CHAPTER VI

GEOCHEMISTRY

Introduction

A total of 43 fresh samples were selected for geochemical analysis. Selected 21 representative specimens of the Haad Nai Phlao Gneiss, 9 specimens of Laem Thong Yang Gneiss, 6 of Khao Dat Fa Granite and 7 of Khao Pret Granite were determined using X-ray fluorescence (XRF) spectrometer for major and trace elements at Mineral Resource Analysis Division, Department of Mineral Resources. The rock samples were crushed to powders of less than -200 mesh in order to minimize matrix effects. Major element determinations were performed on fused glass bead and trace elements were measured on rock powder pellets. FeO was determined by wet analysis using the titration method. The representative samples were analyzed for concentrations of rare earth elements (REE) by instrumental neutron activation analysis (INAA) at the Office of Atomic Energy for Peace, Bangkok.

Major Elements

The chemical compositions and weight norms of these gneissic and granitic rocks are presented in Table 6.1. The granitic rocks are classified chemically according to O' connor (1965) using normative feldspar abundances. This classification scheme is valid for rocks containing more than 10% of normative or modal quartz and also useful for the coarse- grained rocks. Important points of their major element characteristics show the spread of points on the diagrams. It can be noted that the chemical composition of the Khanom granitic units fall with widely

Table 6.1. Chemical analysis (major-oxide concentrations) and CIPW norms of the Khanom Gneissic Complex.

