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Uranium and Thorium Contents of Mesozoic Granites from Peninsular Thailand

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Abstract: Mesozoic granites of Peninsular Thailand contain large amounts of uranium (5–57 ppm, avg. 16.2 ppm), thorium (3–85 ppm, avg. 33 ppm) and potassium (3.5–5.3%, avg. 4.3%). Th/U ratios vary widely (0.2–11). The granites are especially enriched in uranium, thus characterized by low Th/U ratios (avg. 2.0), as compared with data reported from common granitic terrains. Thorium tends to decrease but uranium may increase slightly with increasing a differentiation index. The uranium-enriched granites are seen in high-level plutons.

Predominance of radioactive elements in the Thai granites indicates a large heat generation capacity within the continental crust. The heat may have affected to some extent the present-day geothermal system as well as geological hydrothermal activities. Readily leachable uranium from the U-enriched granites could have been precipitated as secondary uranium minerals in the granite, and may possibly form uranium deposits in the surrounding sediments.

Introduction

During field work for the Geological Research Project of the Prince of Songkhla University in the southern part of Peninsular Thailand (GRP–PSU, 1979), tobernite was seen along weathered cracks of "unaltered granite" at a few places. It was found on Japanese granitoids that this occurrence of secondary uranium minerals (ISHIHARA, 1967) as well as smoky quartz in granite (e.g., Naegi granite) are suggestive of a high concentration of uranium and thorium in the host granitoids (ISHIHARA *et al.*, 1969). Thus the Thai granites were analyzed for U by fluorescence method (MOCHIZUKI and SEKINE, 1976) and Th by spectrophotometry (SEKINE and MOCHIZUKI, 1976). In this paper, the results and their bearing on petrogenesis and uranium exploration are reported.

Granites of Peninsular Thailand are monzogranite and syenogranite containing biotite and muscovite. A majority are porphyritic biotite granite. Muscovite-biotite granite occurs in apical part of individual plutons. The granites are characterized by high contents but narrow range of SiO_2 and K_2O (ISHIHARA *et al.*, 1980). The age seems to be late Triassic (-late Paleozoic) in most cases but granites in Ko (island) Phuket area and some in the backbone range are Cretaceous. Locality of the analyzed samples is shown in Figure 1.

Results

Analytical results are listed in Table 1, together with potassium contents reported in ISHIHARA *et al.* (1980). The Thai granites are characterized by a wide range of uranium and thorium contents, and thus by diversity of Th/U ratios.

It is generally known that common granitoids have averaged uranium content of 3–4 ppm

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Table 1 Uranium, thorium and potassium contents of Mesozoic granites from Peninsular Thailand

Analysis and Sample Nos.	U (ppm)	Th (ppm)	Th/U	K (%)	U/K (×10⁻⁴)	Th/K (×10⁻⁴)
Bu Ke						
(1) 77110408–1	8.6	44	5.1	3.97	2.2	11.1
(2) 77110407–2	7.4	21	2.8	4.07	1.8	5.2
(3) 77110406–4	6.8	25	3.8	3.49	2.0	7.2
(4) 77110406–2*	7.1	15	2.1	5.91	1.2	2.5
Average (n = 3)	7.5	26.3	3.5	3.84	2.0	6.9
Tan Yong						
(5) 77110403–1	8.9	43	4.8	5.03	1.8	8.6
(6) 77110401–1	9.1	34	3.7	4.40	2.1	7.7
(7) 77110402–1	11	15	1.4	4.87	2.3	3.1
Average (n = 3)	9.7	30.7	3.2	4.76	2.0	6.5
Ruso						
(8) 77110313–1	4.3	20	4.7	4.32	1.0	4.6
(9) 77110312–1	7.1	12	1.7	4.34	1.6	2.8
(10) 77110311–1	19	16	0.8	4.34	4.4	3.7
Average (n = 3)	10.1	16	1.6	4.33	2.3	3.7
Pa Na Re						
(11) 77120201–1	14	17	1.2	4.23	3.3	4.1
(12) 77120202–1	13	6.0	0.5	4.07	3.2	1.5
Average (n = 2)	13.5	11.5	0.9	4.15	3.3	2.8
Ku Long						
(13) 77110204–1	12	21	1.8	4.23	2.8	5.0
Pin Yok						
(14) 77110308–1	8.9	34	3.8	4.47	2.0	7.6
Khara Khiri						
(15) 77110202–3	22	31	1.4	4.55	4.8	6.8
(16) 77110203–1	9.5	27	2.8	4.17	2.3	6.5
Average (n = 2)	15.8	29	1.8	4.36	3.6	6.7
Songkhla						
(17) 77112805–3	16	53	3.3	4.48	3.6	11.8
(18) 77112805–1	13	18	1.4	4.26	3.1	4.2
(19) 77112804–2**	21	20	1.0	4.52	4.7	4.4
(20) 77102502–1	57	12	0.2	4.09	13.9	2.9
(21) 77102501–2**	18	8.9	0.5	3.78	4.8	2.4
(22) 77102501–1**	28	10	0.4	4.25	6.6	2.4
Average (n = 6)	25.5	20.3	0.8	4.23	6.0	4.8

