CHAPTER III

ENHANCED AIRBORNE RADIOMETRIC DATA

Introduction

Khanom area has been chosen for a detailed study by airborne radiometric method since it is situated in high mountainous area with complicated geology. The area is covered by complex series of Precambrian (?) rocks, mixing of granite and gneiss or migmatite as well as other high-grade metamorphic rocks. Thus, it is rather difficult to map by an ordinary method.

Different rock types were characterized by using unusual amounts or proportions of radioelements, including K, U and Th. A regional airborne radiometric survey has been recognized as a very effective way of subdividing felsic igneous and metamorphic rocks in poorly mapped shield areas (Chatterjee and Muec-ke, 1982; Corey, 1987; Ford and O' Reilly, 1985; Galbraith and Saunders, 1983; and Slaney, 1985). The method is also successful in distinguishing Sn-W mineralized granitoids (Webster, 1984; Yeates et al., 1982). The method is then applied to granitic terrane in the Hua Hin - Pran Buri area in order to distinguish different types and phases of granites (Tulyatid, 1992).

Airborne radiometric map shows that the content of these radiometric elements within each rock is different depending largely on mineral composition of rocks, resistance of the radioelement to physical and chemical alteration, via genesis and weathering and erosion processes. The objective of this chapter, therefore, is to emphasize how to differentiate various phases of granitic rocks of the Khanom study area.

Method of Study

The radiometric maps and data of the study area are recompiled using a ***GEOSOFT*** software (an upgraded version in 1993) and produced at a map scale 1:100,000 at Airborne Geophysical Data Interpretation Section, Mineral Resources Development Division, Department of Mineral Resources. The maps of the area representing radiometric contents, comprise shaded relief total count (TC); potassium (K); uranium (eU); thorium (eTh); eU/K, eU/eTh and eTh/K; and ternary maps. In this chapter only the maps, scale 1:150,000 are presented.

Airborne Geophysical Survey

The study area is part of the C-1S area of the regional airborne radiometric survey conducted during 1985 and 1987 by Kenting Earth Sciences International Co., Ltd. The survey was conducted with two rotary-wing aircrafts at an appoximate speed of 45 m/sec with a nominal terrain clearance of 122 m. Traverses were conducted in east-west direction with 1 km interval. Radiometric data were acquired with gamma-ray spectrometers equipped with twelve NaI(Tl) detectors (volume 50.34 litres) analyzing energies in the range of 0 to 3 MeV into 256 channels.

Airborne radiometric survey measures gamma radiation flux of potassium, uranium and thorium, which then converted to equivalent concentration at the ground surface. To some extent, it is similar to the surface geochemical data, with the advantages of fast acquisition and low-cost operation. Potassium was measured directly from the gamma-ray photons emitted by ^{40}K, whereas uranium and thorium were measured indirectly from gamma-ray photons emitted by daughter products in their decay series, ^{214}Bi and ^{208}Tl, respectively.

Window count rates were corrected for dead time, cosmic radiation, source size, detector volume and aircraft speed, back-ground radiation, spectral scattering, deviations from 122 m terrain clearance and for ambient temperature and pressure changes. Counts were converted to ground surface concentration units assuming an infinite flat homogeneous source.

Airborne Radiometric Data

Airborne radiometric data of the the study area are shown in Figures 3.1 to 3.7 for individual elements and rations. These maps are illustrated in contour and colour raster forms. In addition, ternary map, which is useful for mainly geological mapping, is presented in Figure 3.8.

Figure 3.1 illustrates the potassium (K) content of the study area. The plot shows high and moderate K content covering the middle part, the low value covers the northernmost part of the area. The granitoid rock unit yields the highest K value.

Figure 3.2 shows the equivalent uranium (eU) content, the high content along part of the granitoid and residual soil of massive limestone. The latter located in eastern, northernmost and lower-western parts.

Figure 3.3 depicts the equivalent thorium (eTh) content. It shows the same area of the high value along the granitoid unit as other elements. It also yield moderate to high radioelement contents over the residual soil of massive limestone.

Figure 3.4 illustrates the eU/K ratio of the study area. This plot represents the reverse plot to the K content plot as the higher content covering the lower-western and northern parts whereas the lower value distributes in the central part. The residual deposit of massive limestone yields the highest ratio content.

In Figure 3.5, it is quite clear that the lowest value of the eTh/K ratio is located in the central part of the study area interpretations as gneissic rocks and clastic sedimentary rocks at the western rim.

