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Preliminary study on heat generation from the granitic rocks in northern Thailand

Kiyoo KAWADA*, Masakatsu SASADA** and Hiroshi KANAYA***

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Abstract: Radioactive elements, Th, U and K are abundant in the Mesozoic granitic rocks of northern Thailand. The heat generation in the eastern granite chain including San Kamphaeng, Mae Chan and Fang geothermal fields ranges from 10.0×10^{-13} to 16.4×10^{-13} cal/cm^3·s. This corresponds to N-S trending high heat flow anomaly greater than 1.5 HFU. The granitic rocks could make a major contribution to the heat flow from this area. The situation of heat generation is more complicated in the central crystalline massif where Mae Chaem and Pa Pae hot springs are located, because of the heterogeneity of the contents of the radioactive elements in the granitic and metamorphic rocks.

1. Introduction

Many hot springs are present in northern Thailand, where Mesozoic granitic rocks are widely distributed. Some of the hot springs are associated with the margin of the granitic plutons (BARR et al., 1979), and some of them appear to be correlative with the fracture system in the granitic region (SASADA et al., this issue). The granitic rocks in Thailand are generally abundant in radioactive elements (THIENPRASERT et al., 1980; ISHIHARA and MOCHIZUKI, 1980; WATTANANIKORN et al., 1981). In order to estimate the heat source of the hot springs, we preliminarily determined the heat generation from the granitic rocks in and around some geothermal fields in northern Thailand.

2. Samples

Twenty eight granitic rocks and seven metamorphic rocks were collected mainly from the five major geothermal fields, that is, San Kamphaeng, Mae Chan, Fang, Pa Pae and Mae Chaem (Fig. 1). Radioactive minerals of zircon, monazite and allanite have been identified under the microscope.

Hot springs are located in the Paleozoic sedimentary and volcanic rocks at San Kamphaeng. Granitic rocks are distributed widely on the east of the manifestation area. They consist of biotite granite and muscovite biotite granite, both of which are characterized by phenocrystic potassium feldspar. Prismatic zircon and granular monazite make a pleochroic halo up to 0.02 mm wide in biotite. Some zircon crystals are zonally arranged in biotite.

Mae Chan hot spring is located on the well-jointed porphyritic hornblende biotite granite, which is altered near the hot water discharge zone. There are three hot springs along Huai Pong Nam River 20 kilometers southwest of Mae Chan. Hornblende biotite granite is distributed both sides of the river. Euhedral allanite and prismatic zircon make a pleochroic halo, when they are in contact with biotite in the porphyritic granite.

Granitic rocks are partly mylonitized in Fang geothermal field. Metamorphic rocks are exposed to the north of the manifestation area. All the granitic rocks from the three

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*Geology Department, Geological Survey of Japan, presently at DRICO Co.