*Dike-like form, excluded from average.
**Tourmaline-bearing muscovite-biotite granites.

Table 1 Continued

Analysis and Sample Nos.	U (ppm)	Th (ppm)	Th/U	K (%)	U/K (×10⁻⁴)	Th/K (×10⁻⁴)
Khao Kachong						
(23) 77112906–1	11	38	3.5	3.98	2.8	9.6
(24) 77112905–2	11	38	3.5	4.06	2.7	9.4
(25) 77112904–2	11	31	2.8	4.23	2.6	7.3
(26) 77112903–1	12	23	1.9	4.45	2.7	5.2
Average (n = 4)	11.3	32.5	2.9	4.18	2.7	7.8
Khao Luang						
(27) 77112304–2**	18	13	0.7	3.69	4.9	3.5
(28) 77112304–4**	13	2.9	0.2	3.04	4.3	1.0
(29) 77112301–2**	18	4.2	0.2	3.65	4.9	1.2
Average (n = 3)	16.3	6.7	0.4	3.46	4.7	1.9
Ko Samui						
(30) 77110907–1	15	57	3.8	4.17	3.6	13.7
(31) 77110909–1	15	76	5.1	4.71	3.2	16.1
(32) 77110905–1	52	85	1.6	5.05	10.3	16.8
(33) 77110905–2	23	53	2.3	5.29	4.4	10.0
Average (n = 4)	26.3	67.8	2.6	4.81	5.5	14.1
Yod Nam mine						
(34) 77T10–4	15	70	4.7	3.98	3.8	17.6
(35) 77111402–3	9.6	35	3.7	4.26	2.3	21.6
(36) 77T11–9	31	43	1.4	4.57	6.8	9.4
(37) 77T11–11	35	58	1.7	4.71	7.4	12.3
(38) 77T10–2	25	28	1.1	3.28	7.6	8.5
(39) 77T10–6	22	27	1.2	4.22	5.2	6.4
(40) 77T10–3	18	16	0.9	3.72	4.8	4.3
Average (n = 7)	22.2	39.6	1.8	4.10	5.4	9.6
Ko Phuket						
(41) 77113001–4	7.0	39	5.6	4.10	1.7	9.5
(42) 77113001–1	5.4	60	11.1	4.36	1.2	13.8
(43) 77113002–2	15	57	3.8	4.62	3.3	12.3
(44) 77113001–7	14	73	5.2	5.05	2.8	14.5
(45) 77113004–1	13	56	4.3	4.91	2.7	11.4
Average (n = 5)	10.9	57	5.2	4.49	2.4	12.7

Analysis numbers, (1)–(45), correspond to the numbers in Fig. 1.
Analyst: T. Mochizuki