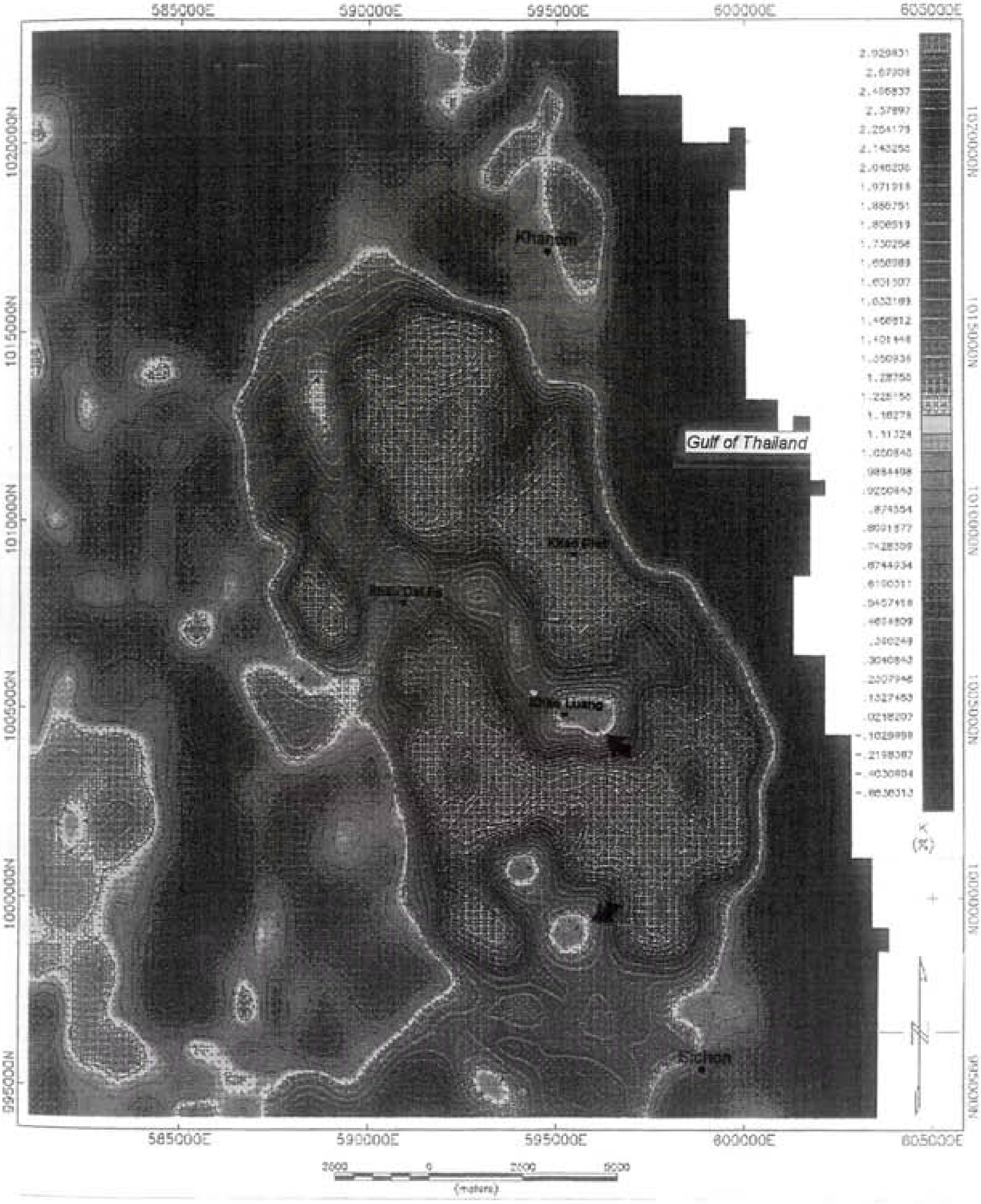

Figure 3.1. Airborne radiometric map of potassium element. The lowest K content within the highest value of the Khao Dat Fa granitoid possibly represents carbonate roof pendant (arrowed).

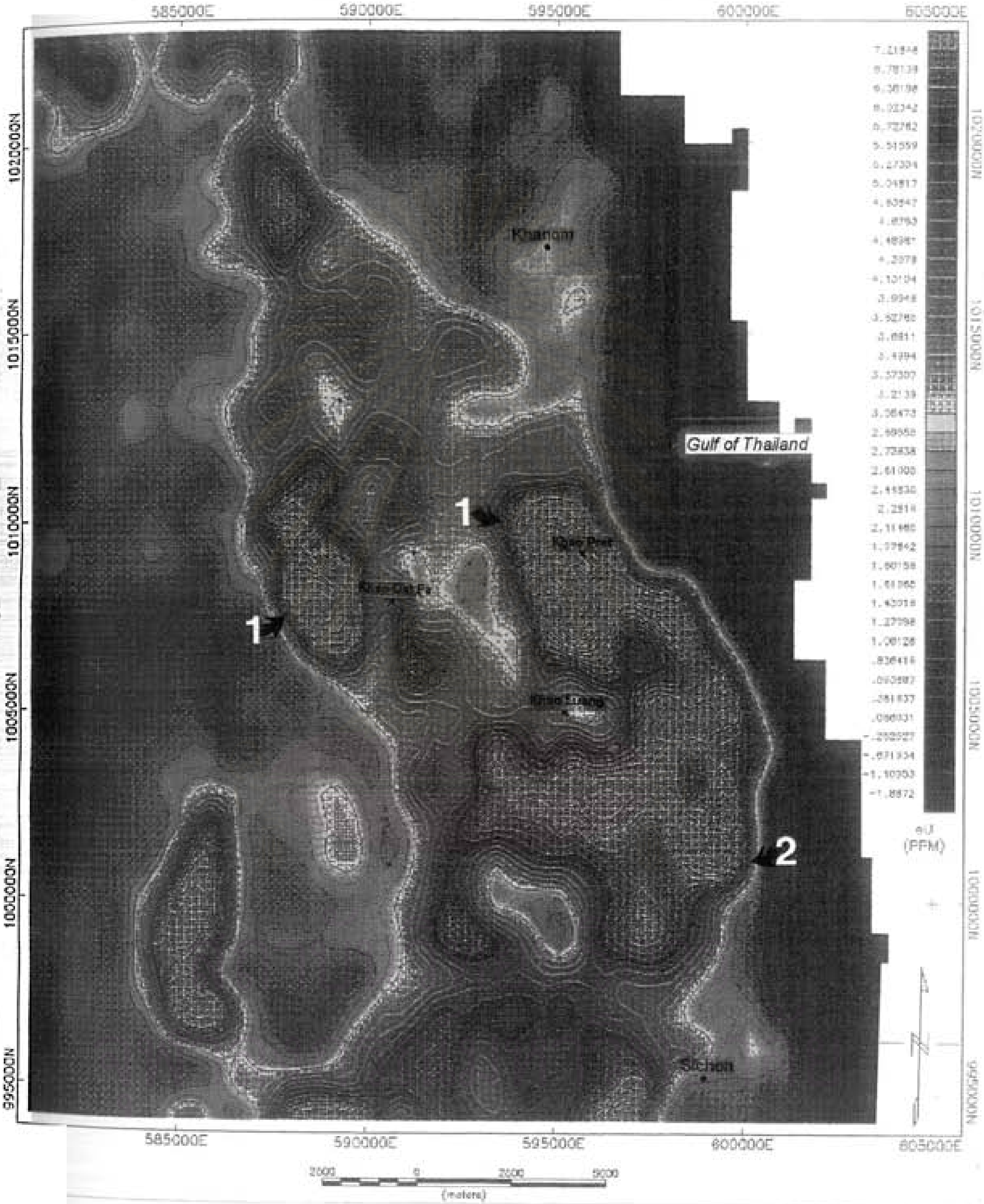

Figure 3.2. Airborne radiometric map of uranium element. The highest U contents are non-foliated granite (arrowed 1) and porphyroblast gneiss (arrowed 2)

