios. It is suggested that the Haql granite was subjected to hydrothermal action causing redistribution and enrichment of U and Th.

Introduction

The Midyan Region is in the northernmost part of Saudi Arabia. According to Ramsay *et al.* (1986a) it consists mainly of five intrusive granitic suites of regional extent. These suites, known as the Muwaylih, Ifal, Atiya, Haql, and Midyan suites, were identified as lithostratigraphic units as well as rock associations, characterized by distinctive petrographic, mineralogic and chemical features. The suites are generally metaluminous, except the Midyan suite which is metaluminous to marginally peralkaline. The Atiya, Haql, and Midyan suites comprise post-tectonic plutons (Davies 1979, Ramsay *et al.* 1986b, Stoeser 1986). They may be correlated with suites in the Eastern Desert of Egypt (El-Gaby 1975, Ramsay *et al.* 1986a, Akaad and Noweir 1980, Hassan and Hashad 1990, Greenberg 1981 and Clark 1985).

Despite the age overlap between Haql and Midyan Suites, the peralkaline granites (Midyan) constitute the last granitic phase of Pan African thermal event and the de-

velopment of the Arabian Shield (Radain 1980, Stoeser 1986). Some of the plutons of the Midyan Region are metallogenically specialized or otherwise economically significant, and they contain two important rare metal deposits (Drysdal and Douch 1986, Jackson 1986, and Ramsay *et al.* 1986a and b). The present work describes new uranium-thorium occurrences in a granitic pluton of Haql suite characterized by highly anomalous contents of some trace elements. These occurrences were discoverd during a reconnaissance ground radiometric survey.

Study Area

The three granitic suites, the Atiyah, Midyan and Haql granites are represented in the study area (Fig. 1). The country rocks are mainly slightly metamorphosed volcanic, volcanoclastic and sedimentary rocks with minor ultramafic and dioritic rocks. The Atiya granite intrudes the volcanic and volcanoclastic rocks; and in turn is intruded by Haql and Midyan granites. The Haql granite, which is a part of Ghena pluton (Ramsay *et al.* 1986a and Ramsay 1986) is intruded by Midyan granite. The modal composition of 18 samples of the three granites is given in Figure 2. Atiyah granite is massive and medium- to coarse-grained equigranular, but porphyritic in certain parts. It has a sharp contact with the other two granites. The mineral composition are mainly perthite, oligoclase, and mica. Accessory minerals are sphene, zircon, apatite, fluorite and opaques. The Haql granite is commonly pink to buff, and is mostly hematitized and silicified. It is also generally highly fractured and deeply weathered. Essential minerals are perthite, quartz, biotite and subordinate plagioclase. Accessory minerals are ilmenite and titanomagnetite, zircon, apatite, fluorite and allanite. In some samples zircon and opaques are exceptionally abundant and opaques may occur as veinlets, as well as discrete grains and inclusions together with zircon within quartz. Midyan granite consists mainly of perthite, plagioclase, quartz, riebekite and biotite. Accessory minerals are zircon, fluorite, apatite and opaques. Aplite and pegmatite dykes are abundant in the studied area. The aplite dykes show similar silicification, hematitization and extraordinary enrichment in zircon and opaques to the Haql granite.

Radioactivity

Field radiometry

Radioactivity in the field was measured across the rock units by using a portable Exploranium GR-110 scintillometer that recorded total gamma-activity emitted from potassium thorium and uranium radiations. It displays the recorded gamma-activity in counts per second (cps). During the field reconnaissance, one second time constant was used, but for spot measurements time constant of ten seconds was used. The readings were recorded by placing the instrument on a flat surface to avoid the mass effect. A reconnaissance survey was conducted to determine anomalous spots and to record the level of radioactivity in the various rock units. The field measurements showed that the Haql granite is the most radioactive rock type in the studied area, followed by some pegmatites and aplites. Total gamma-activity in these units reached up to 1800 cps. One mineralized spot gave more than 10,000 cps (off scale of

