CHAPTER IV

GEOCHEMISTRY OF GRANITE

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The geochemical characteristics based on major and trace element contents of the granitic rocks from Takua Pit Thong mine have been investigated. Totally, six samples essentially fine-to-medium-grained biotite ($\pm$ muscovite, tourmaline) granite from various places in the concession area have been carefully selected for the analytical work. It was unfortunate that there was no good sample of coarse-grained biotite-muscovite granite suitable for the chemical study. All the samples have also been studied petrographically in the previous section.

The results of major-oxide analyses as well as CIPW norms and differentiation index are tabulated in Table 1. The trace element concentrations and some certain elemental ratios are displayed in Table 2.

All major oxides and trace element concentrations are reported in weight percentage and part per million (ppm), respectively. The differentiation index is calculated from the sum of normative quartz, orthoclase and albite of which having been corrected to 100 percent (Thornton and Tuttle, 1960).

4.1 Major Oxide Variations

From the analytical results shown in Table 1, the Harker variation diagrams of various major oxides plotted against SiO_2 content

Table 1 Major element-oxide, CIPW norms and Differentiation Index (D.I.) of the Takua Pit Thong granite.

Sample No	ORR1-2	ORR1-3	ORR1-12	ORR2-1	RSD9-1	RSD14-1
Major element oxides (Wt%)						
SiO_2	73.89	74.34	73.77	74.42	75.57	73.29
TiO_2	0.17	0.14	0.16	0.18	0.04	0.22
Al_2O_3	13.04	14.20	13.97	14.43	13.28	13.98
Fe_2O_3	0.33	0.07	1.22	0.83	0.18	0.74
FeO	1.05	1.11	0.46	0.46	0.40	1.23
MnO	0.02	0.03	0.04	0.02	0.04	0.02
MgO	0.23	0.28	0.18	0.19	0.08	0.53
CaO	0.81	0.55	0.65	0.45	1.03	0.72
Na_2O	3.05	3.29	2.80	2.79	3.08	2.54
K_2O	5.57	5.65	5.48	5.32	5.19	5.75
P_2O_5	0.21	0.10	0.15	0.14	0.05	0.20
S	0.01	0.01	0.01	0.01	0.01	0.01
H_2O^+	0.14	0.07	0.48	0.83	0.06	0.51
Total	99.42	99.84	99.37	100.07	99.01	99.74
CIPW norms						
Q	32.72	31.46	35.28	36.98	35.35	34.15
or	32.91	33.38	32.38	31.43	30.67	33.98
ab	25.81	27.84	23.69	23.61	26.06	21.49
an	2.65	2.08	2.25	1.32	4.78	2.27
C	1.92	1.91	2.61	3.60	0.84	2.75
hy en	1.96	2.48	0.45	0.47	0.77	2.62
mt	0.48	0.10	1.11	0.99	0.26	1.07
hm	–	–	0.45	0.15	–	–
il	0.32	0.27	0.30	0.34	0.08	0.42
ap	0.49	0.23	0.35	0.32	0.12	0.46
py	0.02	0.02	0.02	0.02	0.02	0.02
Salic tot	96.01	96.67	96.21	96.94	97.70	94.64
Femic tot	3.27	3.10	2.68	2.29	1.25	4.59
D.I.	92.10	92.89	92.38	92.72	93.06	90.32

are presented in Figure 17. Also including in these diagrams are values of major oxides of 14 specimens from the Khao Daen granite reported by Nakapadungrat et al. (1985). Eventhough, obvious correlation could not be drawn from most of the plots (correlation coefficient varying from 0.19 to 0.86), it is still possible to recognize some variation trends. Generally, the TiO_2, Al_2O_3, $FeO + Fe_2O_3$, MnO, MgO, CaO and perhaps P_2O_5 decrease whereas Na_2O and K_2O tend to be uniform or slightly increase with increasing SiO_2 content. These trends are exactly the same as those observed in the Phuket granites (Charusiri and Pongsapich, 1982). Moreover, the Takau Pit Thong granite generally contains SiO_2 content higher than the Khao Daen granite.

The variation in compositions of the said granites can also be clearly observed from the AFM and K_2O-Na_2O-CaO diagrams as shown in Figures 18 and 19. The AFM ($A = Na_2O + K_2O$, $F = FeO + Fe_2O_3$, $M = MgO$) diagram displays a well defined variation trend toward the alkali enrichment extending from the Khao Daen granite to the Takua Pit Thong granite along the A-F sideline (Figure 18). Decreasing $FeO + Fe_2O_3$ as well as MgO but enrichment $Na_2O + K_2O$ are the characteristic of this trend. A similar feature can also be easily seen from the K_2O-Na_2O-CaO plot in Figure 19. Although, the trend is not as obvious as in the AFM diagram, it is possible to recognize that the $K_2O + Na_2O$ increases as the CaO decreases from the Khao Daen granite to the Takua Pit Thong granite. Furthermore, this trend has tendency to move toward the K_2O rather than the Na_2O.

The alkalinity ratio plotted against SiO_2 contents (Wright, 1969 cited in Sheraton and Labonne, 1978) is illustrated in Figure 20.