Units	Hand Nai Phlao Gneiss																				
Sample No.	KN1-2	KN2-2	KN2-3	KN12-1	KN18-1	KN18-2	KN18-3	KN18A	KN19-1	KN19-2	KN19-3	KN24-1	KN24-2	KN24-3	KN54-1	KN54-2	KN54-3	KN54-4	KN54-5	KN68	KN72
Symbols	●	○	○	○	●	●	●	●	●	●	○	●	●	●	●	○	●	●	●	●	●
SiO2	74.40	74.14	72.50	71.05	74.40	76.77	75.01	75.45	71.85	69.62	71.10	73.87	73.96	77.52	67.57	71.85	66.55	74.24	72.89	75.86	67.28
TiO2	0.22	0.27	0.47	0.63	0.34	0.18	0.35	0.26	0.30	0.37	0.55	0.51	0.53	0.14	0.59	0.60	0.57	0.32	0.42	0.10	0.41
Al2O3	14.70	14.19	14.03	14.28	13.46	12.96	13.18	12.56	14.87	15.84	14.45	13.90	13.79	12.64	15.71	14.91	16.51	13.49	13.68	13.81	16.39
Fe2O3	0.71	0.38	0.88	0.74	1.33	0.98	1.25	1.32	0.87	0.85	0.74	0.67	0.65	0.34	1.24	0.91	1.83	1.11	1.19	0.11	1.86
FeO	0.95	1.26	2.14	2.81	1.33	0.84	1.45	0.36	1.62	2.32	2.48	1.56	1.54	0.83	2.91	2.14	2.18	1.36	1.90	0.69	1.92
MnO	0.03	0.04	0.06	0.06	0.08	0.05	0.07	0.05	0.06	0.08	0.05	0.06	0.06	0.05	0.08	0.06	0.10	0.09	0.07	0.02	0.08
MgO	0.24	0.21	0.48	0.66	0.41	0.21	0.43	0.36	0.34	0.55	0.63	0.55	0.55	0.25	1.07	0.45	0.96	0.40	0.30	0.10	0.69
CaO	0.55	1.16	1.52	1.69	1.91	1.61	2.39	1.32	2.04	2.56	1.47	1.05	0.96	1.16	2.52	1.09	3.44	2.09	1.45	0.91	2.73
Na2O	1.25	1.74	2.12	2.83	1.02	1.89	0.85	1.60	1.50	1.70	2.13	1.71	1.71	1.10	2.56	2.12	1.82	1.57	1.03	1.93	1.90
K2O	5.10	4.97	4.39	3.39	4.45	3.25	3.65	4.79	4.96	4.78	4.97	4.92	5.03	4.88	3.91	4.94	4.03	3.95	5.62	5.10	5.24
P2O5	0.18	0.37	0.16	0.25	0.08	0.02	0.07	0.03	0.15	0.21	0.23	0.05	0.05	0.04	0.25	0.13	0.29	0.06	0.13	0.11	0.25
H2O-	0.29	0.19	0.23	0.21	0.19	0.22	0.19	0.04	0.24	0.28	0.27	0.12	0.04	0.15	0.04	0.00	0.30	0.25	0.22	0.25	0.25
LOI	0.98	0.76	0.65	1.02	0.68	0.65	0.79		0.87	0.52	0.58	0.60	0.64	0.53	0.81	0.52	1.05	0.75	0.77	0.75	0.65