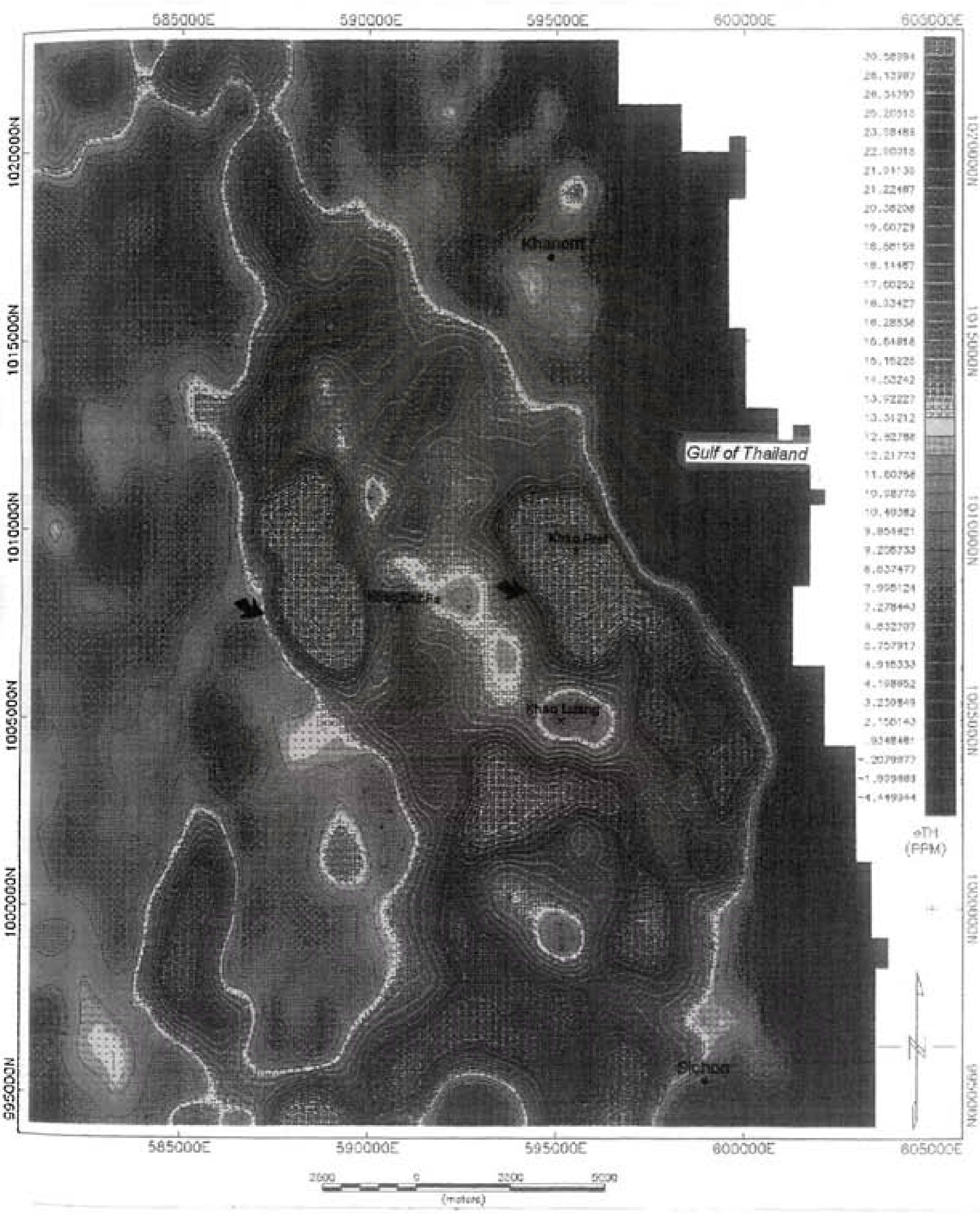

Figure 3.3. Airborne radiometric map of thorium element. The non-foliated granite (arrowed) shows the highest Th content.

Figure 3.4. Airborne radiometric map of uranium / potassium ratio. The residual deposit (arrowed) of massive limestone yields the highest value.