**Geothermal Research Department, Geological Survey of Japan

***Geophysics Department, Geological Survey of Japan

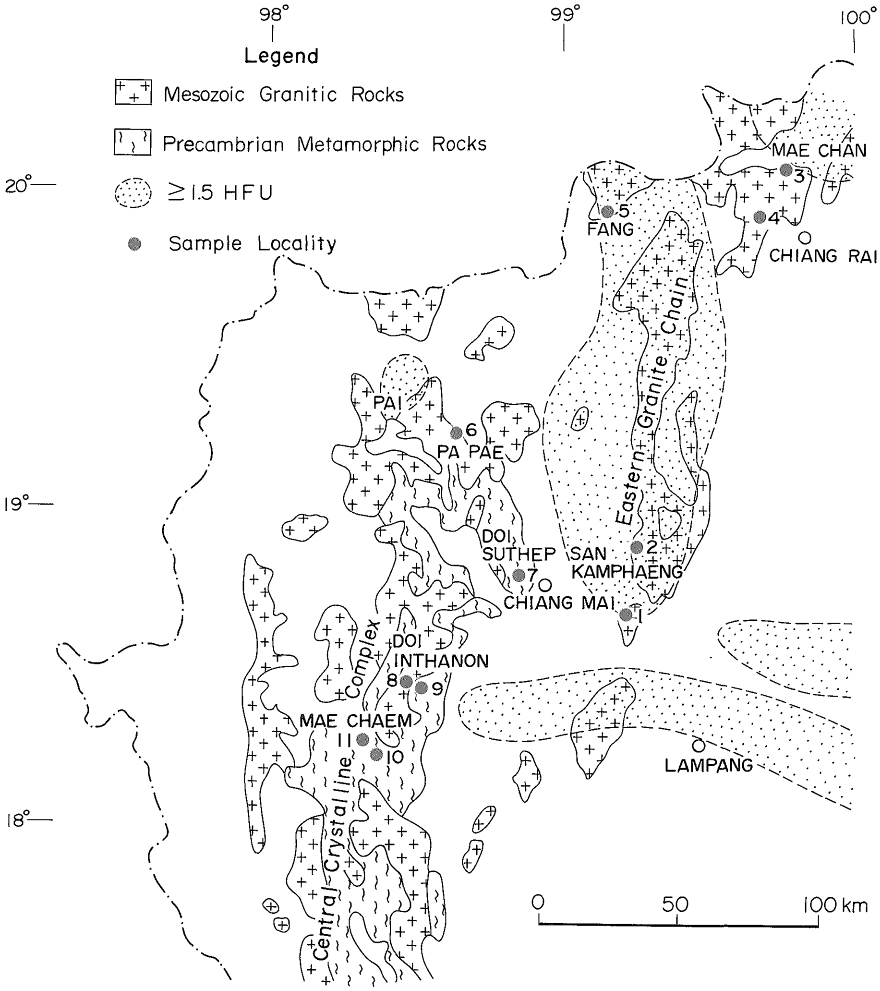

Fig. 1 Distribution of granitic and metamorphic rocks, high heat region, and locality of samples in northern Thailand.
High heat flow anomaly greater than 1.5 HFU is based on THIENPRASERT and RAKSASKULWONG (1984).

areas described above belong to the eastern granite chain of Triassic age (BRAUN et al., 1976).

Pa Pae geothermal field is located at the margin of the granitic pluton on the northern end of the central crystalline complex (Fig. 1). Granitic rocks consist of well foliated porphyritic biotite granite and minor fine-grained granite.

Mae Chaem hot spring is situated at the middle part of the central crystalline complex composed of foliated granitic rocks and Precambrian metamorphic rocks. Most granitic rocks near the hot spring are well foliated biotite granite. They intrude paragneiss and other metamorphic rocks concordantly. A predominant radioactive mineral is zircon. But its content is variable especially in the metamorphic rocks.

3. Analytical procedure for Th, U and K

About two kilograms of granitic and metamorphic rocks were crushed under 40–50 meshes, and 500 grams of them were packed into cylindrical polypropylene containers. Each container was stored at least two weeks before counting in order to attain a complete