TOTAL	99.60	99.68	99.63	99.62	99.68	99.63	99.68	98.14	99.67	99.68	99.65	99.57	99.51	99.63	99.26	99.72	99.63	99.68	99.67	99.74	99.65
CIPW NORM																					
Q	50.01	43.04	39.18	36.65	47.09	50.01	50.65	45.39	39.40	34.70	35.24	41.92	41.82	49.71	30.31	37.22	32.32	45.12	41.87	43.39	29.70
C	3.50	4.79	3.45	3.54	3.73	3.50	3.70	2.45	3.74	3.76	3.49	4.02	3.95	3.57	3.34	4.44	3.66	3.02	3.63	3.77	3.27
Or	19.45	29.75	26.28	20.36	26.62	19.45	21.86	28.86	29.74	28.57	29.73	29.42	30.08	29.15	23.48	29.43	24.24	13.66	33.66	30.53	31.36
Ab	16.19	14.91	18.16	24.34	8.73	16.19	7.29	13.80	12.88	14.55	18.24	14.64	14.64	9.41	22.01	18.08	15.67	13.46	8.83	16.54	16.28
An	7.96	3.38	6.58	6.86	9.06	7.96	11.55	6.48	9.27	11.46	5.86	4.94	4.49	5.55	11.04	4.60	15.44	10.11	6.43	3.84	12.06
Hy	1.06	2.18	3.78	5.35	1.98	1.06	2.28	0.91	2.76	4.52	4.75	2.98	2.93	1.75	6.26	3.45	4.20	2.24	2.73	1.31	3.22
Mt	1.44	0.56	1.29	1.09	1.95	1.44	1.84	0.58	1.28	1.25	1.09	0.98	0.95	0.50	1.83	1.33	2.70	1.63	1.75	0.16	2.73
Il	0.35	0.52	0.90	1.22	0.65	0.35	0.67	0.50	0.58	0.71	1.06	0.98	1.02	0.27	1.14	1.15	1.10	0.62	0.81	0.19	0.79
Ap	0.05	0.89	0.38	0.60	0.19	0.05	0.17	0.07	0.36	0.50	0.55	0.12	0.12	0.10	0.60	0.31	0.70	0.14	0.31	0.26	0.60
D.I.	85.65	87.70	83.62	81.35	82.44	85.65	79.80	88.05	82.02	77.82	83.21	85.98	86.54	88.27	75.80	84.73	72.23	72.24	84.36	90.46	77.34
K2O/Na2O	4.08	2.86	2.07	1.20	4.36	1.72	4.29	2.99	3.31	2.81	2.33	2.88	2.94	4.44	1.53	2.33	2.21	2.52	5.46	2.64	2.76
Fe^{+3}/Fe^{+2}	0.12	1.65	0.45	0.52	0.39	0.34	0.19	0.19	0.24	0.16	0.13	0.18	0.14	0.19	0.19	0.19	0.38	0.37	0.28	0.07	0.43
Na/K	0.18	0.26	0.36	0.62	0.17	0.43	0.17	0.25	0.22	0.26	0.32	0.26	0.25	0.17	0.49	0.32	0.34	0.29	0.14	0.28	0.27
A/CNK	1.45	1.29	1.29	1.37	1.39	1.47	1.54	1.18	1.32	1.36	1.23	1.28	1.79	1.26	1.38	1.30	1.47	1.38	1.22	1.22	1.29

Table 6.1.(continue).