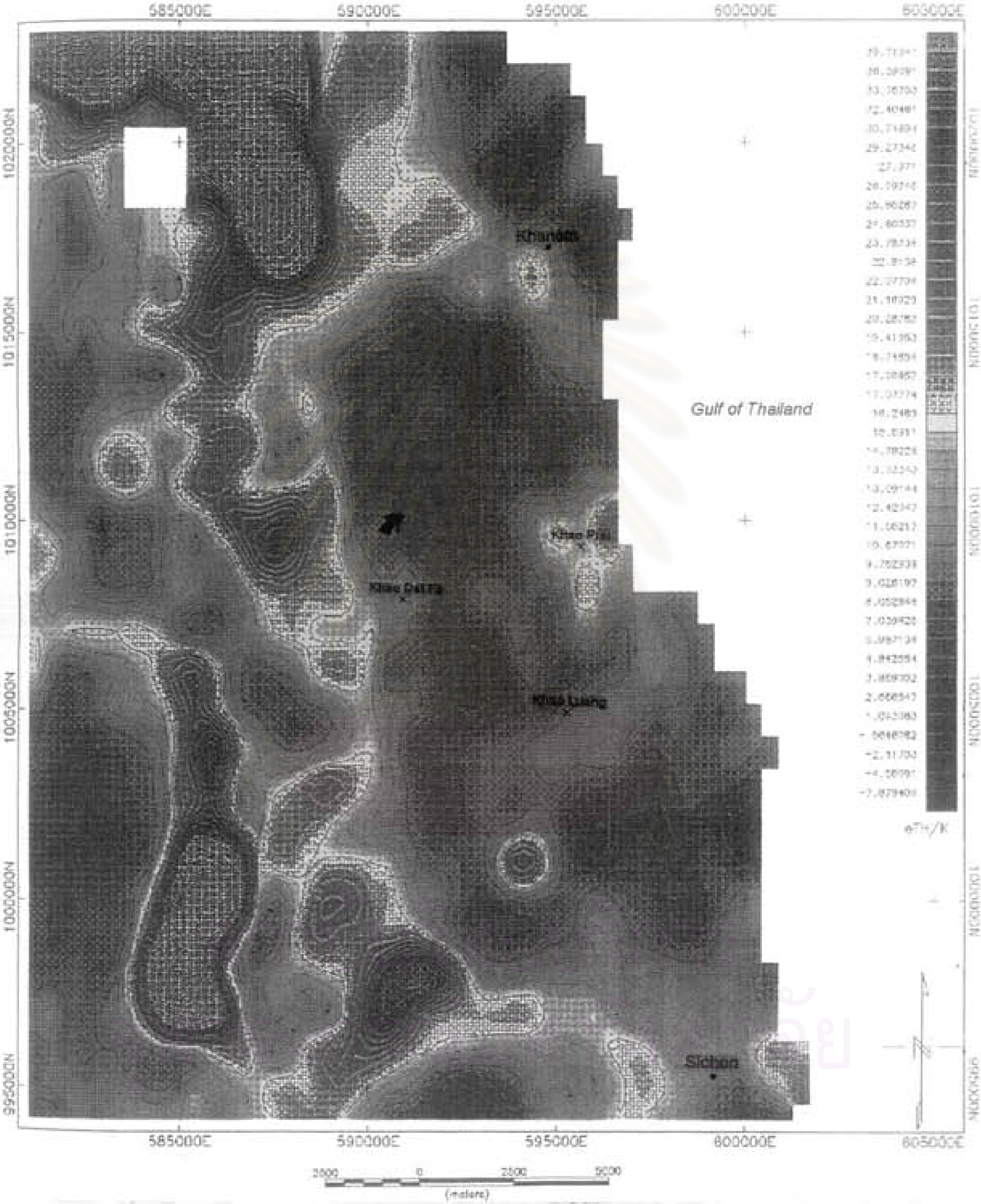

Figure 3.5. Airborne radiometric map of thorium / potassium ratio. The lowest value is located to the northernmost part of the Khao Dat Fa mountain (arrowed) indicating the foliated granite.

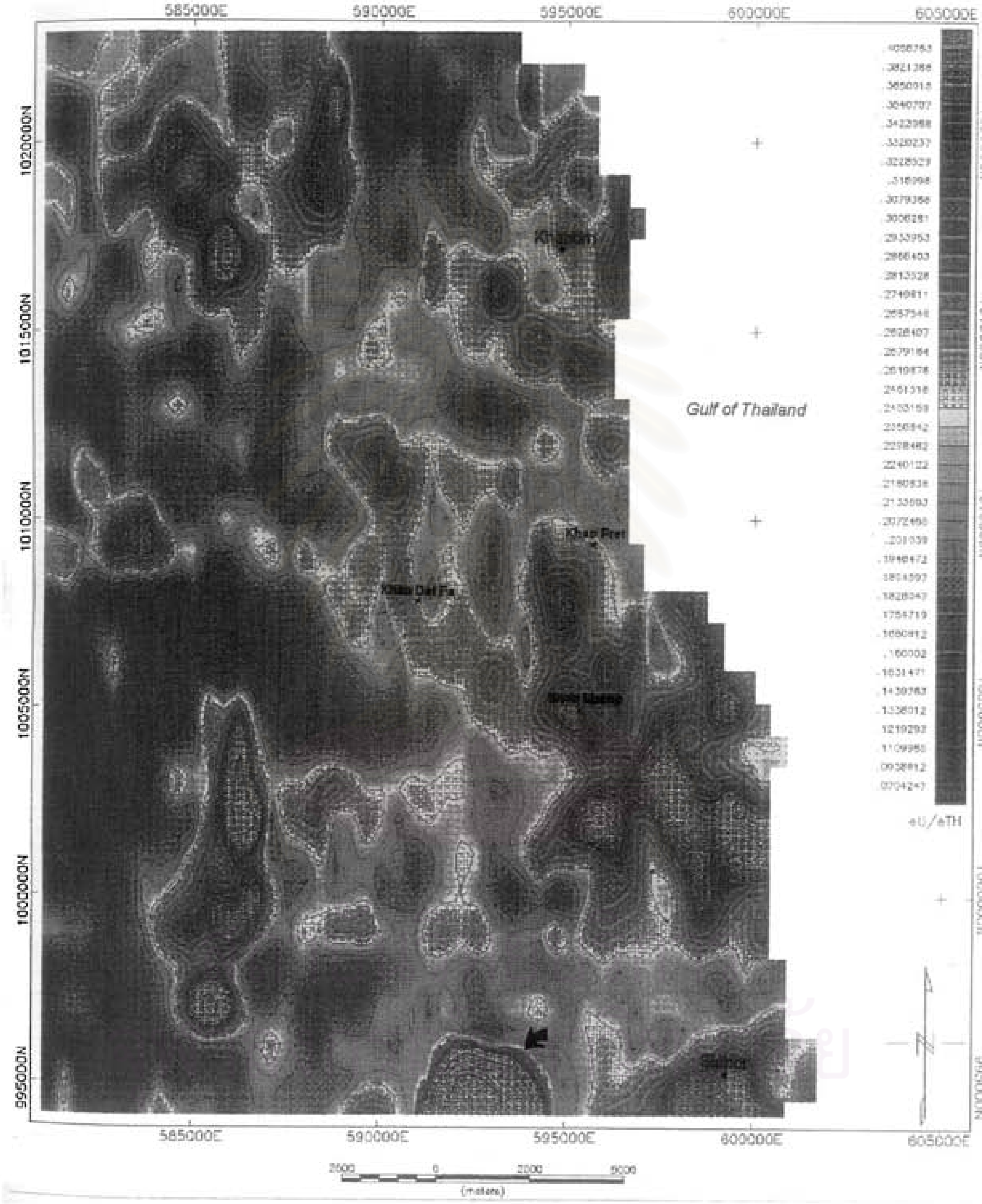

Figure 3.6. Airborne radiometric map of uranium / thorium ratio. The highest value is located at the southern part of the study area, which is leucocratic granite (arrowed).

Figure 3.7. Airborne radiometric map of shaded relief total count elements. The granitoid terrain yields the highest radioelement content. The moderate value channel within high value, it indicates fault zone. Noted that boundaries of granitic rocks are quite clear.

Figure 3.8. Airborne radiometric ternary map (K=magenta,U=yellow,Th=cyan).
The dark colour areas indicate high radioactive content. It clearly shows that the granitic rocks of the area can be easily distinguished.