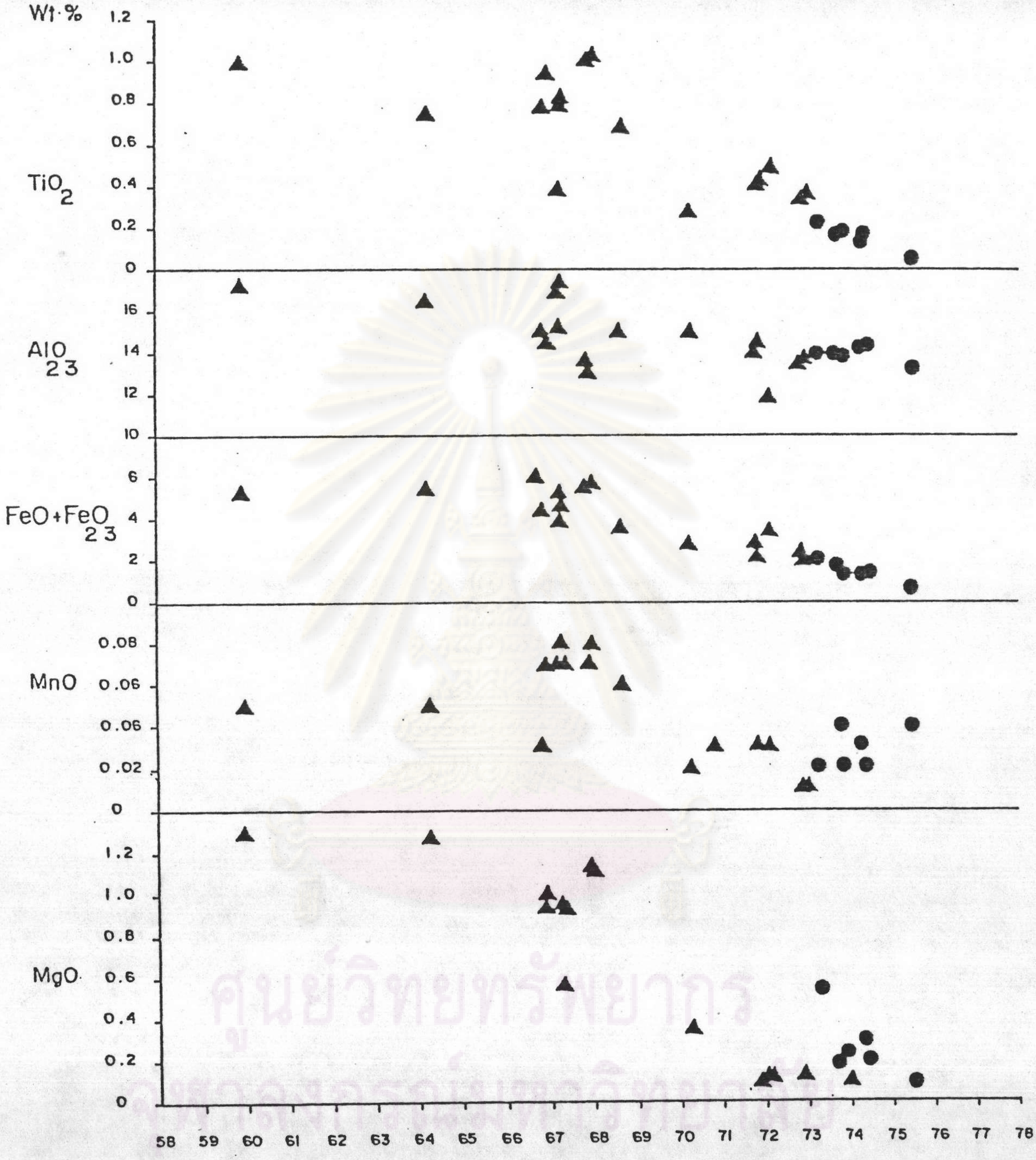

Figure 17 Harker variation diagram of the major element-oxides against SiO_2 content. Soid circles and triangles represent the values from the present study and Nakapadungrat et al. (1985), respectively.

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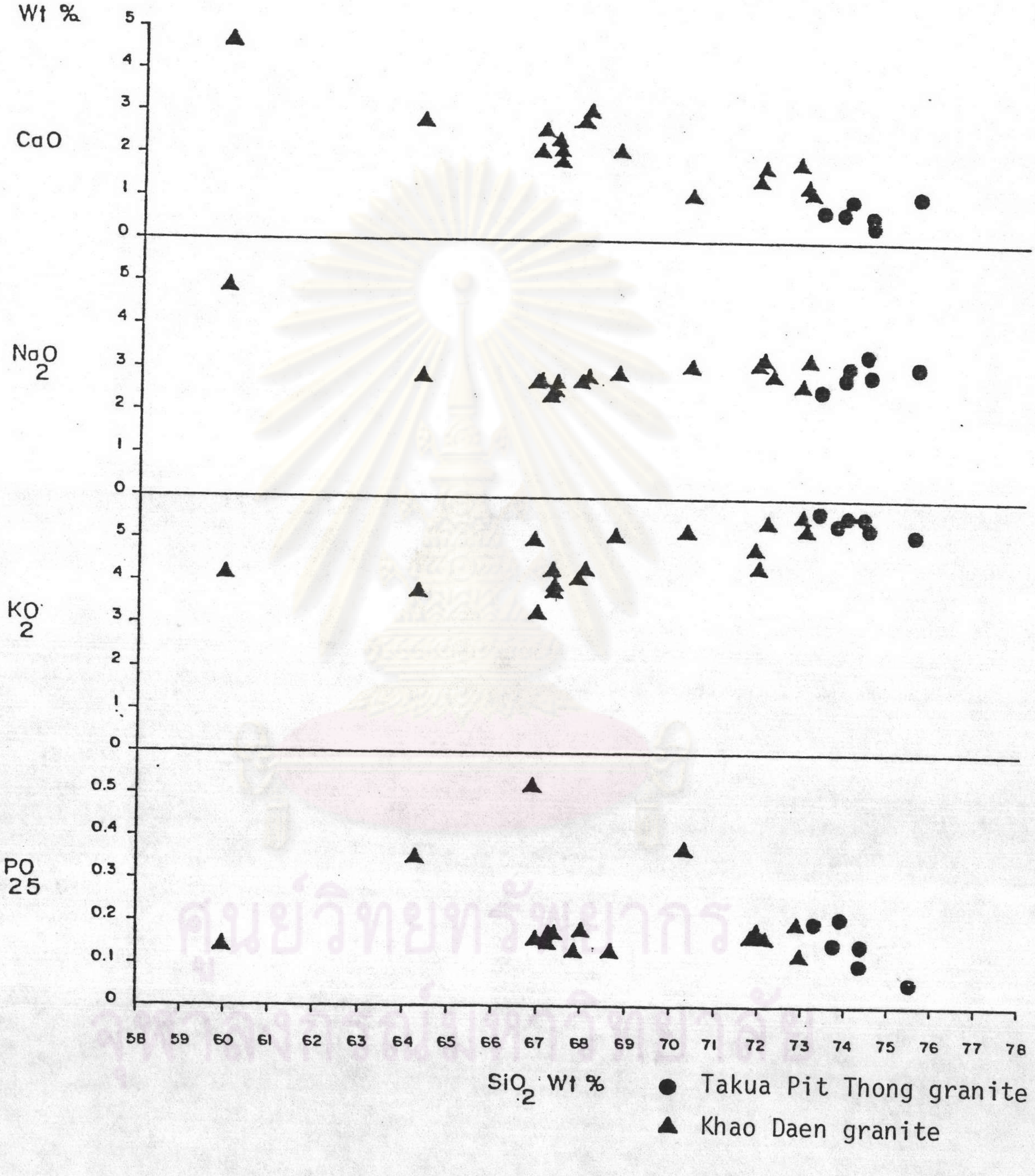