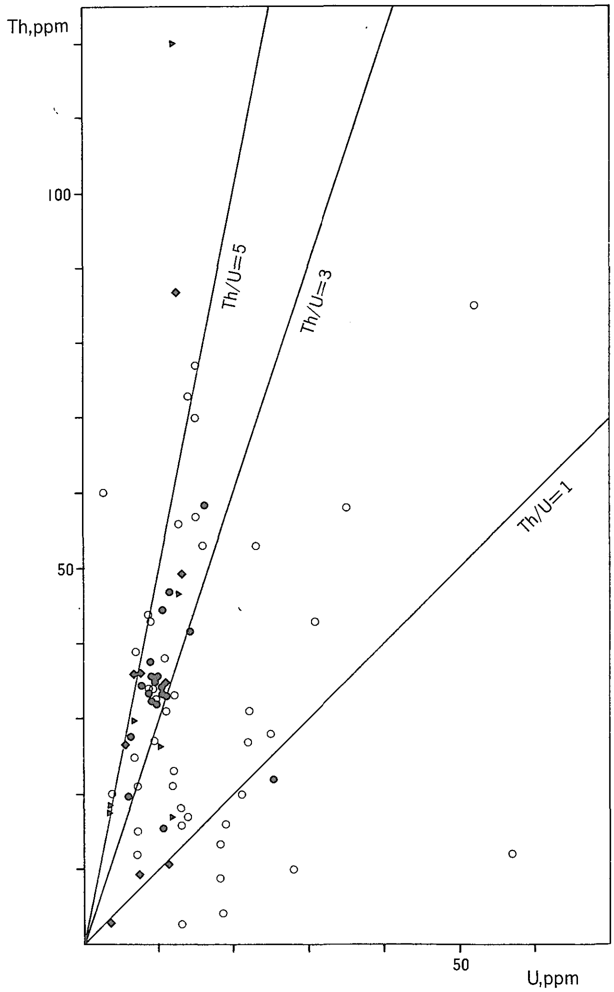

Fig. 2 Uranium versus thorium contents.
Solid circle: granitic rocks from the eastern granite chain; solid diamond: those from the central crystalline complex; solid triangle: metamorphic rocks from northern Thailand; open circle: granitic rocks from the Peninsular Thailand (Ishihara and Mochizuki, 1980).

equilibrium of radon-222.

Determination of Th, U and K were mainly performed by γ-spectrometry on 1000 channel analyzer with 5×5 in., NaI(Tl) crystal detector and partially on 4000 channel analyzer with coaxial Ge detector comparing the counts with those of the standard samples. New Brunswick Laboratory (N. B. L.) analyzed ores were used as calibration standards to determine the contents of Th and U in these rocks. Potassium bromide grading superpure reagent was used for determination of potassium content in rocks.

4. Analytical results

Results of the analysis for radioactive elements are listed on Table 1. Generally the granitic rocks in northern Thailand are abundant in Th, U and K. The variation range of Th and U of the granitic rocks from the central crystalline complex is larger than that from the eastern granite chain (Fig. 2). The Th/U ratio ranges from 3 to 5 in most granitic rocks. The granitic rocks from northern Thailand generally show higher Th/U ratio

Table 1 Contents of radioactive elements in the granitic and metamorphic roks of northern Thailand

Sample Nos.	Loc. Nos.	Th (ppm)	U (ppm)	Th/U	K (%)	Rock
(Granitic rocks)						
SAN KAMPHAENG						
KK-83121801	1	35.4	9.6	3.7	4.06	Porphyritic biotite granite
KK-83121802	1	33.5	10.3	3.3	4.26	Porphyritic biotite granite
MS-82Y2401	1	35.6	9.5	3.7	4.23	Porphyritic biotite granite
MS-82Y2402	1	33.2	12.3	2.8	4.28	Porphyritic biotite granite
MS-82Z 0301	1	41.8	14.7	2.8	4.64	Porphyritic biotite granite
IT-SK-1	1	34.9	9.3	3.8	3.66	Porphyritic biotite granite
IT-SK-5	1	34.0	10.8	3.1	4.14	Porphyritic biotite granite
KK-SK-3	2	22.0	25.2	0.9	4.38	Muscovite biotite granite
KK-SK-3B	2	33.1	8.9	3.7	3.56	Porphyritic biotite granite
KK-CM2	2	34.4	7.7	4.4	3.68	Porphyritic biotite granite
MS-82Y2307	2	31.8	9.1	3.5	3.63	Porphyritic biotite granite
Average (n=11)		33.6	11.6	2.9	4.05	
MAE CHAN						
KK-MCN-2	3	46.9	12.6	3.7	3.40	Porphyritic hornblende biotite granite
MS-82Z0101	3	37.4	8.8	4.2	4.62	Porphyritic hornblende biotite granite (altered)
MS-82Z0102	3	44.7	11.0	4.0	3.88	Porphyritic hornblende biotite granite
MS-82Y3001	4	58.1	16.3	3.6	4.09	Hornblende biotite granite
Average (n= 4)		46.8	12.2	3.8	4.00	
FANG						
KK-FANG-2	5	27.6	6.5	4.2	3.30	Mylonite
MS-82Y2501	5	15.1	11.4	1.3	4.31	Mylonite
IT-FANG-1	5	19.9	6.5	3.1	3.60	Foliated biotite granite
IT-FANG-4	5	32.4	8.9	3.6	3.67	Biotite granite
Average (n= 4)		23.8	8.3	2.9	3.72	
PA PAE						
KK-PP-1	6	35.7	7.0	5.1	2.45	Foliated muscovite-bg biotite tonalite
MS-82Y2703A	6	35.8	8.0	4.5	3.08	Foliated biotite granite
Average (n= 2)		35.8	7.5	4.8	2.77	
DOI SUTHEP						
KK-83122101	7	10.4	11.5	0.9	3.82	Garnet-bg muscovite biotite granite
DOI INTHANON						
MS-82Z0701	8	34.6	10.6	3.3	4.81	Muscovite biotite granite
MAE CHAEM						
KK-HOD-1	10	9.4	7.9	1.2	2.44	Foliated biotite granodiorite
MS-82Y2601	10	87.7	12.5	7.0	4.76	Foliated biotite granite
IT-MCM-1	10	49.2	13.1	3.8	4.82	Foliated biotite granite
KK-TP-2	11	3.8	3.9	1.0	1.31	Biotite muscovite granodiorite
MS-82Y2602A	11	26.5	5.9	4.5	3.25	Foliated biotite granodiorite
Average (n=5)		35.3	8.7	4.0	3.32	
(Metamorphic rocks)						
KK-FANG-1	5	17.5	3.3	5.3	2.14	Orthogneiss
MS-82Y2702C	6	26.4	10.4	2.5	2.93	Paragneiss
KK-83122102	7	16.7	11.8	1.4	2.76	Paragneiss
KK-83122501	9	46.6	12.4	3.8	3.57	Paragneiss
KK-83122502	9	29.8	6.8	4.4	3.82	Paragneiss
KK-MCM-2	10	120.0	12.1	9.9	4.46	Paragneiss
KK-HOD-2	10	18.5	3.4	5.4	1.66	Calcareous gneiss
Average (n= 7)		39.4	8.6	4.6	3.05	