Units	Laem Thong Yang Gneiss								Khao Dat Fa Granite						Khao Pret Granite						
Sample No.	KN22-1	KN30	KN30-2	KN70-2	KN70-3	KN71	KS84A	KS157-1	KN59	KN63	KN74	KS116B	KS153	KS156	KN21-4	KN21-5	KN21-6	KN21-7	KN22	KN49	KN58
Symbols	■	■	⊠	■	■	⊠	■	■	✱	✱	✱	✱	✱	✱	△	△	△	▲	▲	▲	▲
SiO2	73.47	71.37	73.53	72.78	71.72	73.63	74.16	71.27	71.52	72.10	70.06	73.02	73.08	71.96	64.11	60.84	66.72	69.86	68.65	71.42	71.50
TiO2	0.22	0.52	0.26	0.45	0.51	0.28	0.29	0.88	0.72	0.42	0.33	0.41	0.57	0.45	0.70	0.89	0.49	0.42	0.34	0.69	0.66
Al2O3	14.68	13.97	14.74	14.05	14.40	14.38	13.78	14.81	14.68	16.02	15.34	12.91	12.92	13.81	17.34	18.19	16.58	15.51	15.31	15.58	15.71
Fe2O3	0.30	1.57	0.68	0.66	0.52	0.57	0.30	0.95	0.94	0.58	1.34	0.73	0.86	0.81	1.73	2.56	1.40	1.44	2.48	0.64	0.73
FeO	1.14	0.52	0.95	2.07	2.38	1.15	1.86	2.22	2.18	1.36	1.69	1.65	2.03	1.92	2.75	3.00	2.97	1.45	0.74	1.48	1.70
MnO	0.03	0.05	0.02	0.06	0.05	0.02	0.04	0.05	0.12	0.03	0.09	0.09	0.15	0.05	0.09	0.10	0.10	0.07	0.08	0.05	0.05
MgO	0.25	0.52	0.23	0.43	0.58	0.19	0.21	0.82	0.87	0.37	0.48	0.59	0.67	0.51	1.26	1.59	1.06	0.48	0.74	0.35	0.38
CaO	0.78	1.57	0.78	1.66	1.50	0.66	0.87	1.27	1.62	0.88	2.29	1.22	1.15	1.45	3.91	4.46	3.31	2.38	2.48	0.90	1.02
Na2O	2.33	1.84	1.88	1.89	1.40	1.14	2.08	2.74	1.53	2.46	1.85	2.00	1.00	2.21	1.45	1.85	2.59	1.71	1.93	2.19	2.18
K2O	4.96	5.21	4.90	4.58	5.46	6.50	5.10	3.68	4.47	4.83	5.25	6.09	5.43	5.14	4.59	4.50	3.22	5.14	5.12	5.55	5.31
P2O5	0.22	0.21	0.19	0.18	0.17	0.13	0.13	0.18	0.10	0.16	0.18	0.08	0.09	0.15	0.43	0.56	0.33	0.22	0.77	0.12	0.14
H2O-	0.42	0.04	0.29	0.21	0.32	0.29	0.21	0.04	0.04	0.08	0.22	0.07	0.08	0.04	0.34	0.27	0.19	0.22	0.07	0.04	0.02
LOI	0.79		1.16	0.64	0.63	0.64		0.49	0.83	0.81	0.53		0.97	0.36	0.95	0.84	0.70	0.76		0.52	0.44
TOTAL	99.59	97.39	99.61	99.66	99.64	99.58	99.03	99.40	99.62	100.10	99.65	98.86	99.00	98.86	99.65	99.65	99.66	99.66	98.71	99.53	99.84
CIPW NORM																					
Q	39.45	38.19	42.79	39.84	38.12	40.78	39.94	37.35	40.50	36.98	33.72	34.35	43.08	35.53	28.33	21.86	30.29	35.09	34.04	4.67	35.66
C	4.66	3.03	5.48	3.44	3.92	4.64	3.61	4.49	4.68	5.57	2.91	1.01	3.60	2.37	3.97	3.56	3.65	3.38	3.98	4.67	4.89
Or	29.80	31.63	29.50	27.40	32.70	38.94	30.50	22.00	26.75	28.78	31.38	36.44	32.77	30.86	27.58	26.99	19.27	30.79	30.68	33.14	31.58
Ab	20.04	15.99	16.20	16.18	12.00	9.78	17.81	23.45	13.11	20.98	15.83	17.13	8.64	18.99	12.47	15.88	22.19	14.66	16.55	18.72	18.56
An	2.47	6.59	2.68	7.14	6.42	2.46	3.51	5.18	7.48	3.35	10.30	5.60	5.22	6.31	16.87	18.74	14.44	10.51	7.37	3.72	4.17
Hy	2.20	1.33	1.39	3.74	4.70	1.71	3.33	4.02	4.48	2.32	2.84	3.43	4.11	3.53	5.87	6.16	6.39	2.13	1.87	2.04	2.48
Mt	0.44	0.34	1.00	0.97	0.76	0.84	0.44	1.39	1.38	0.85	1.96	1.07	1.27	1.19	2.55	3.77	2.05	2.12	1.68	0.94	1.06
Il	0.42	1.01	0.50	0.86	0.98	0.54	0.56	1.69	1.38	0.80	0.63	0.79	1.10	0.87	1.35	1.72	0.94	0.81	0.65	1.32	1.26
Ap	0.53	0.51	0.46	0.43	0.41	0.31	0.31	0.43	0.24	0.38	0.43	0.19	0.22	0.36	1.04	1.35	0.79	0.53	1.85	0.29	0.33
D.I.	89.29	85.81	88.49	83.42	82.82	89.50	88.25	82.80	80.36	86.74	80.93	87.92	84.49	85.38	68.38	64.73	71.75	80.54	81.27	56.53	85.80
K2O/Na2O	2.13	2.83	2.61	2.42	3.90	5.70	2.45	1.34	2.92	1.96	2.84	3.04	5.43	2.32	3.16	2.43	1.24	3.01	2.65	2.53	2.44
Fe^{+3}/Fe^{+2}	0.12	1.36	0.32	0.14	0.10	0.22	0.19	0.07	0.19	0.19	0.36	0.20	0.19	0.19	0.28	0.38	0.21	0.44	1.50	0.19	0.19
Na/K	0.35	0.26	0.28	0.31	0.19	0.13	0.30	0.55	0.25	0.38	0.26	0.24	0.14	0.32	0.23	0.30	0.59	0.24	0.28	0.29	0.30
A/CNK	1.27	1.80	1.36	1.28	1.25	1.17	1.20	1.41	1.43	1.38	1.24	0.98	1.21	1.14	1.46	1.44	1.52	1.29	1.23	1.26	1.30