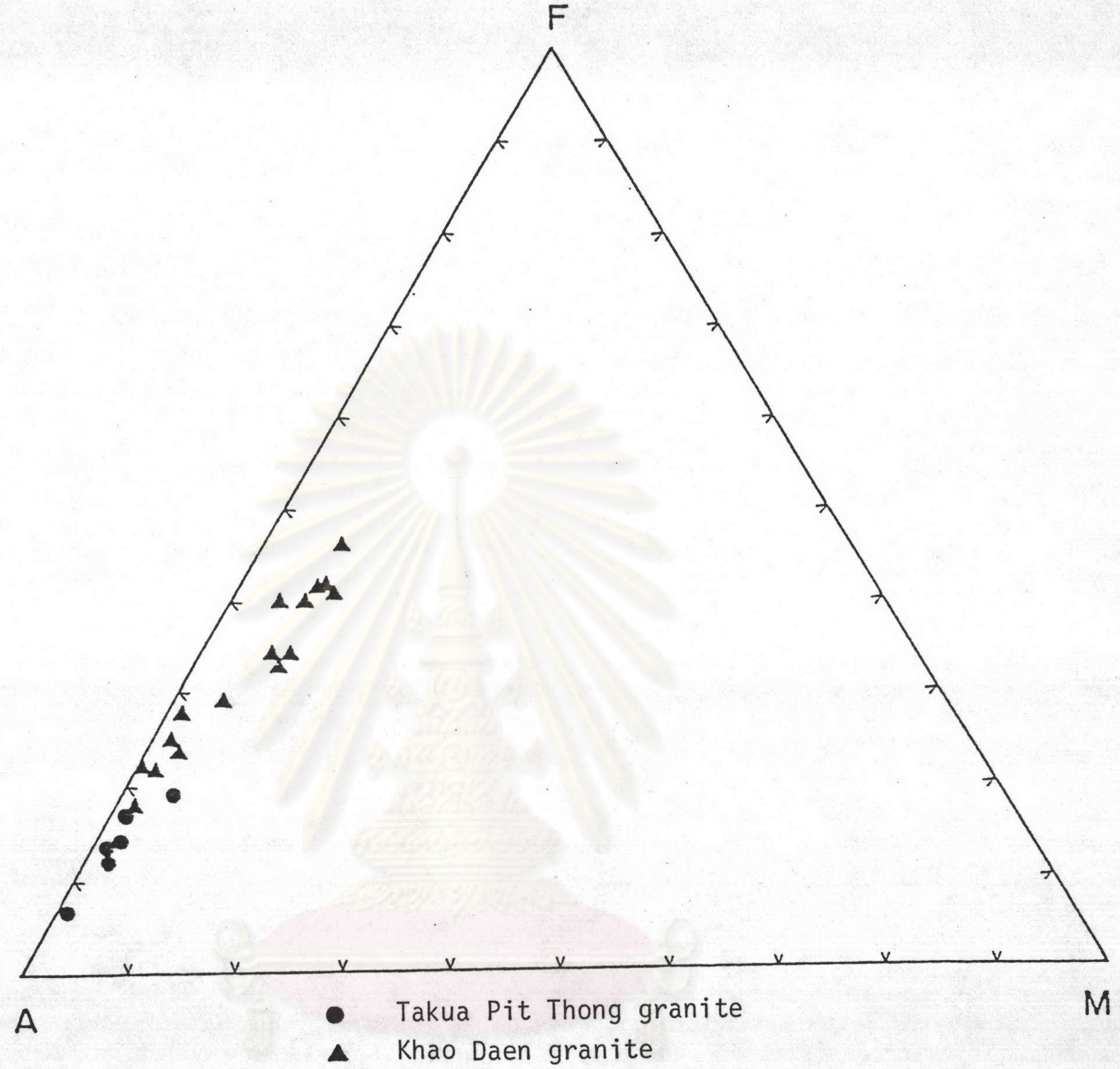

Figure 18 A $(Na_2O + K_2O)$ - F$(FeO + Fe_2O_3)$ - M(MgO) diagram for the Takua Pit Thong granite and the Khao Daen granite (Nakapadungrat et al., 1985) showing chemical variation trend.

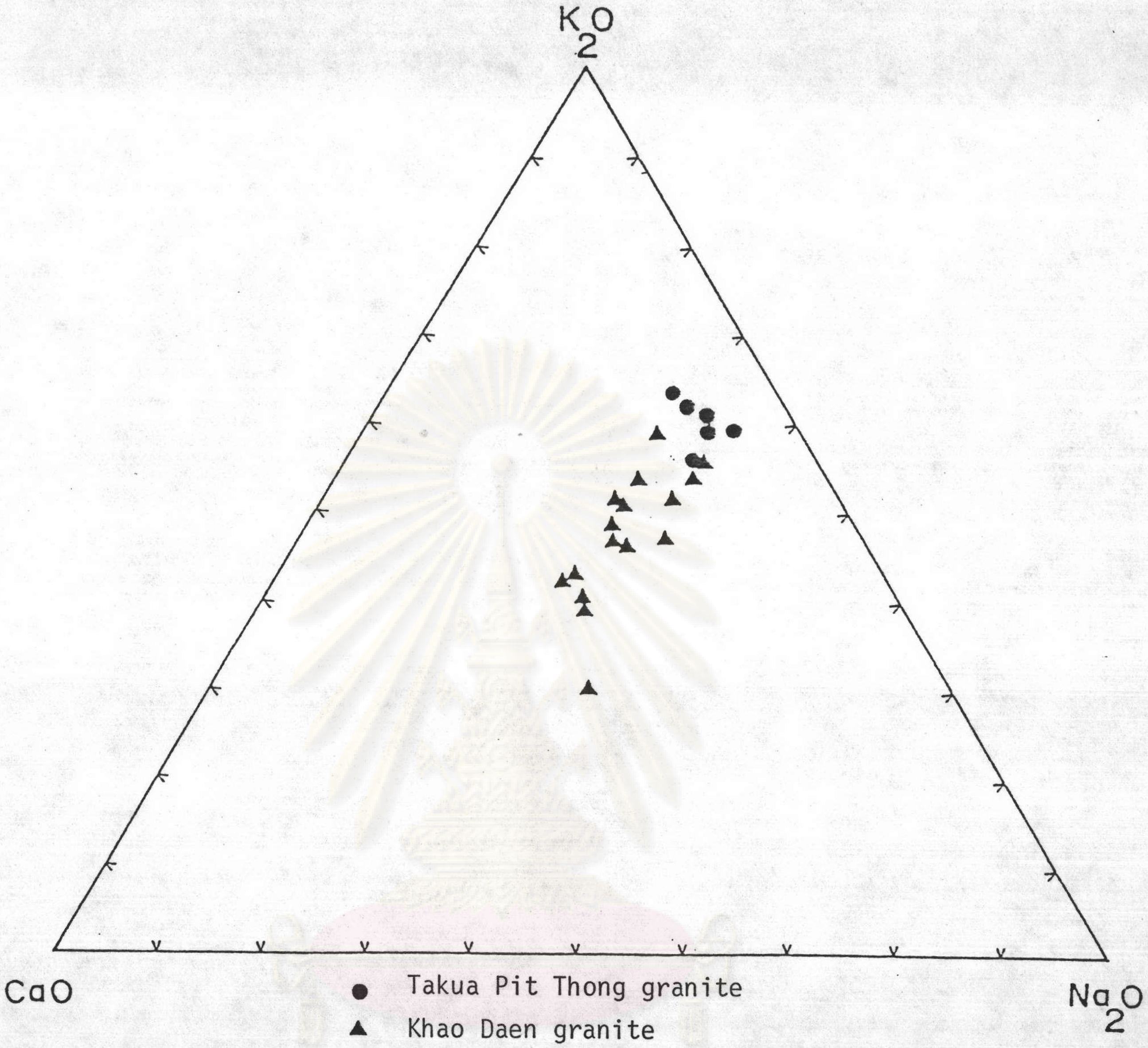

Figure 19 K_2O - Na_2O - CaO diagram for the Takua Pit Thong granite and the Khao Daen granite (Nakapadungrat at al., 1985) showing chemical variation trend.