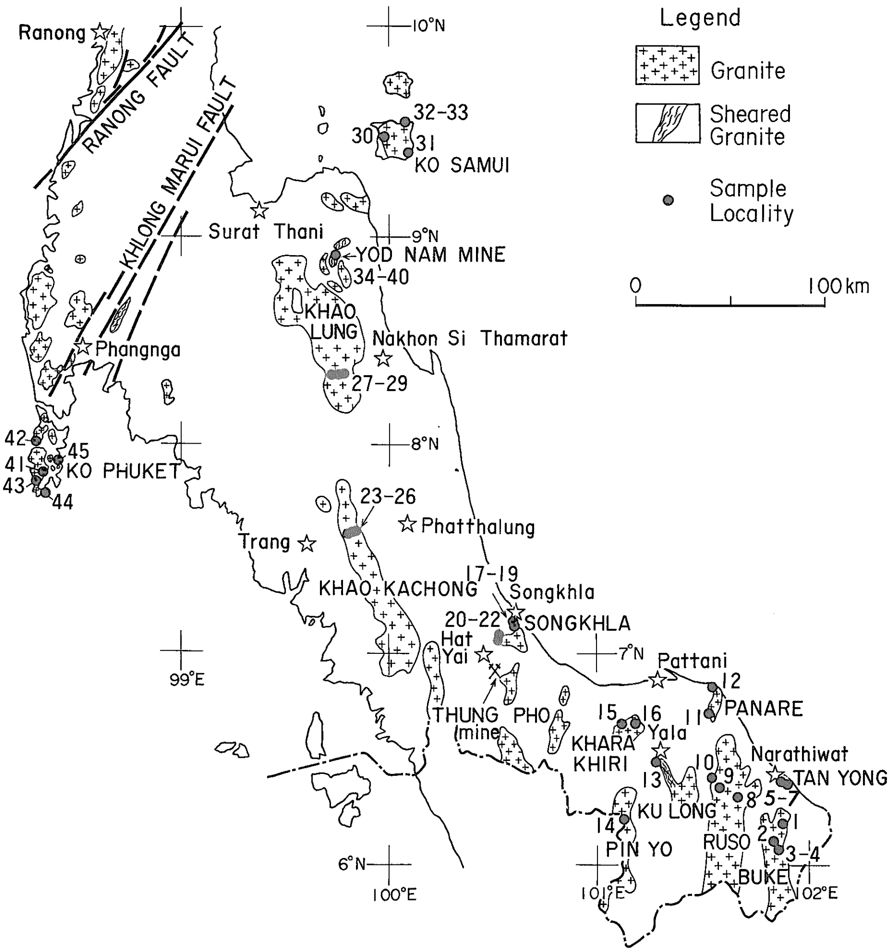

Fig. 1 Distribution of Mesozoic granites and locality of the analyzed samples in Peninsular Thailand. Numbers correspond to those of Table 1.

and Th/U ratio around 4 (Adams *et al.*, 1959; Clark *et al.*, 1966; Ishihara *et al.*, 1969; Kanaya and Ishihara, 1975). In the case of Thai granites, however, uranium varies from 5 to 57 ppm and thorium ranges from 3 to 85 ppm, yielding their Th/U ratios from 0.2 to 11. These values are rather unusual, because K_2O contents are more or less constant (4.2–6.4%).

Among the studied plutons of varying size, samples from two large plutons, Bu Ke and Khao Kachong, give relatively constant values: 6.8–8.6 ppm U and 21–44 ppm Th for the Bu Ke, 11–12 ppm U and 23–38 ppm Th for the Khao Kachong. Generally speaking, granites occurring in northwestern part of the studied area are enriched in both uranium and thorium, as compared with those of the southeastern part (Figs. 1, 2), among which the highest is obtained from Ko Samui pluton ($U/K = 5.5 \times 10^{-4}$, $Th/K = 14.1 \times 10^{-4}$ in average). Cretaceous granites of Ko Phuket ($Th/K = 12.7 \times 10^{-4}$) and Yod Nam mine ($Th/K = 9.6 \times 10^{-4}$) are high in thorium, but uranium is concentrated in Yod Nam mine ($U/K = 5.4 \times 10^{-4}$), Khao Luang ($U/K = 4.7 \times 10^{-4}$) and Songkhla ($U/K = 6.0 \times 10^{-4}$) plutons. These granites are related to tin and tungsten mineralization (Ishihara *et al.*, 1980).