than those from the Peninsular Thailand (Fig. 2).

5. Heat generation

The average of the heat generation of 28 granite samples is calculated to be 13.0×10^{-13} cal/cm^3·s using conversion factors of Roy et al. (1968). The heat generation of the granitic rocks from the Peninsular Thailand is 16.6×10^{-13} cal/cm^3·s on an average (ISHIHARA and MOCHIZUKI, 1981). These values from Thailand are higher than the average heat generation of granite due to radioactive decay, 7.0×10^{-13} cal/cm^3·s (KAPPELMEYER and HAENEL, 1974).

The N-S trending high heat flow anomaly over 1.5 HFU is observed in the eastern granite chain (Fig. 1) and the heat flow is greater than 2.5 HFU at San Kamphaeng geothermal field (THIENPRASERT and RAKSASKULWONG, 1984). The average heat generation of the granitic rocks from San Kamphaeng, Mae Chan and Fang are 13.8×10^{-13}, 16.4×10^{-13}, and 10.0×10^{-13} cal/cm^3·s respectively. If the thickness of the granitic rocks is assumed to be 10 kilometers as assumed at the Peninsular Thailand (ISHIHARA and MOCHIZUKI, 1980), resulting heat flow from the granitic plutons ranges from 1.0 to 1.6 HFU. This could be a background value in the eastern granite chain.

The situation of the heat generation is more complicated in the central crystalline complex, because the contents of radioactive elements in the granitic and metamorphic rocks are highly variable. Since neither we have enough data of Th, U and K contents, nor heat flow data are available at present, except from Pai basin (THIENPRASERT and RAKSASKULWONG, 1984), discussion on the heat budget in the central crystalline complex will be a future problem.

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タイ北部の花崗岩類からの発熱量についての予察的研究

河田清雄・笹田政克・金谷　弘

要　旨

タイ北部の地熱地帯から採取した花崗岩類28試料及び随伴する変成岩類7試料につき，放射性元素であるTh，U，Kの存在量をγ-スペクトロメトリーにより求め，発熱量を計算した．サンカンペンからメチャンに至る東部花崗岩列は，主として斑状花崗岩から構成され，放射性元素に富む．ここでは花崗岩類の厚さを10 kmと仮定すると，同地域の熱流量（$\geq$1.5 HFU）のかなりの部分が，花崗岩類からの発熱で説明できる．一方パパエ，メチャムのある中央結晶質複合岩体では，花崗岩類は組成的に不均質な部分が多く，全体の発熱量の予測が難しい．なお今回分析したタイ北部の花崗岩類の発熱量の平均は13.0×10^{-13} cal/cm^3•sである．

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