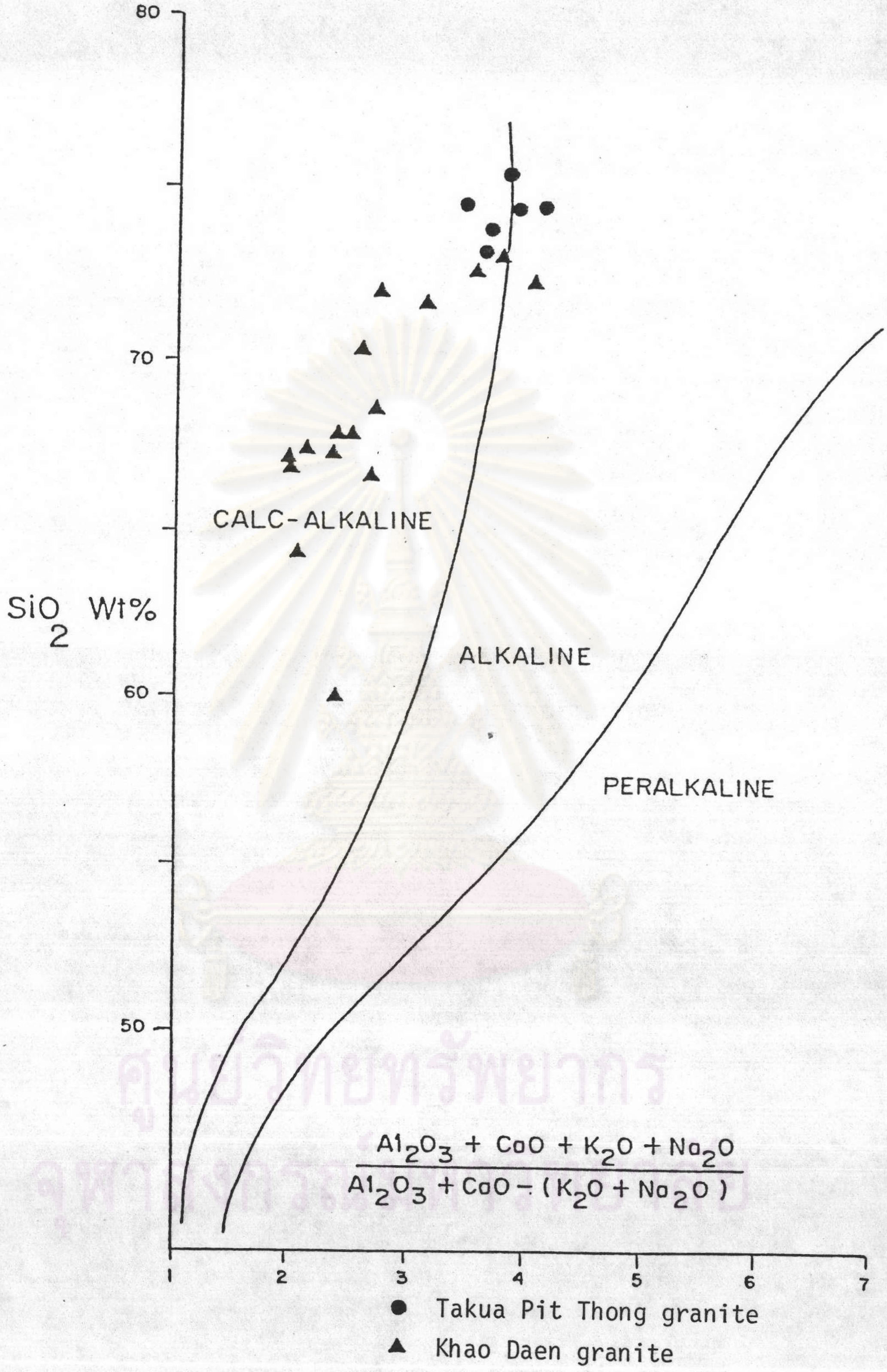

Figure 20 Alkalinity ratio variation diagram for the Takua Pit Thong granite and the Khao Daen granite (Nakapadungrat et al., 1985). The alkalinity fields are from Wright (1969, cited in Sheraton and Labonne, 1978).

The majority of the Takua Pit Thong and Khao Daen granites shows a typically calc-alkaline affinity, though a few samples fall within the alkaline field. This appears to be the characteristics of many calc-alkaline associations (Sheraton and Labonne, 1978). Trend of increase in SiO_2 as well as alkalinity ratio is also observed from the Khao Daen granite to the Takua Pit Thong granite (Figure 20).

From the above major-oxide variation diagrams, it is possible to conclude that the Takua Pit Thong and Khao Daen granites might be magmatic consanguinity whereby the former might have been the late and highly differentiated phase of the later one. Based on field evidences, they also occur in the same pluton. It is noteworthy that the Khao Daen as well as the Takua Pit Thong granites are also of the same magmatic evolution as the granites from Ko Phuket and Takua Pa-Phangnga (Nakapadungrat et al., 1985).

4.2 Trace Element Variations

The variation diagrams of Rb and Sr concentrations as well as Rb/Sr, Ca/Sr and K/Rb ratios plotted versus SiO_2 content of the Takua Pit Thong and the Khao Daen granites are illustrated in Figure 21. Eventhough, no definite trend could be drawn from the diagrams due to compositional gap between those two granites, the general increase in Rb concentration or Rb/Sr ratio and decrease in Sr concentration and K/Rb ratio as increasing SiO_2 content can be observed from the Khao Daen granite to the Takua Pit Thong granite. The Ca/Sr ratio, however, seems to be unchanged (Figure 21). Such the increase and decrease in the trace element concentrations and

Table 2 Trace elements and elemental ratios of the Takua Pit Thong granite.

Sample No.	ORR 1-2	ORR 1-3	ORR 1-12	ORR 2-1	RSD 9-1	RSD 14-1
Trace elements (ppm)						
Rb	856	1,163	941	981	876	791
Sr	43	44	36	32	48	60
Ba	146	344	526	337	35	268
Sn	42	51	34	34	51	49
W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Nb	57	45	67	58	18	45
Ta	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Elemental ratios						
K/Rb	54.01	40.32	48.34	45.06	49.18	60.34
Ba/Rb	0.17	0.29	0.56	0.34	0.04	0.34
K/Ba	316.69	136.34	86.48	131.04	1230.92	178.10
Ca/Sr	134.63	89.34	129.04	100.50	153.36	85.76
Rb/Sr	19.91	26.43	26.14	30.66	18.26	13.18

N.D. = not detected

ratios are well known features in crystallization of late stage residual products (Taylor, 1968; Ewer and Scott, 1977).

It is rather unfortunate, however, that no other trace element data is available from the Khao Daen granite (Nakapadungrat et al., 1985). Therefore the variation diagram of the trace elements (Ba, Nb and Sn) versus SiO_2 contents of merely Takua Pit Thong granite (not shown in this report) could show only a cluster of points without obvious trend due to small compositional variation. Nevertheless, the Takua Pit Thong granite contains relatively high Sn (34 - 51 ppm) and Nb (18 - 67 ppm) contents, but low Ba and Ba/Rb ratio (< 0.6) which are indicative of late stage strongly fractionated granite (Tauson and Kozlov, 1973).