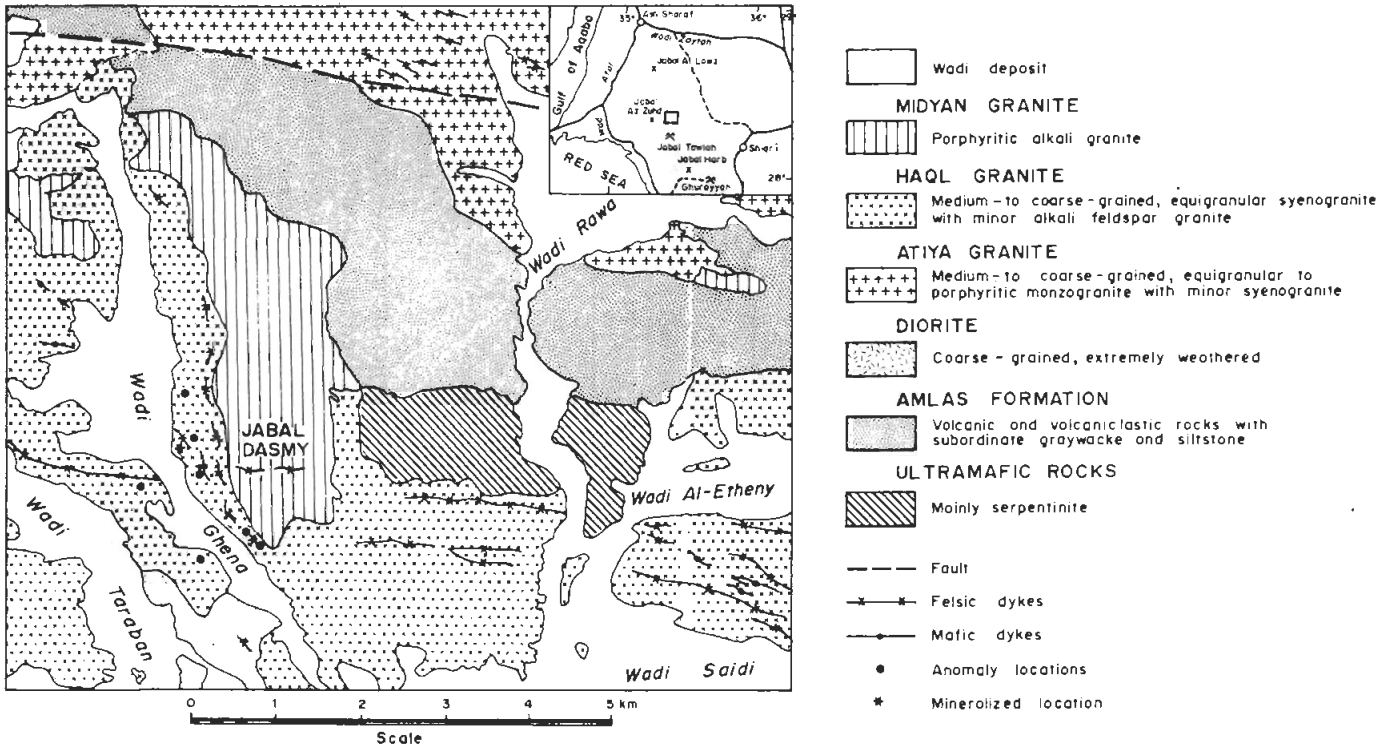

FIG. 1. Location map and the distribution of the anomalous spots in the studied area.