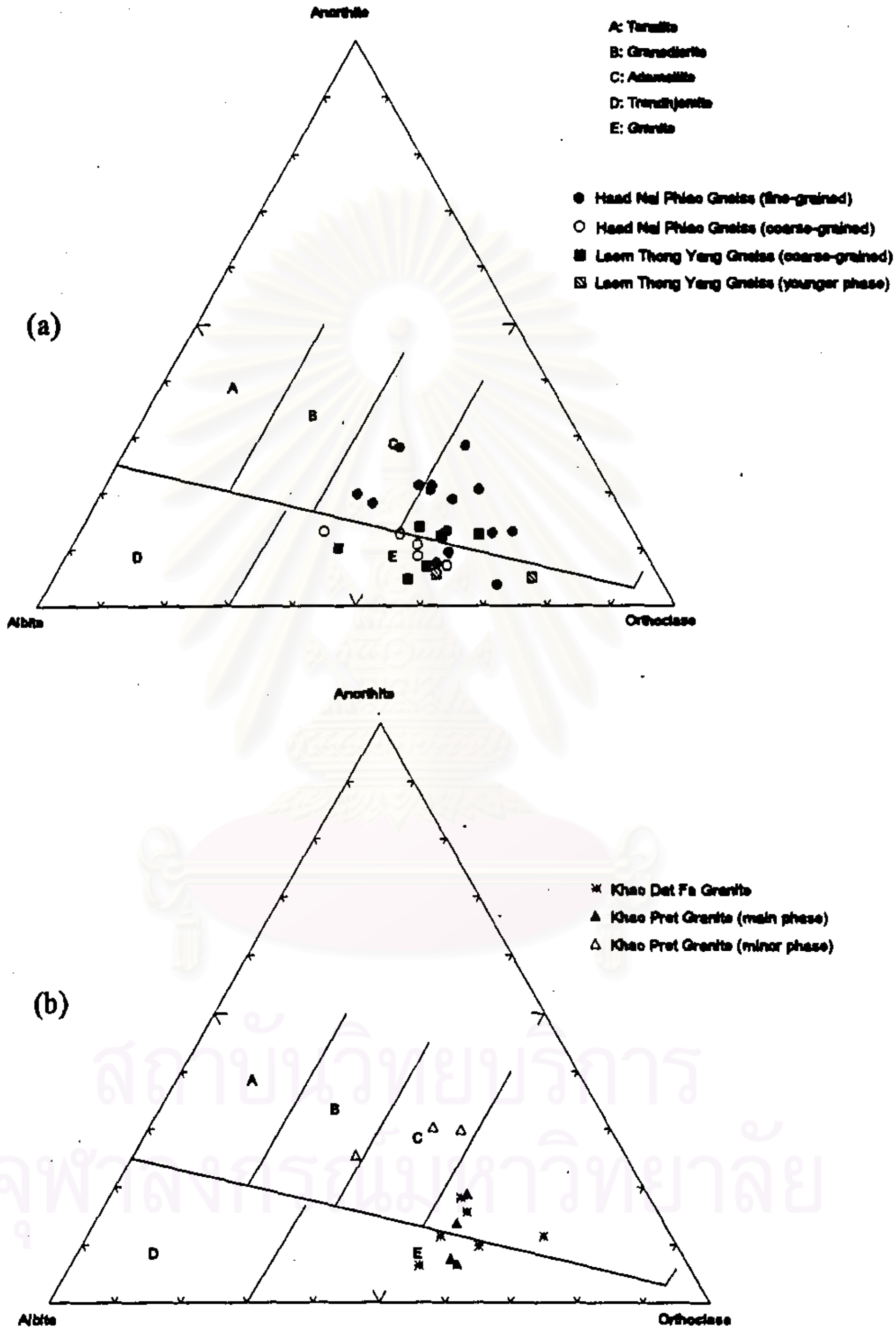


Figure 6.1. Normative feldspar diagram for the classification of the Khanom gneiss (a) and granite (b) after O'connor (1965).

scattered patterns in the fields of granite, adamellite (quartz monzonite) and granodiorite fields, however the latter is uncommon.

SiO_2 values in the Haad Nai Phlao Gneiss range from 66.55 to 77.52% (average 72.76%), the Laem Thong Yang Gneiss range from 71.27 to 74.16% (average 72.74%), the Khao Dat Fa Granite range from 70.06 to 73.08% (average 71.96%) and 68.65 to 71.50% (average 70.36%) for the Khao Pret Granite.

TiO_2 contents range from 0.34 to 0.69% (average 0.53%) for the Khao Pret Granite, those of the Khao Dat Fa Granite range from 0.33 to 0.72% (average 0.48%), those of the Laem Thong Yang Gneiss range from 0.22 to 0.88% (average 0.43%) and 0.10 to 0.63% (average 0.39%) for the Haad Nai Phlao Gneiss. The range in TiO_2 values is related to variation in either or both bimodal titanite, and ilmenite content.