Uranium is least ($U/K = 1–2 \times 10^{-4}$) in the most calcic granite of the Bu Ke pluton in

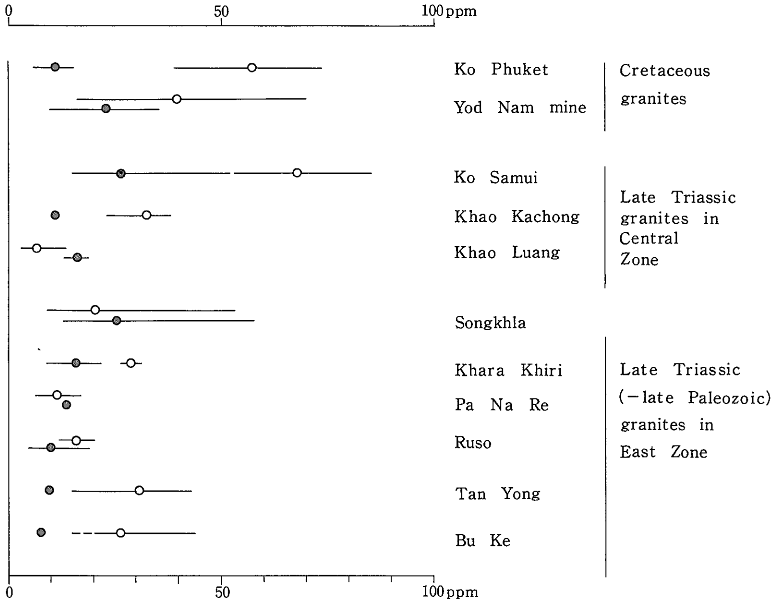

Fig. 2 Average contents of uranium (solid circle) and thorium (open circle) of the studied granites. Bar indicates their range.

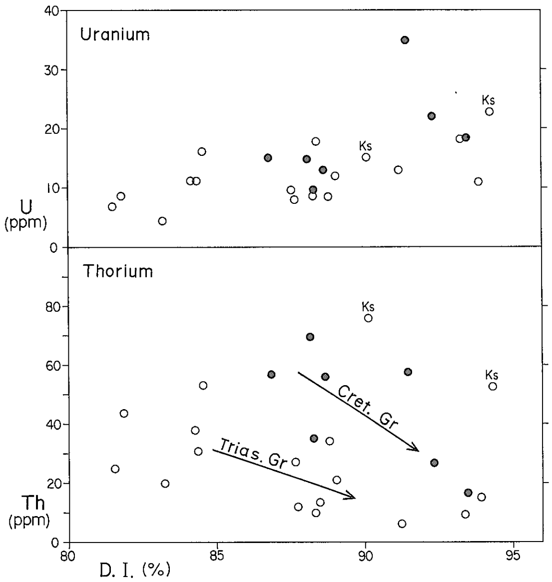

Fig. 3 Uranium and thorium contents plotted against differentiation index (D.I.). Open circle implies late Triassic granite; solid circle, Cretaceous granite. KS, Ko Samui.

the studied area. Thorium is generally low in tourmaline-containing granites, particularly of Khao Luang pluton (Th/K = 1–3 × 10^{-4}).

Uranium and thorium are plotted against differentiation index (D.I., normative qz + ab + or recalculated excluding H_2O) (Fig. 3). Uranium shows a slight increasing nature against increase of this index. Thorium, on the other hand, reveals different trend. Cretaceous granites indeed show a decreasing tendency and, if the Ko Samui samples are excluded, late Triassic granites can be considered to have the same trend as the Cretaceous one. Thorium may be preferentially fixed in an early crystallized accessory minerals (Roger and Adams, 1969).

Application

It was found that Mesozoic granites of Peninsular Thailand contain large amounts of radioactive elements. Averages of the analyzed samples are given in Table 2. Heat generation capacity of the Thai granites is three times more than that of typical granitic terrain in Japan. Many of the analyzed samples were obtained from apical part of granite batholith. However,

Table 2 Averages of radioactive elements of granitoids from Peninsular Thailand and Japan.