The binary elemental variation diagrams (Figures 22, 23 and 24) indicate that the Takua Pit Thong granite is relatively more depleted in Sr and Ca and enriched in Rb and K than the Khao Daen granite. The Ca/Sr ratios are, however, unchanged at around 130, except two samples up to around 375, for both granites (Figure 22). The K/Rb ratios of the Khao Daen and Takua Pit Thong granites decrease from the average value of around 84 to 50 and the Rb/Sr ratios increase from those of around 8 to 22, respectively. The positive correlation trend could also be drawn from the Khao Daen to Takua Pit Thong granites in the K_2O - Rb plot (Figure 23).

The binary elemental ratio variation diagram (Figure 25) again reveals a similar result that the K_2O/CaO and Rb/Sr ratios of the Takua Pit Thong granite are relatively higher than those of the Khao Daen granite eventhough the positive correlation trend is not

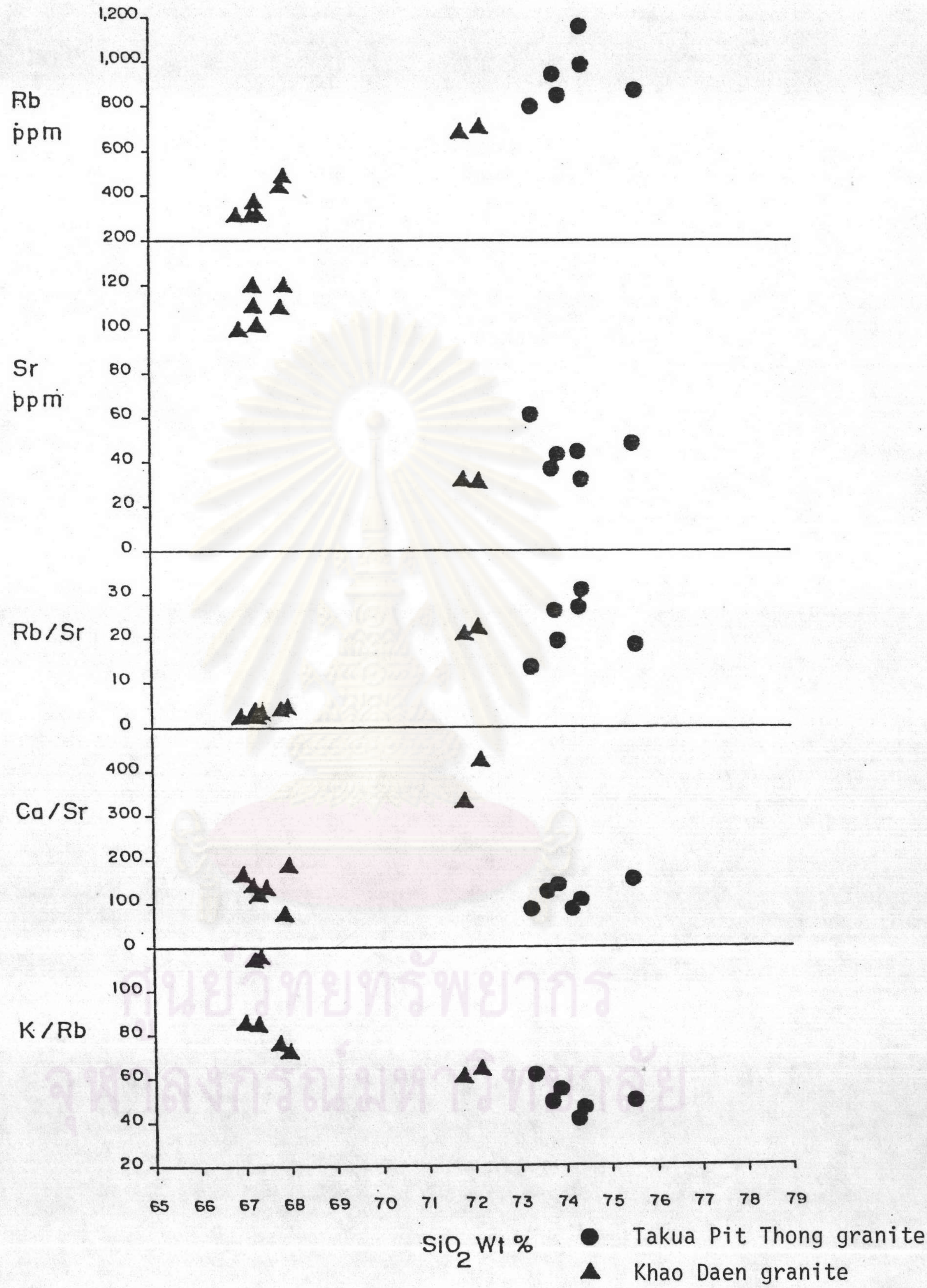

Figure 21 Variation of the Rb, Sr and Rb/Sr, Ca/Sr and K/Rb ratios against SiO_2 for the Takua Pit Thong granite and the Khao Daen granite (Nakapadungrat et al., 1985).