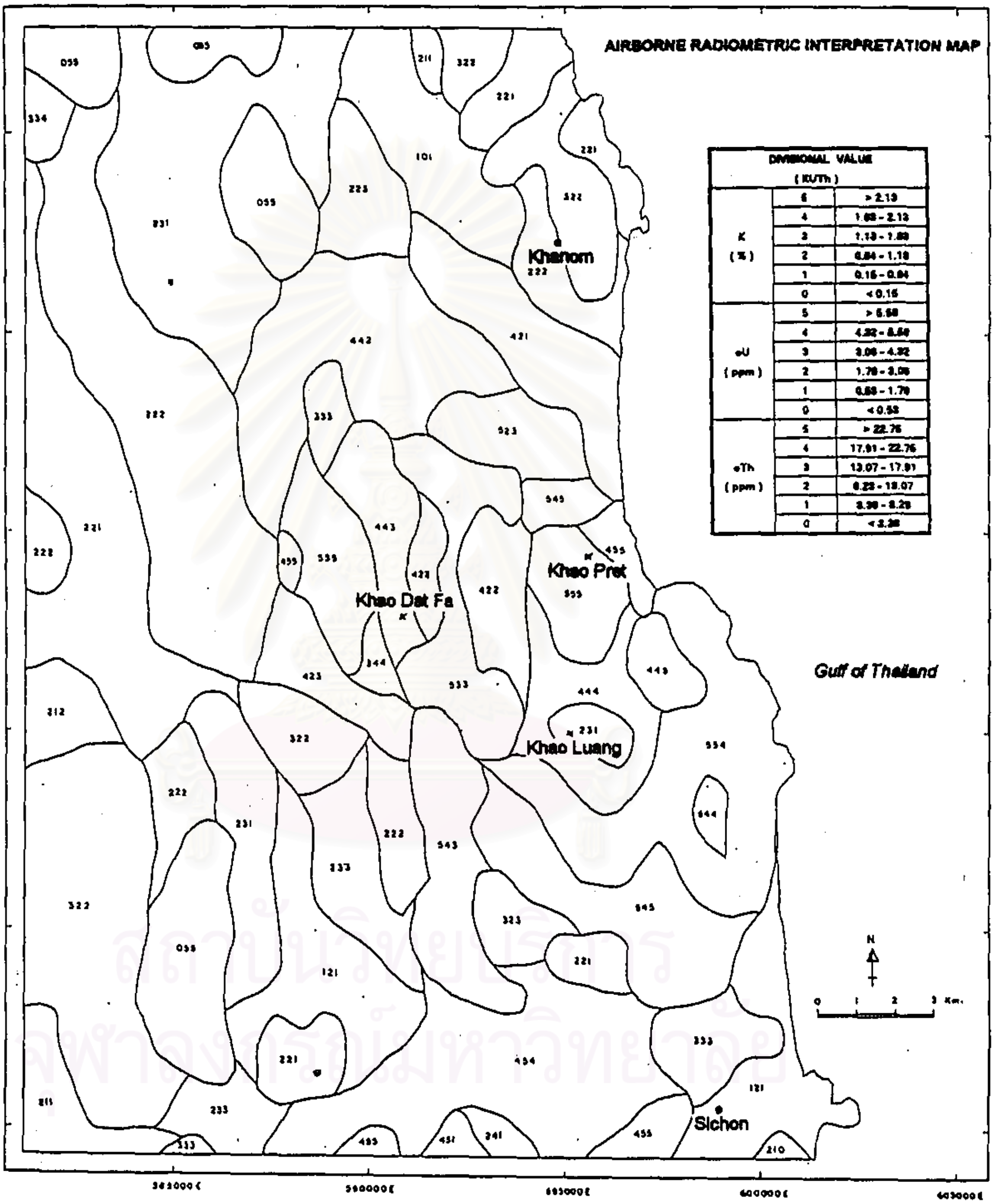

Figure 3.9. Airborne radiometric interpretation map of the Khanom area.