Al_2O_3 values vary from 15.31 to 15.71% (average 15.53%) for the Khao Pret Granite, 12.91 to 16.02% (average 14.28%) for the Khao Dat Fa Granite, 13.78 to 14.35% (average 14.35%) for the Laem Thong Yang Gneiss, 12.56 to 16.39% (average 14.25%) for the Haad Nai Phlao Gneiss. Al_2O_3 displays a slightly negative correlation with SiO_2. High values of Al_2O_3 correlate with high amounts of plagioclase in the Khao Pret Granite.

Fe_2O_3 contents range from 0.64 to 2.48% (average 1.32%) for the Khao Pret Granite, 0.58 to 1.34% (average 0.88%) for the Khao Dat Fa Granite, 0.11 to 1.33% (average 0.95%) for the Haad Nai Phlao Gneiss, and 0.30 to 1.57% (average 0.69%) for the Laem Thong Yang Gneiss. The variation in Fe_2O_3 correlates with the mafic mineral content, i.e., biotite.

MgO values range from 0.35 to 0.74% (average 0.49%) for the Khao Pret Granite, 0.37 to 0.87% (average 0.58%) for the Khao Dat Fa Granite, 0.19 to 0.82 (average 0.40%) for the Laem Thong Yang Gneiss, and 0.10 to 1.07% (average 0.47%) for the Haad Nai Phlao Gneiss. It illustrates a negative correlation to SiO_2.

The range in MgO contents is fairly consistent with variation in modal abundance of mafic mineral as is the case for Fe_2O_3 .

CaO contents range considerably from 0.90 to 2.48% (average 1.70%) for the Khao Pret Granite, 0.88 to 2.29% (average 1.44%) for the Khao Dat Fa Granite, 0.55 to 2.39% (average 1.41%) for the Haad Nai Phlao Gneiss, and 0.55 to 2.73% (average 1.70%) for the Laem Thong Yang Gneiss.

Na_2O contents range from 1.71 to 2.19% (average 2.00%) for the Khao Pret Granite, 1.00 to 2.46% (average 1.84%) for the Khao Dat Fa Granite, 1.14 to 2.74% (average 1.91%) for the Laem Thong Yang Gneiss, and 0.85 to 2.83% (1.72%) for the Haad Nai Phlao Gneiss. High Na_2O values can be correlated with a high plagioclase abundance, as is the case for Al_2O_3 .

K_2O contents range from 4.47 to 6.09% (average 5.20%) for the Khao Dat Fa Granite, 3.68 to 6.50% (average 5.05%) for the Laem Thong Yang Gneiss, 5.12 to 5.55% (average 5.28%) for the Khao Pret Granite and 3.25 to 5.62% (average 4.59%) for the Haad Nai Phlao Gneiss. K_2O is a very mobile constituent and is possible for highly altered granitoids from any tectonic environment to have abnormally low K_2O values (Hong, 1992). This alteration can be easily identified petrographically. The sample which have high abundances of K_2O normally show extensive sericitization of feldspar.

The abundance of P_2O_5 varies from 0.12 to 0.77% (average 0.31%) for the Khao Pret Granite, 0.13 to 0.22% (average 0.18%) for the Laem Thong Yang Gneiss, 0.08 to 0.18% (average 0.13%) for the Khao Dat Fa Granite, and 0.02 to 0.37% (average 0.15%) for the Haad Nai Phlao Gneiss. Some samples show relatively high P_2O_5 contents which are attributed to high abundance of apatite.