Locality and number of samples	U (ppm)	Th (ppm)	K (%)	HG (cal/cm^3 sec)
Thailand, all the granites (n = 45)	16.2	33.0	4.31	16.6×10^{-13}
ditto, deep phase granites (n = 10)	9.8	26.8	4.13	11.6×10^{-13}
Central Japan (n = 107 for U & Th, 44 for K)	3.2	13.4	2.98	4.9×10^{-13}

HG, heat generation, calculated using conversion factors of ROY *et al.* (1968). The Japanese data were taken from the Chubu transect of ISHIHARA *et al.* (1969) and ISHIHARA and TERASHIMA (1977).

biotite granites of Bu Ku, Ruso and Khao Kachong plutons may extend deeply. Heat production rate of these granites estimated from the uranium, thorium and potassium data is calculated to be 11.6 × 10^{-13} cal/cm^{3}sec. It is not unreasonable to assume this kind of coarse-grained granite to extend 10 km in depth in the continental crust. If so, the granite itself can produce 1.2 HFU (× 10^{-6} cal/cm^{2}sec). Observed heat flow in land part of Thailand are 1.0–1.5 HFU of the Khorat plateau and 2.0 HFU of Phetchabun province of the western edge of the plateau (THIENPRASERT *et al.*, 1978).

Granites similar to those of Peninsular Thailand occur in northern Thailand (NUTALAYA, 1975). In the well known hot spring area of northern Thailand, RAMINGWONG *et al.* (1978) described that "most of hot springs are regionally related to granitic rocks and lie generally within 10 km of the granitic rock outcrops". The high heat generation capacity of the Thai granites indicates that the heat generated by radioactive decay may have contributed, at least some extent, to the hot spring system. Similar phenomenon could have occurred during geologic time.

Throughout geochronological studies of granites in Malay peninsula, younging K–Ar age on micas against Rb–Sr whole rock ages has been found in an extensive area from western Malaysia (BIGNELL and SNELLING, 1977) to southernmost Thailand (ISHIHARA *et al.*, 1980). This rejuvenation was considered due not to later overlapping magmatism but to largely mechanical heat (PATALAKHA *et al.*, 1978; BARTON and ENGLAND, 1979) provided by regional shearing along fault zones. A large production capacity of heat within the Thai granites obtained in this study may add another supporting evidence for this interpretation.

Secondary uranium mineral found in Silathong quarry of Songkhla pluton and others (GRP–PSU, 1979) must have been originated in the host granite that has high uranium contents as well as low Th/U ratios, because there is no other rocks which could be source for the mineral. Uranium-rich granite has often genetic connection with bedded-type uranium deposits. Wherever the uranium deposits occur in sediments that overlie granitoids in Japanese islands, even 4 ppm U vs. 2 ppm U in the basement granitoids would provide significant effect on formation of overlying uranium deposits (ISHIHARA and SUZUKI, 1969). All the studied granites in Thailand have an advantage as to the source materials, because of their high uranium contents.

Cenozoic sedimentary basins are known to exist in Peninsular Thailand (JAVANAPHET, 1969). If suitable reducing agent and structural elements for precipitation of uranium minerals are found in these basins, there could be a chance of bedded-type uranium deposits, other than sedimentary uranium deposits in Khorat plateau (SUWANASING and INTHUPUTI, 1978).

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タイ国半島部，中生代花崗岩類のウランとトリウム含有量

石原舜三・望月常一

要　旨

タイ国南部の中生代花崗岩類はシリカ (70–74% SiO_2) とカリウム(3.5–5.3%K) に富み，ウラン (5–57 ppm U, 平均16.2)，トリウム (3–85 ppm Th, 平均 33.0 ppm Th) も多く含まれ，したがって Th/U 比はばらつくが，一般には低い (0.2–11, 平均2.0)，トリウムは分化指数の増加と共に減少し，ウランは若干増加する傾向がみられる．すなわち，分化岩石ではウランが多く，Th/U 比が低い．このような花崗岩は岩体頂部に産出し，Sn–W 鉱化作用とも関係している．

U, Th, K などの放射性成分が多いことから，タイ花崗岩類は西南日本内帯の花崗岩類より 3 倍以上の発熱能力を有する．かりに，バソリス状粗粒花崗岩が深部に 10 km 連続すると仮定すると，1.2 HFU が花崗岩のみから得られることになる．この熱は現在の熱水系や過去の地質時代に K–Ar/Rb–Sr 年代に不一致性をもたらした熱水系の熱源の一つであった可能性がある．またウランに著しく富むことは堆積型ウラン鉱床の起源岩としてすぐれており，周辺の新しい堆積物に移動沈殿している可能性は追求される価値がある．

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