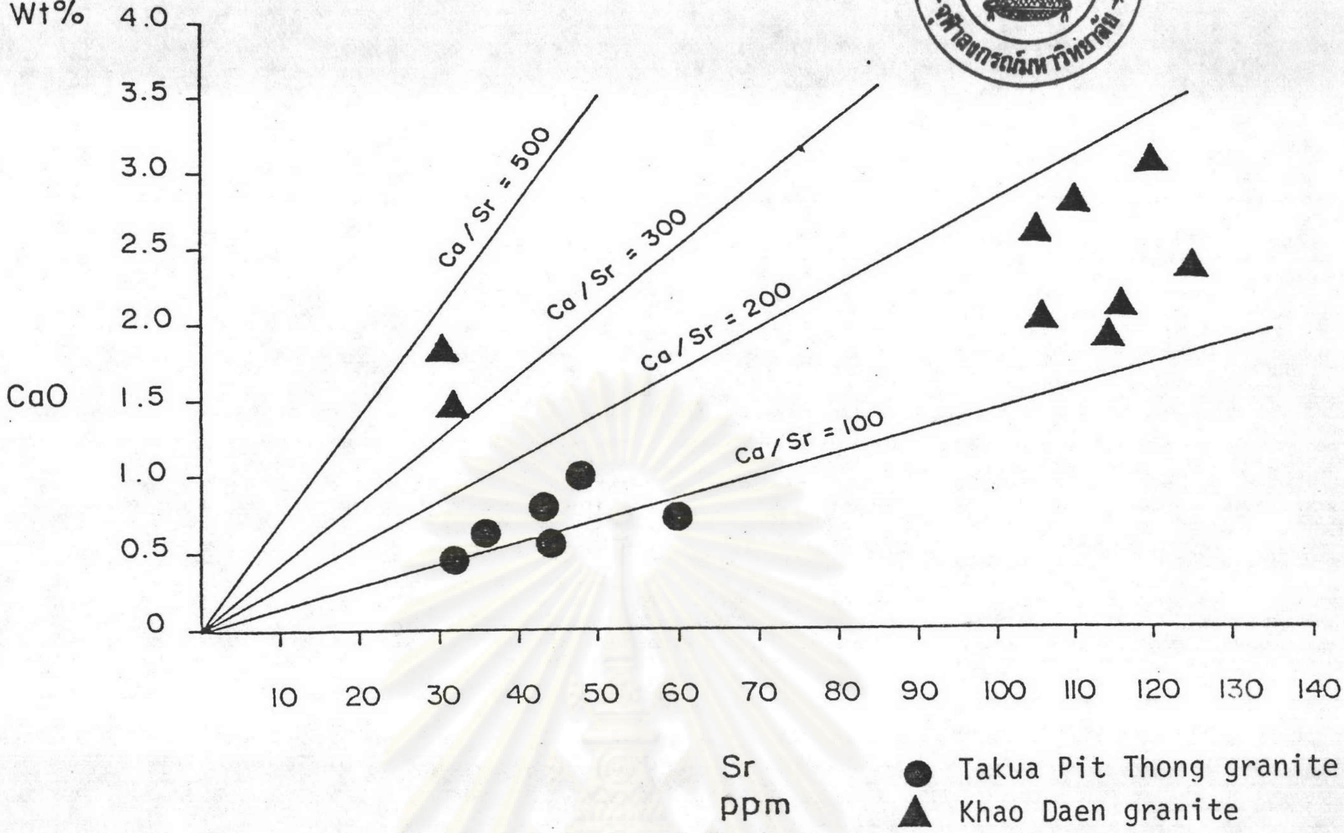

Figure 22 Variations of CaO versus Sr for the Takua Pit Thong granite and the Khao Daen granite (Nakapadungrat et al., 1985).

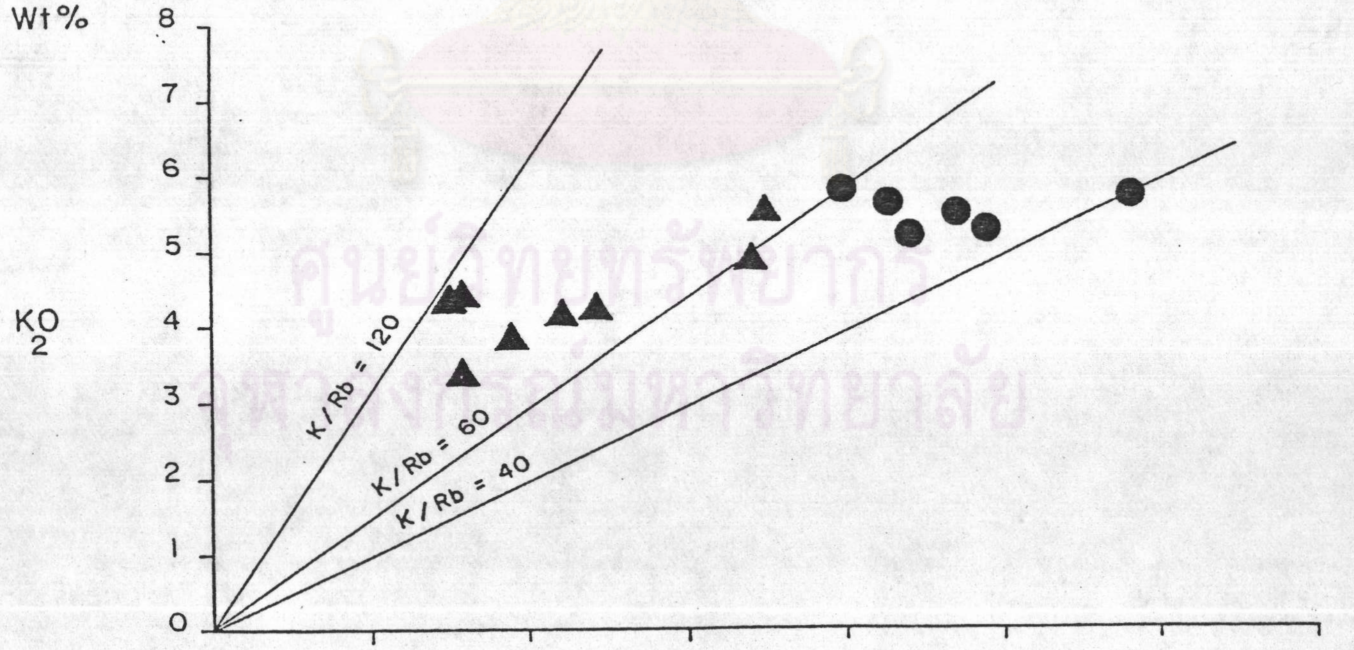

Figure 23 Variations of K_2O versus Rb for the Takua Pit Thong granite and the Khao Daen granite (Nakapadungrat et al., 1985).

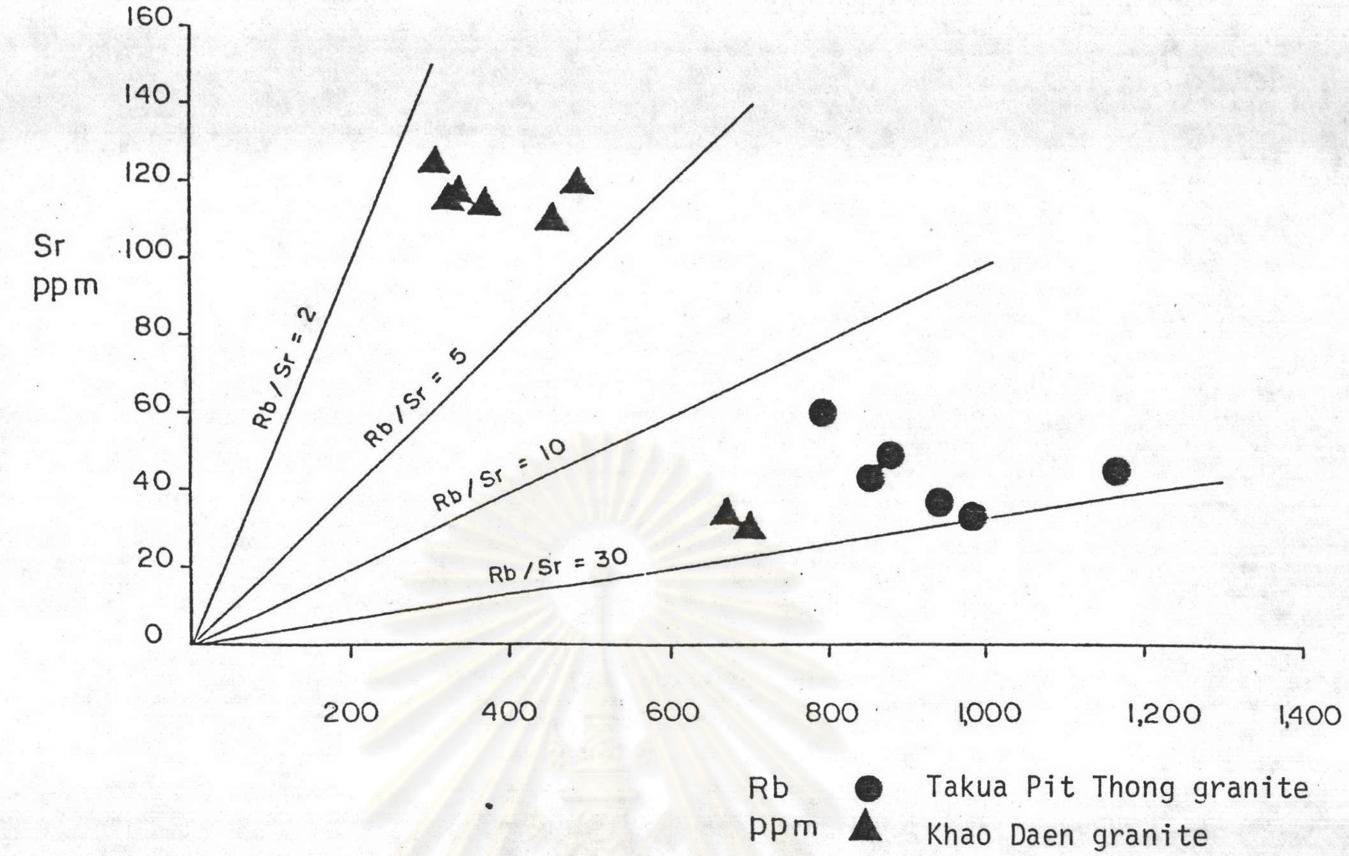

Figure 24 Plots of Sr content against Rb content for the Takua Pit Thong granite and the Khao Daen granite (Nakapadungrat et al., 1985).