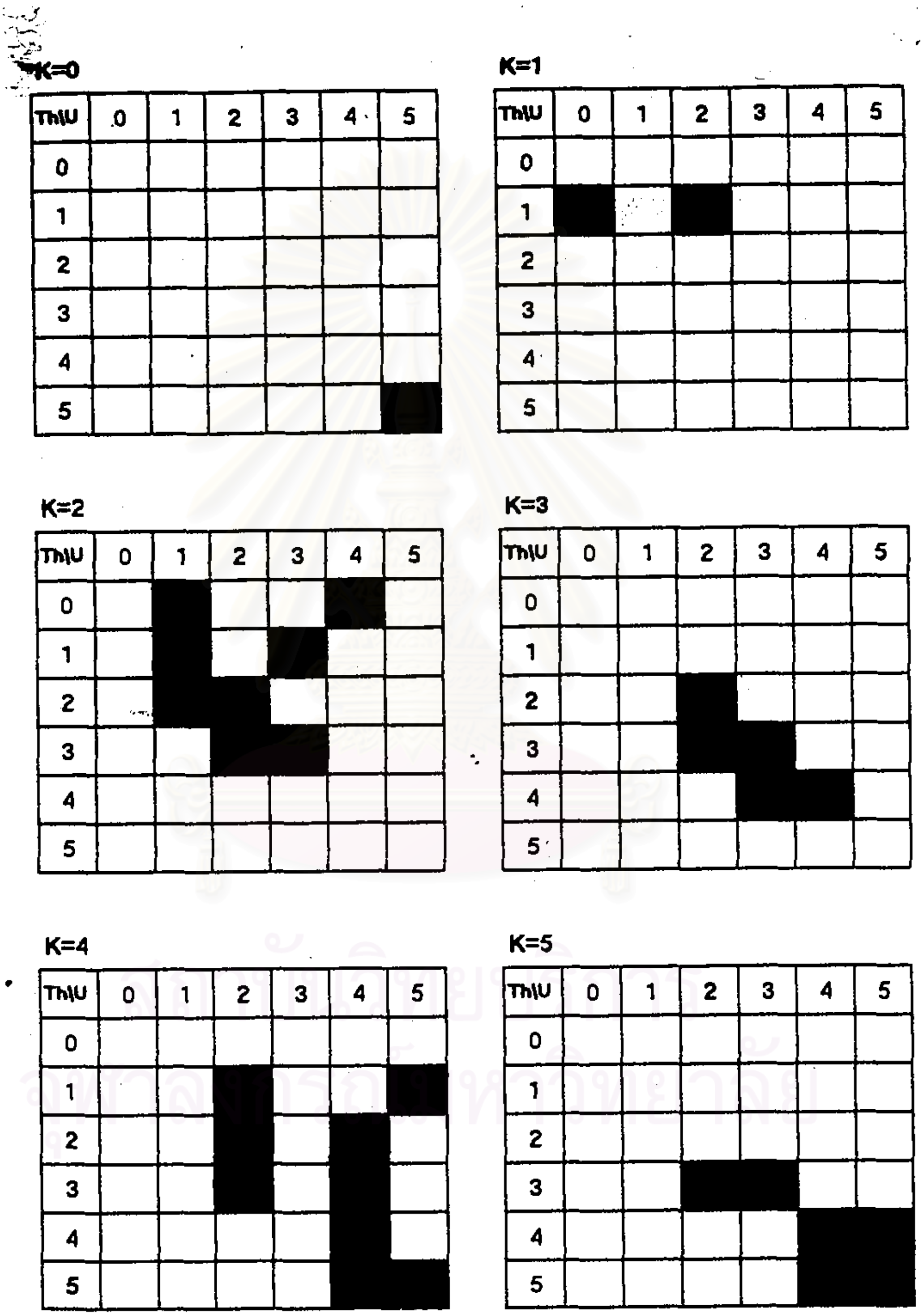

Figure 3.10. Distribution of divisional values of Th\U at individual fixed K values for interpretation of radiometric maps.

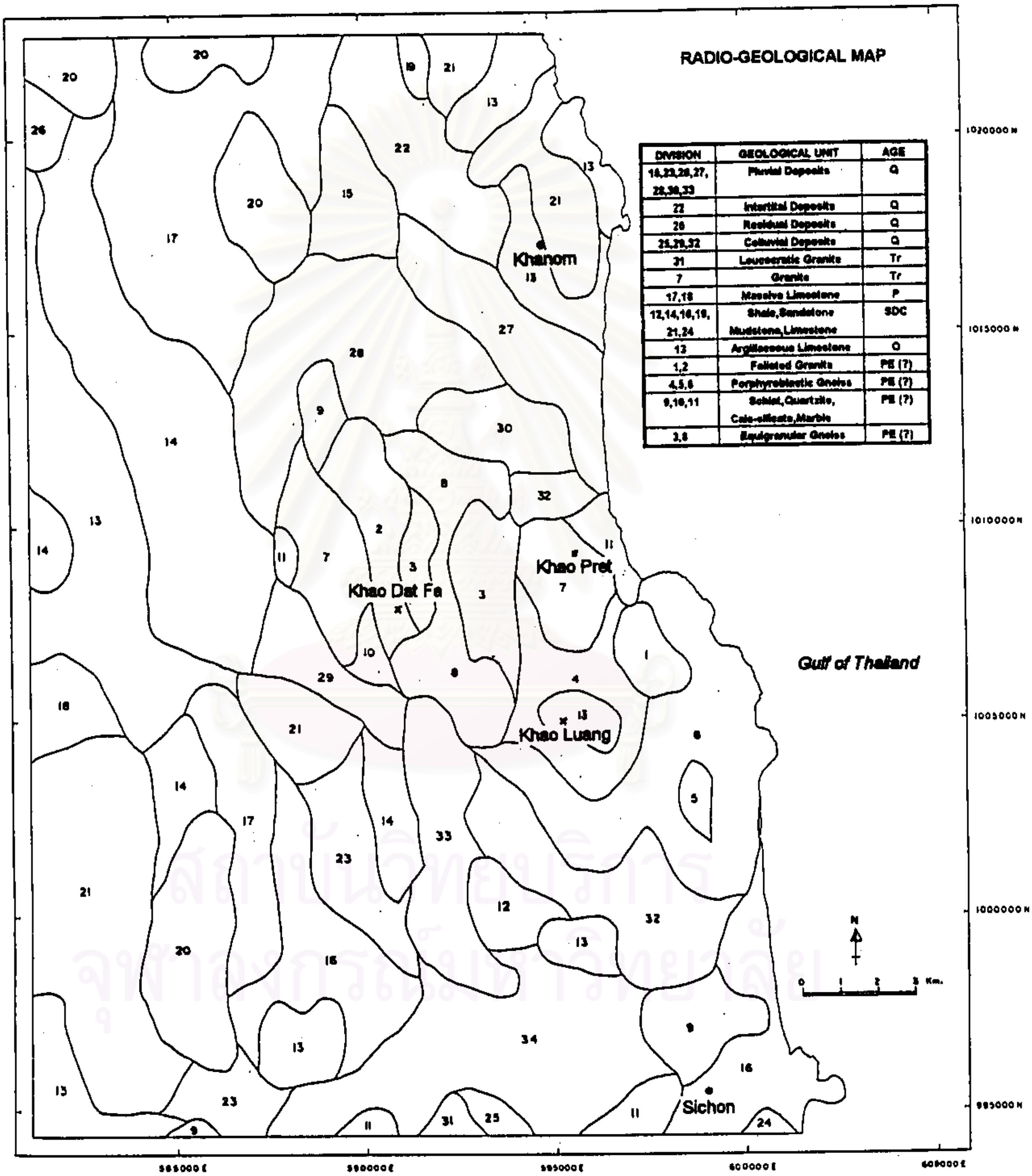

Figure 3.11. Radio-geological map of the Khanom area.

In Figure 3.6, generally the highest content of the eU/eTh ratio is located at middle-southern part of the study area, which is possibly granite. In the field it is leucocratic granite. The lowest values covering the western rim and northern part are clastic sedimentary rocks. This map is clearly differentiate hard rock outcrops from their weathered sediments.

In Figure 3.7, image of total count plot of the study area is shown with a NE sun illumination (45^{o} for both declination and inclination). The green-colour areas represent relatively low radioelement contents whereas the red- and the pink- colour areas show rather high radio content. Most of the lineament show NE-SW, NW-SE and N-S directions.

Figure 3.8 depicts the ternary map of the study area. The dark colours indicate rather high K, U and Th values, which is granitic terrane. The red area is located at the southern rim possibly indicating leucocratic granite and the green area is residual soil of massive limestone.

Interpretation

The application of airborne radiometric data for geological mapping is based upon the hypothesis that rock types are composed of certain amounts of rock minerals comprising specific quantities of radioactive elements-potassium, uranium and thorium. In turn, the character of gamma-rays emitted from these minerals can be used as an essential tool to differentiate rock types.