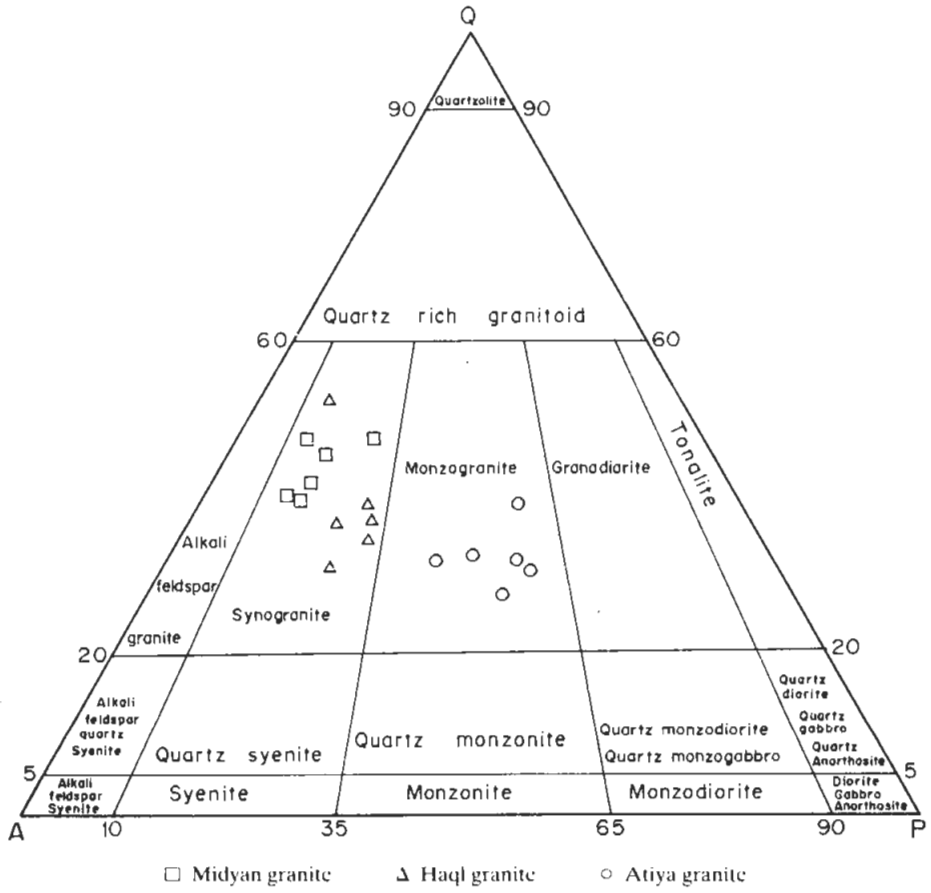

FIG. 2. Modal classification of granites in the study area according to Streckeisen (1976).

the scintillometer). Yellow secondary uranium mineral was recognized at the spot. A concentrate of the yellow mineral was analyzed by X-ray diffraction after heating to 1000°C. This analysis indicates that it is uranophane. The maximum gamma-activity of the wadi sediments and terraces is less than 120 cps. The volcanics and other country rocks are characterized by similar background level and attained maximum of 200 cps along some spots of the contact with granites. Ultramafic rocks showed the lowest gamma-activity, less than 100 cps.

The result of 191 measurements on the three granite types together with pegmatite and aplite dykes indicate that the Haql granite, as well as aplite and pegmatite dykes host the most radioactive localities, but the other two granites are barren. The calculated threshold value for granitic rock types in the studied area is 400 cps (Al-Fotawi 1989). A total of 34 anomalies in Haql granite, aplites and pegmatite where the radioactivity was above this level were recorded. These anomalies are of very limited

extent and die out within less than a meter. The host rocks are mostly highly weathered, fractured, hematitized and silicified. Figure 1 shows the locations where anomalies of > 700 cps occur, as well as the location of the mineralized spot.

Spectrometry

Fifty-five samples from the three granite types and the pegmatite and aplite dykes, were assayed by a Gull beta-gamma-spectrometry, following the method of Gazzaz and Hashad (1988). The samples were selected to represent the whole range of gamma–activity recorded in the field. Because of its importance as a possible host for uranium mineralization, Haql granite was represented by more samples than the other units.

Each sample was counted for a period of 6000 seconds. Standard samples were prepared from a series of certified reference samples with high U, Th or K concentrations obtained from the IAEA (International Atomic Energy Agency). Dilution was made by U-, Th- and K- free materials e.g. leached quartz and / or dunite. Calculation of precision based on replicate analysis of selected standards and reference samples indicates that the recommended values range between 12% at the low concentration levels (< 4 ppm U, < 8 ppm Th and < 0.5% K) and gradually up to 7% for higher concentrations.

The summary statistics of the spectrometric measurements, together with the corresponding field data, as well as averages for 176 samples from the NE Arabian Shield (Stuckless *et al.* 1984) are presented in Table 1.

TABLE 1. Summary statistics of the spectrometric data of the five units in the study area, compared with data of 176 samples from NE Arabian Shield (1).

		HQL n = 26	PEG n = 6	APT n = 7	MID n = 7	ATY n = 8	Granites of the NE Arabian Shield (1) n = 176
eU ppm	Av.	18	17	38	5	5	
	Range	1 to 98	4 to 34	3 to 125	2 to 10	1 to 12	0.96 to 20.5
	mean	9	13	110	5	4	5.57
eTh ppm	Av.	57	57	110	28	17	
	Range	3 to 469	4 to 187	12 to 407	9 to 93	9 to 26	2.45 to 43.5
	mean	30	31	53	21	16	16.54
eK %	Av.	2.1	2.4	1.4	1.8	2.0	
	Range	0.4 to 6.3	1.6 to 3	0.2 to 2.9	1.3 to 2.4	1.5 to 2.6	2.52 to 6.01
	mean	2	2	1	1.8	2.0	4.02
$\frac{e\,Th}{eU}$	Av.	6.2	3.3	2.9	4.8	6.1	
	Range	0.2 to 36.1	0.6 to 6.7	0.6 to 4.5	3.3 to 9.3	2.2 to 23	1.06 to 6.48
	mean	3	2.5	2.4	4.5	4.4	2.93
cps	Av.	580	610	599	220	202	
	Range	170 to 1800	440 to 950	350 to 950	134 to 360	130 to 350	
	mean	477	587	560	266	191	