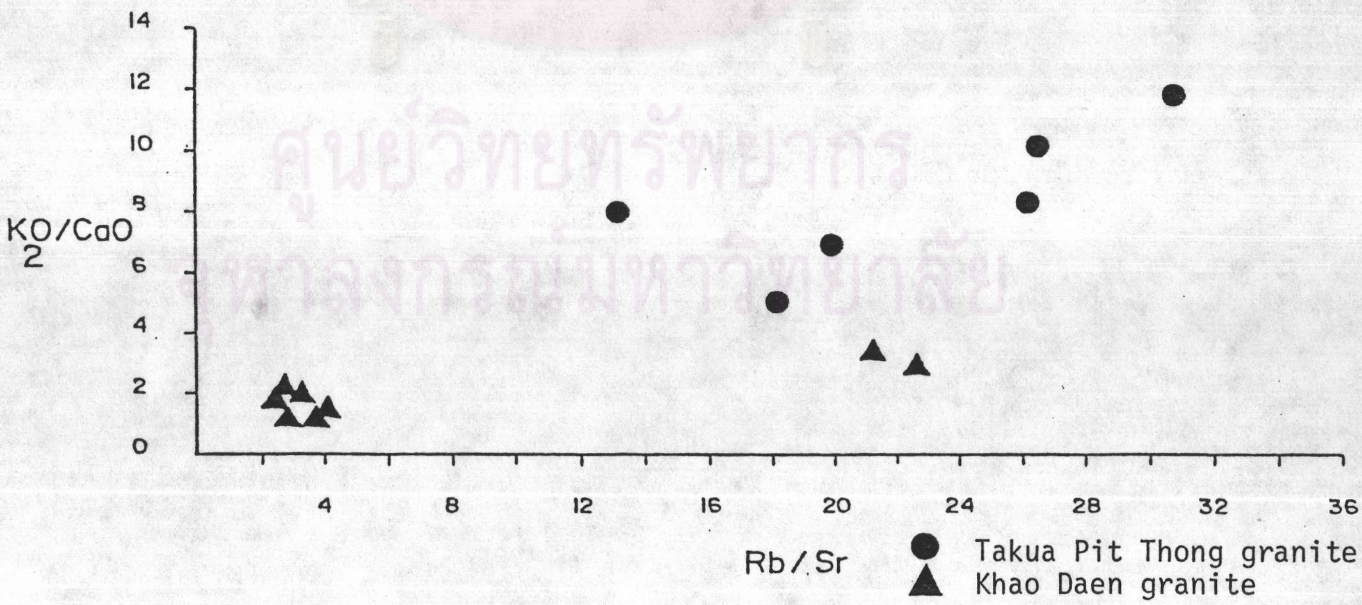

Figure 25 Variations of K_2O/CaO versus Rb/Sr for the Takua Pit Thong granite and the Khao Daen granite (Nakapadungrat et al., 1985).

so obvious as theoretically expected (Heir and Billing, 1970; Groves and Taylor, 1973).

The Rb/Sr and K/Rb ratios have long been known as a useful guide for understanding of a magmatic differentiation. This is because the ionic and atomic properties of Rb are similar to K, and Sr to Ca. Those interrelated elements should be strongly positive correlated. The Rb is commonly enriched in residual liquids resulting from fractionation while the Sr is depleted in late crystallization due to the element capture in early-formed minerals. In other words, for a single fractionation sequence, the Rb/Sr ratio is likely to increase but the K/Rb ratio generally decreases toward the acid end of the sequence (Taylor, 1965; Groves and Taylor, 1973). The K/Rb ratio less than 160 typically occurs in strongly differentiated granites and pegmatites (Taylor, 1965; Branshaw, 1967 and Groves, 1972). The Rb/Sr ratio is increasing but the K/Rb ratio is decreasing from the Khao Daen to Takua Pit Thong granites and both of them have the K/Rb ratio less than 120. It is therefore likely that both the Khao Daen and Takua Pit Thong granites are strongly fractionated and that the latter one is even more fractionated relative to the former one.

In addition to above diagrams, the Rb, Ba and Sr concentrations of the Takua Pit Thong granite are also plotted in the Rb-Ba-Sr ternary diagram in Figure 26 with the diorite to granite fields determined by El Bouseily and El Sokkary (1975) as well as the superimposed differentiation trend. All the plots fall within the strongly differentiated granite suggesting undoubtedly that the Takua Pit Thong granite is a product of late stage differentiation.