The main objective of airborne radiometric data interpretation is to delineate radiometric units (referred herein as divisions) and areas of the same radiometric character, onto the map. The "zoning" is the procedure by which the radiometric map units which more or less consistent radiometric characteristics are recognized and delineated. These characters include a large number of parameters which describe not only the intensity and relief of radiometric content but also textural characteristics of lineaments that make up the radiometric divisions.

The divisions are described semi-quantitatively by an numeric code, (KUTh) referred to the potassium, equivalent uranium and equivalent thorium values, respectively, and the signal strength is indicated by symbols (555) strong, (333) average and (000) weak which relate to preselected levels. These divisions are developed arbitrarily by human judgment utilizing the radiometric rasters and contours maps.

The radiometric interpretation map (Figure 3.9) is the process by which radioelement variations are related to source types in the ground, which depicts distribution of divisional values of interpretation map as shown in Figure 3.10. This section depicts the result of interpretation which is mainly based upon the enhanced airborne radiometric data together with aerial photographic image and ground truth surveys. The radiometric divisions are assumed to be representatives of rock units and are named geologically after the rock units were subsequently mapped for that area. The map produced outlining the various radiometric divisions is unofficially called a "radio-geological" map (Figure 3.11), on the basis of these combination parameters, into 34 divisions. A comparison of K, eU and eTh ranges among radioelement contents of division and equivalent geologic units are displayed in Table 3.1.

For the K content, the usually high values of K (usually >2.5 %) are interpreted basically to represent the granitoid terranes. Sedimentary rocks are manifested by relatively much lower K contents (generally <1.0 %). However, with the use of only K parameter, it is quite difficult to differentiate clastic from non-clastic units. On the other hand, K contents higher than non-metamorphosed sediments, i.e. between 1.0 to 2.5 %, are considered to be metamorphic rocks. Fluvial and other Quaternary unconsolidated deposits can be reflected by a wide rage of K content, dependings upon source materials of the deposits.

The eU values show more essential results. Range of high eU values (5.5-13.5 ppm) is limited to the granitic terranes. Quite low values (1.0-3.0 ppm) of eU are restricted to clastic sedimentary rocks and argillaceous limestone. Intermediate eU values (2.0-6.0 ppm) are interpreted to represent areas occupied by unconsolidated sediments and slightly higher value (2.0-4.0 ppm) is for sediments of massive limestone. This limestone has weathered product of high eU, but argillaceous limestone generally yields relatively high K content, possibly reflecting admixtures of clay-minerals. Areas dominated by metamorphic rocks (gneissic and schistose) usually yield higher eU values, but in general lower than those of the granitoid terrane.

The values of eTh indicate results somewhat similar to those of the eU values. Details of eTh results/interpretation are shown in Table 3.1.

The combination and ratios of these radioelement parameters can help in the interpretation of geological mapping. At least 34 divisions (nos.1 to 34 in Table 3.1) are recognized from the radio-geological interpretation. Granitiod rocks (granitic & gneissic) can be also differentiated using values shown in Table 3.1. For example, it is quite clear that Division no. 7 shows relatively high K, eU, eTh contents and can be easily distinguished from the other divisions. The less values of eTh/K ratio occur in the southernmost part of the area, the high values of K, eU and eU/eTh occur approximately at the same location. This particular signature has been recognized as late-stage leucocratic granite. The eU/eTh ratio is clearly divided between hard granitoid outcrop and their weathered products. The gneissic rocks can be distinguished from the other granitic rocks by their lower values of eU/K and eTh/K radioelement ratios.

Division nos. 3 and 8 reflect the equigranular gneiss as visualized in the field. Division nos. 9, 10 and 11, on surrounding granitoids, cover the area of metamorphic rocks that consist of schist, quartzite, calc-silicate and marble. Division nos. 4, 5 and 6 cover various phases of porphyroblastic gneiss. In the porphyroblastic gneiss, various divisions may indicate different phases of parential granite intrusions.

This may be caused by the existence of variable grain sizes and textures. In addition, intrusions of later granites and the hydrothermal alteration parts play some essential parts in these variations. Division nos. 1 and 2 may indicate the foliated granite. Division no. 13 is interpreted to represent the argillaceous limestone. Division nos. 12, 14, 16, 19, 21 and 24 cover much of the area of clastic sedimentary rocks consisting of shale, sandstone and mudstone. Division nos. 17 and 18 possibly indicate the more massive limestone. Division no. 7 indicate the non-foliated granite and division no. 31 indicates leucocratic granite.

Division nos. 25, 29 and 32 covering the colluvial deposits, may indicate either the washover of the source rocks or the very thin overburden over the granitic rocks. It is the same as that of division no. 20 which possibly indicates the residual deposits on the massive limestone. Division no. 22 indicates the intertidal deposits. And division nos. 15, 23, 26, 27, 28, 30 and 33 covering the fluvial deposits.

Figure 3.12 is a lineament map that is produced on the basic of shaded-relief total count plot of the study area (Figure 3.7). Most of the lineament show NE-SW and NW-SE directions. It is also visualized from this preliminary result that the NE lineaments cross-cutting the NW lineaments, and the N-trending lineaments may represent the oldest one. There are two major faults whose trend are more or less in the NW- direction, namely Sichon and Khanom Faults zones. These faults are observed fairly well in Figures 3.3 and 3.7. These two faults are first recognized in the field by Mr. Apichart Lumjuan (personal communication., 1995). In addition, the much lower contents of individual radioelements (see also Figures 3.1, 3.3, 3.4 and 3.7) with similar values to the carbonates and situated at the Khao Luang may bed interpreted to represent the (meta)sediments assigned to be of the Haad Nai Phlao Gneiss unit.