It is evident that eU is highest in aplite, followed by pegmatite and Haql granite. Midyan and Atiya granites show the lowest eU content, even though still higher than the average given by Heier and Rogers (1963) for continental crust (2.1-3 ppm). The highest eTh averages are in aplite, followed by Haql granite and pegmatite with similar averages; eTh is lowest in Atiya granite. The box and whisker plots (Fig. 3) illus-

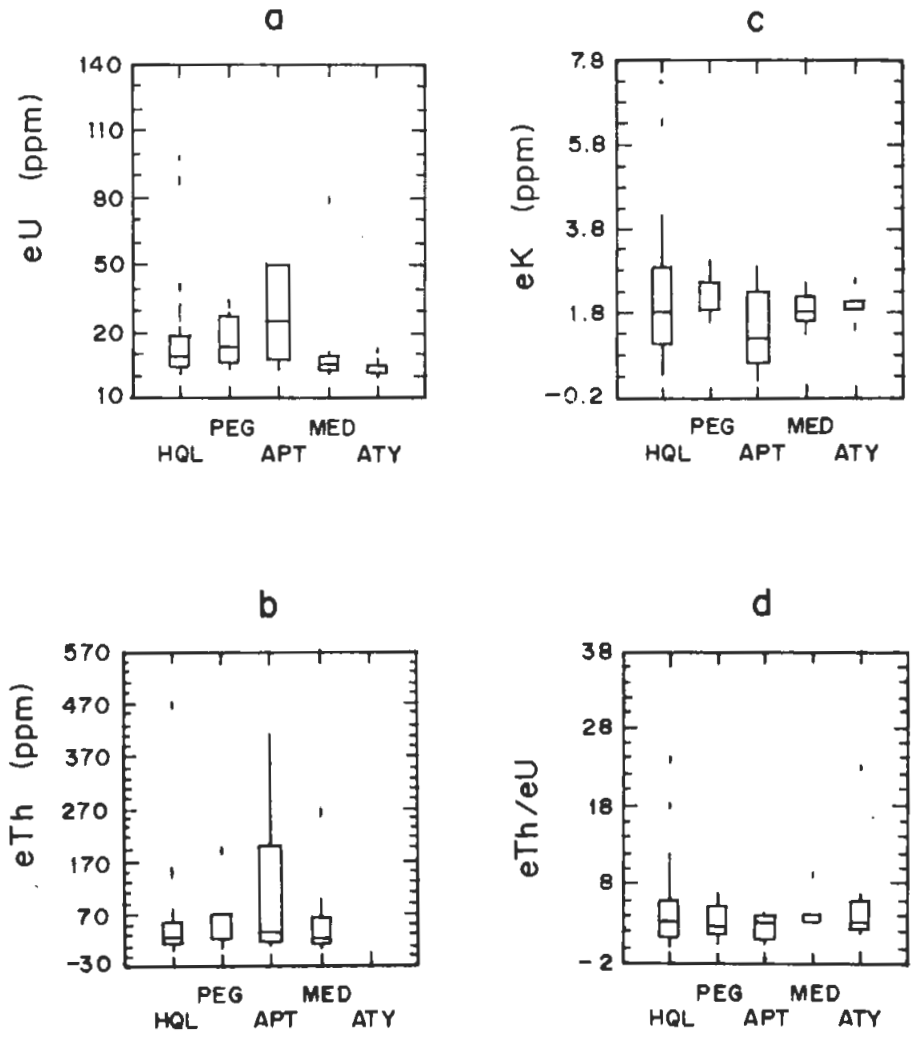

FIG. 3. Multiple box and wisker plots of the spectrometric data in the granites and related dikes in the study area.

HQL = Haql granite PEG = Pegmatite
MED = Midyan granite APT = Aplite
ATY = Atiya granite

trate clearly the widespread of uranium and thorium about the mean in the aplite dikes, and to lesser extent of uranium in Haql granite and pegmatite. eK is highest in pegmatite, followed by Haql, Atiya and Midyan granites, but is still in the range of the potassium content for the continental crust and about half the potassium content suggested by Stuckless for the granites in the northeast Arabian Shield. eTh/eU is clearly variable with most variation in Haql granite (0.2-36.1).