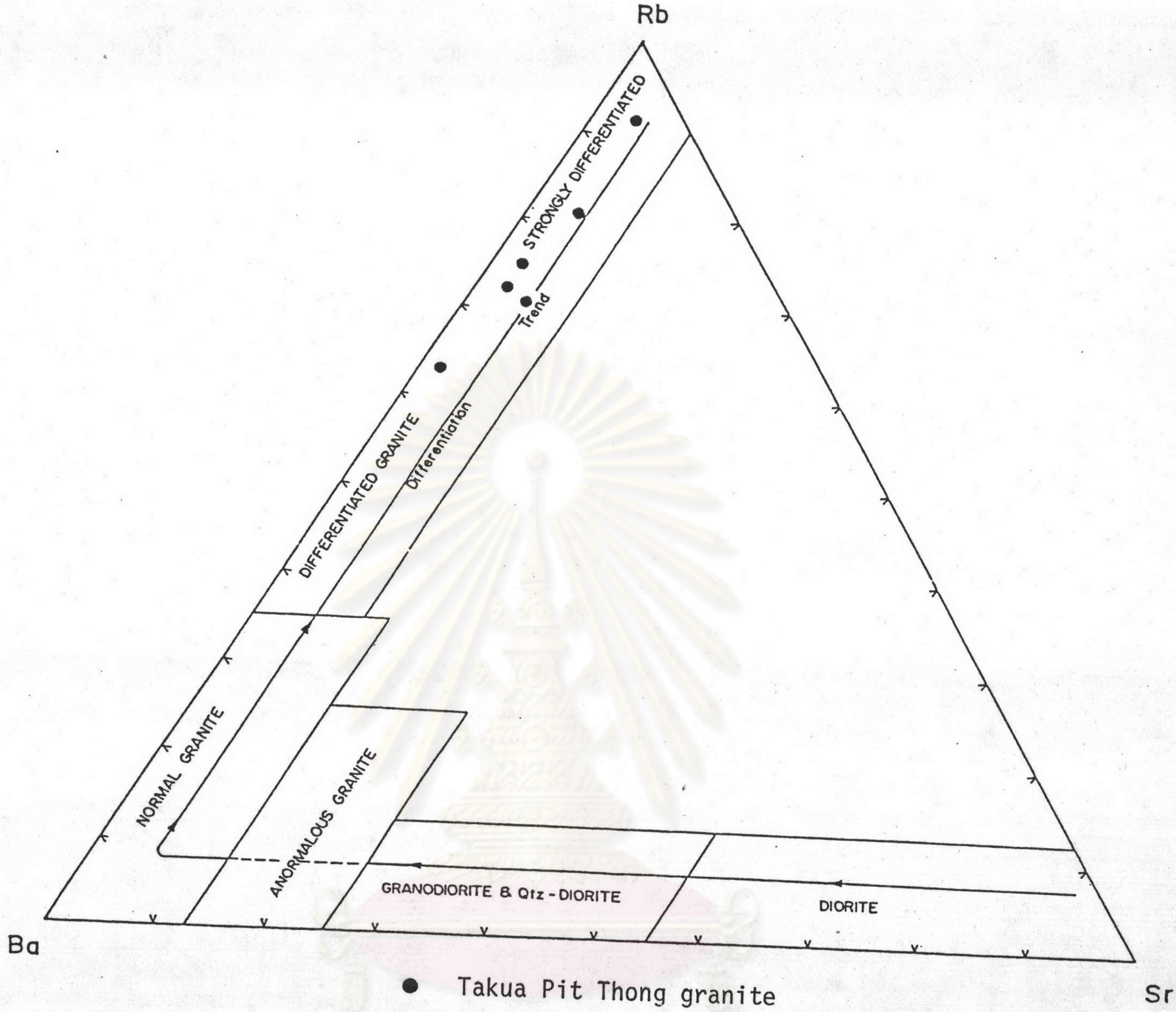

Figure 26 Rb-Ba-Sr variation diagram for the Takua Pit Thong granite (after El Bouseiley and El Sokkary, 1975).

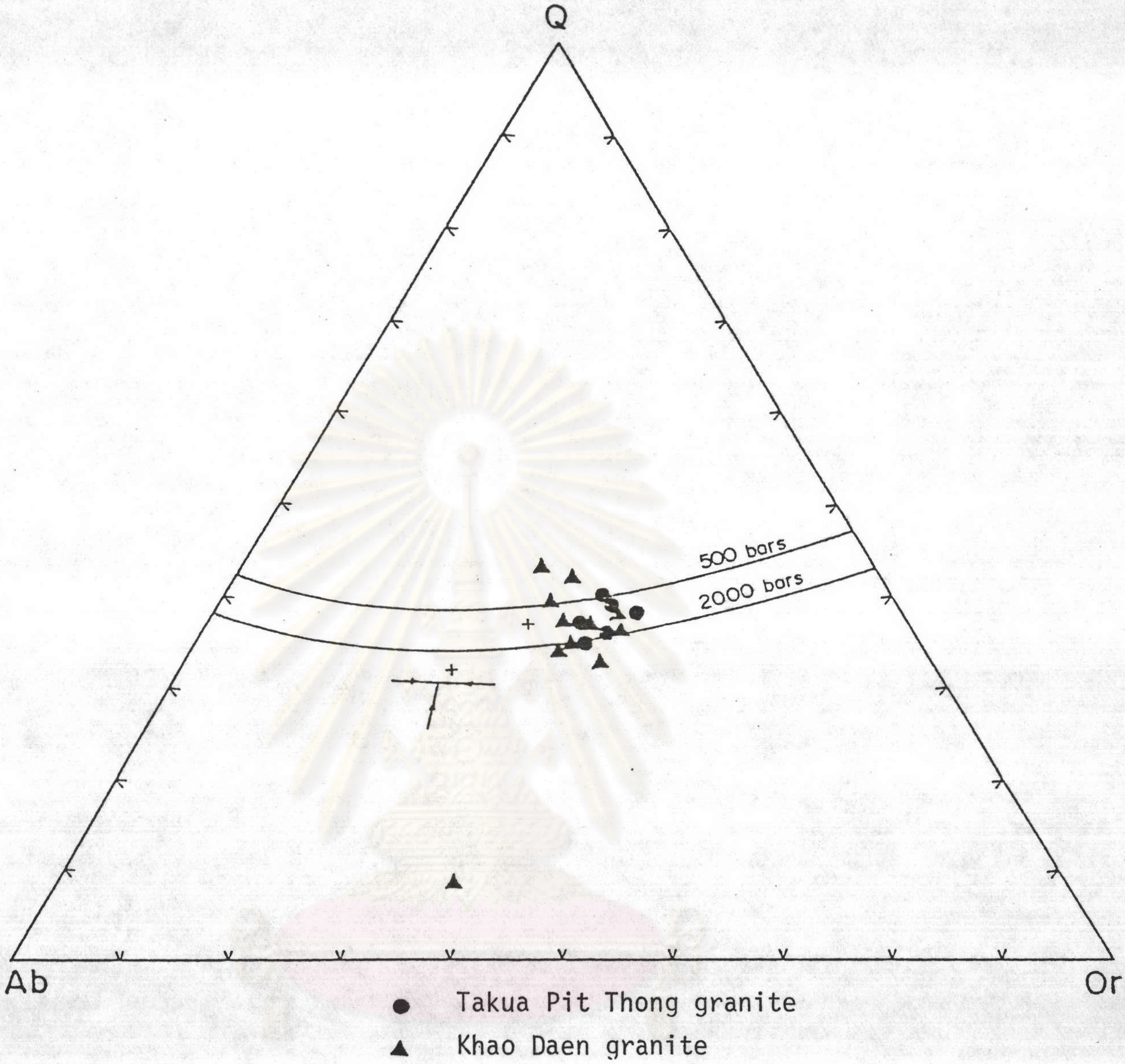

Figure 27 Normative Q-Ab-Or diagram for the Takua Pit Thong granite and the Khao Daen granite (Nakapadungrat et al., 1985). The quartz-feldspar field boundaries at 500 and 2,000 bars P_{H_2O}, and positions of quaternary isobaric minima are from Tuttle and Bowen (1958).

Finally, from the CIPW norms of the Takua Pit Thong shown in Table 1 and the Khao Daen granites (Nakapadungrat et al., 1985), the normative quartz, albite and orthoclase are recalculated at 100 percent and plotted on the experimentally derived phase diagrams in the system Q-Ab-Or-H_2O (after Tuttle and Bowen, 1958) as shown in Figure 27. Almost all the sample plots are clustered between the quartz-feldspar field boundaries at 500 and 2,000 bars water pressure. This data suggest that the Takua Pit Thong and Khao Daen granites are a high level granitic intrusion (Burnham, 1979) similar to the Phuket granite (Charusiri, 1980) and Mae Chedi granite (Hansawek, 1983).