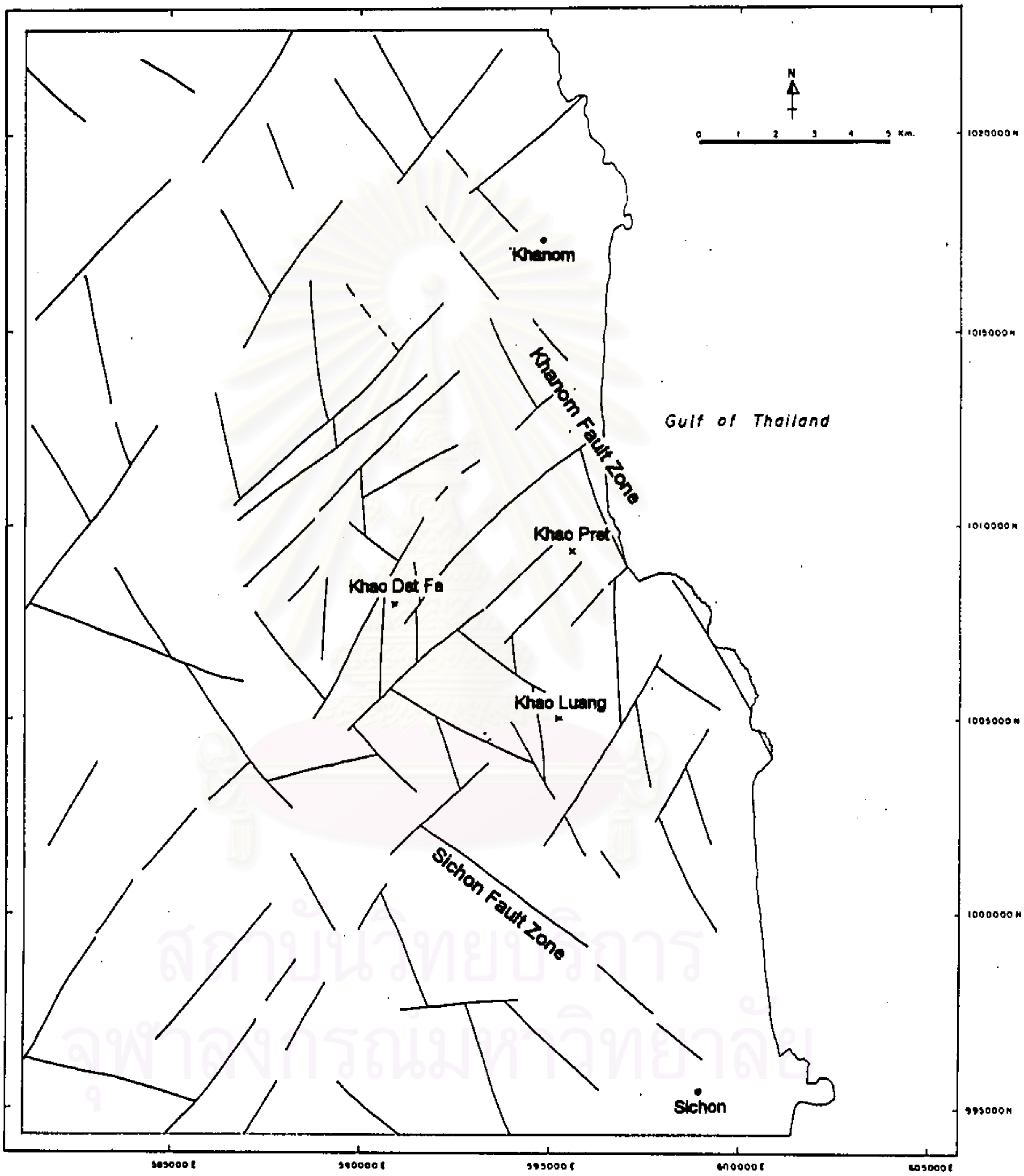

Figure 3.12. Lineament map of the Khanom area, interpreted on the basis of shaded relief total count map (Figure 3.7).

Table 3.1. Interpreted maximum-range radioelement contents of the Khanom area.

DIVISION	K (%)	eU (ppm)	eTh (ppm)	Equivalent Geological Units
1	1.8-3.0	5.5-8.0	20-35	Foliated granite
2	1.6-3.4	3.5-6.5	14-20	Foliated granite
3	1.2-3.0	3.0-4.0	12-20	Equigranular gneiss
4	1.4-2.8	3.5-8.0	15-30	Porphyroblast gneiss
5	2.4-3.0	6.5-8.0	20-24	Porphyroblast gneiss
6	2.0-3.6	4.0-10	20-30	Porphyroblast gneiss
7	2.0-3.6	6.0-13.5	20-56	Granite
8	2.0-3.0	4.0-6.0	15-24	Equigranular gneiss
9	1.2-2.0	3.0-4.0	15-20	Sediments & Metamorphic rocks
10	1.2-2.4	4.0-6.0	25-30	Metamorphic rocks
11	1.0-2.0	7.0-12.0	20-40	Sediments & Metamorphic rocks
12	1.5-3.0	3.0-5.0	15-25	Clastic sedimentary rocks
13	0.6-1.0	1.0-3.0	5-10	Argillaceous limestone
14	0.5-1.0	1.0-3.0	5-15	Clastic sedimentary rocks
15	0.6-1.0	1.0-3.0	10-20	Fluvial deposits
16	0.3-1.0	1.0-2.0	8-10	Sediments & Sedimentary rocks
17	0.5-1.0	2.0-4.0	5-10	Sediments & Massive limestone
18	0.1-1.0	0.5-1.0	8-10	Massive limestone
19	0.5-1.0	1.0-1.5	5-10	Clastic sedimentary rocks
20	0.1-0.4	4.0-10.0	15-30	Residual deposits
21	1.0-1.5	1.0-2.0	8-12	Sediments & Sedimentary rocks
22	0.5-1.0	1.0-20	5-10	Intertidal deposits
23	1.0-1.2	2.0-4.0	10-16	Fluvial deposits
24	0.6-0.8	1.0-1.5	4-6	Clastic sedimentary rocks
25	1.0-1.8	4.0-5.0	4-10	Colluvial deposits
26	0.6-1.2	2.5-4	12-20	Fluvial deposits
27	0.5-3.0	1.5-4.0	5-15	Sediments & Sedimentary rocks
28	1.0-3.8	3.0-5.0	18-28	Fluvial deposits
29	1.0-3.4	2.0-10.0	14-30	Colluvial deposits
30	2.4-3.0	3.0-4.0	16-20	Fluvial deposits
31	1.8-2.2	5.5-6.0	2-12	Leucocratic granite
32	1.8-3.7	4.0-7.0	18-30	Colluvial deposits
33	2.0-3.0	4.0-6.5	16-25	Sediments & Sedimentary rocks
34	0.6-2.2	4.0-6.5	18-28	Fluvial deposits