Fluorimetry

Total chemical uranium (U) was determined on selected samples in order to test the equilibrium state. The state of equilibium in any sample is defined by a D-factor, which is total uranium/equivalent uranium (Hansink 1976). If this factor is more than one or less than one, this would mean addition or removal of uranium respectively (Hansink 1976). A total of 28 samples from those analyzed spectrometrically were selected for fluorimetric analysis. Table 2 and 3 presents the data for the analyzed samples. The D-factor for the Haql granite varies from 0.08 to 9.00 with an average of 1.92. In seven samples the D-factor is greater than one, and in the other five samples is less than 1. Only three of the twelve samples have a D-factor close to 1, but the rest are significantly different. Most samples of the other four units show values close to unity despite the great variation in U content (137 ppm in sample 124 to 1 ppm in sample 39 C). Only one sample of pegmatite shows a high D-factor (26.86 in sample 183), indicating enrichment in uranium. A sample of Atiya granite shows a slightly high value (4 in sample 26).

Discussion

The average uranium content of all the studied rock units is high relative to the average for continental crust and higher than the average of the other granites in Saudi Arabia except that of Gurrayah and Jabal Said. Variations in eU/eTh values indi-

TABLE 2. Total uranium (U), equivalent uranium (eU) and D-factor in selected samples of Haql granite.

Field No.	eU	U	D (U/eU)
15	14	18	1.29
20	88	17	0.19
341	1	9	9.00
141	2	4	2.00
48	26	21	0.80
51	33	37	1.12
55	2	6	3.00
59	4	11	2.75
83	13	1	0.08
132	33	14	0.42
194	4	9	2.25
205	41	6	0.15
Range	1-88	1-37	0.08-9
Average	21.75	12.75	1.92

TABLE 3. Total uranium (U), equivalent uranium (eU) granites and dykes of the study area.

Aplite				Pegmatite				Aty				Mid			
Field No.	eU ppm	U ppm	D U/eU	Field No.	eU ppm	U ppm	D U/eU	Field No.	eU ppm	U ppm	D U/eU	Field No.	eU ppm	U ppm	D U/eU
121	50	81	1.62	52	28	30	1.07	26	1	4	4	441	79	83	1.05
124	125	137	1.1	183	7	188	26.86	39C	2	1	0.50	93	4	5	1.25
182	25	37	1.48	211	34	38	1.12	54	3	6	2	102	5	10	2
207	28	33	1.18	188	–	8.75	–	67	8	11	1.38	138	10	10	1
Range			1.1-1.62				1.07-26.86				0.50-4				1-2

cate that uranium was remobilized after its primary crystallization (Fowler 1981 and Pagel 1982). This result is supported by the variable D-factor, which indicates a high state of disequilibrium due to the mobility of uranium, particularly in Haql granite. Uranium attains equilibrium in about 1.5 m.y. (Reeves and Brooks 1978). The latest mobilization of uranium in these units therefore took place within the last 1.5 m.y. as there was not enough time to restore equilibrium.

The presence of secondary uranium minerals near the contact with mafic dyke indicates the effect of mafic dykes in fixing uranium from solution in secondary minerals (Pagel 1982).

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تراكيز اليورانيوم والثوريوم في جرانيت حقل بإقليم مدين شمال غرب المملكة العربية السعودية

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المستخلص . تم تحديد أربعة وثلاثون شاذة إشعاعية تحتوى على تركيزات عالية من اليورانيوم والثوريوم في منطقة شرق جبل الزهد في إقليم مدين بشمال غرب المملكة العربية السعودية . وتوجد هذه الشاذات في جرانيت حَقْل وقواطع البجماتيت والأبليت المصاحبة له والموجودة غالبا بالقرب من حدوده مع كتلة من جرانيت مَدْيَنْ البورفيري الأحدث . ومن المظاهر الشائعة في جرانيت حَقْل آثار عمليات التشقق والسلكتة والتلون بأكاسيد الحديد . وقد تم التعرف على اليورانوفين في إحدى هذه الشاذات . ويدل التغير الكبير في نسب اليورانيوم المكافىء إلى اليورانيوم ، والثوريوم إلى اليورانيوم والبوتاسيوم إلى اليورانيوم على تحرك اليورانيوم في الصخور التي تم دراستها . ويعتقد بناء على ذلك أن جرانيت حَقْل قد تعرض لتأثير حرمائي سبَّب إعادة توزيع اليورانيوم والثوريوم وتركيزهما به .