Figures 6.2a and b. show the variation of SiO_2 content of individual granitic units with respective to the other major oxide. SiO_2 contents from all granitic units

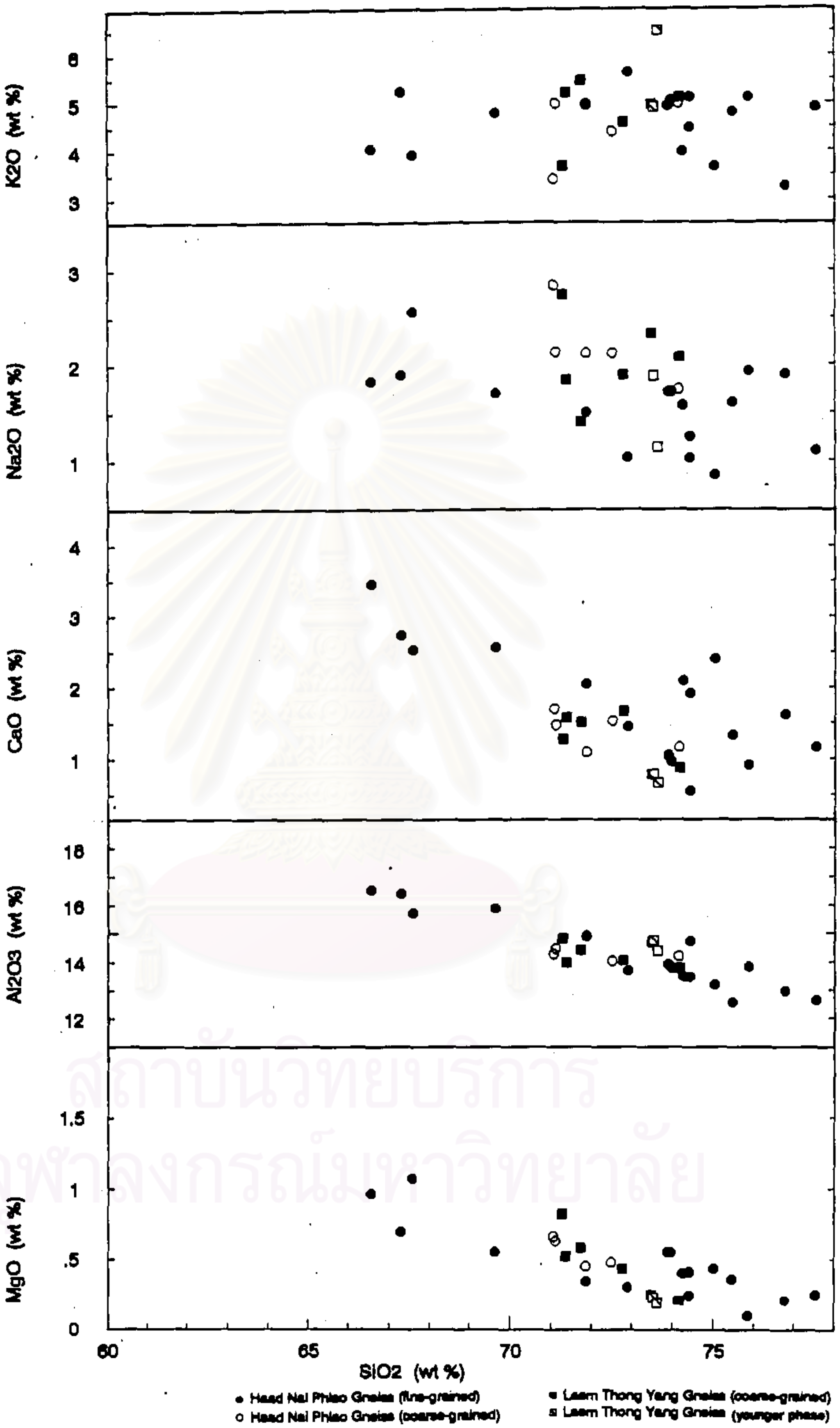


Figure 6.2a. Major oxide analyses of the Khanom gneissic samples potted on MgO, Al_2O_3, Na_2O, K_2O and CaO versus Si_2O (as Harker variation diagram).

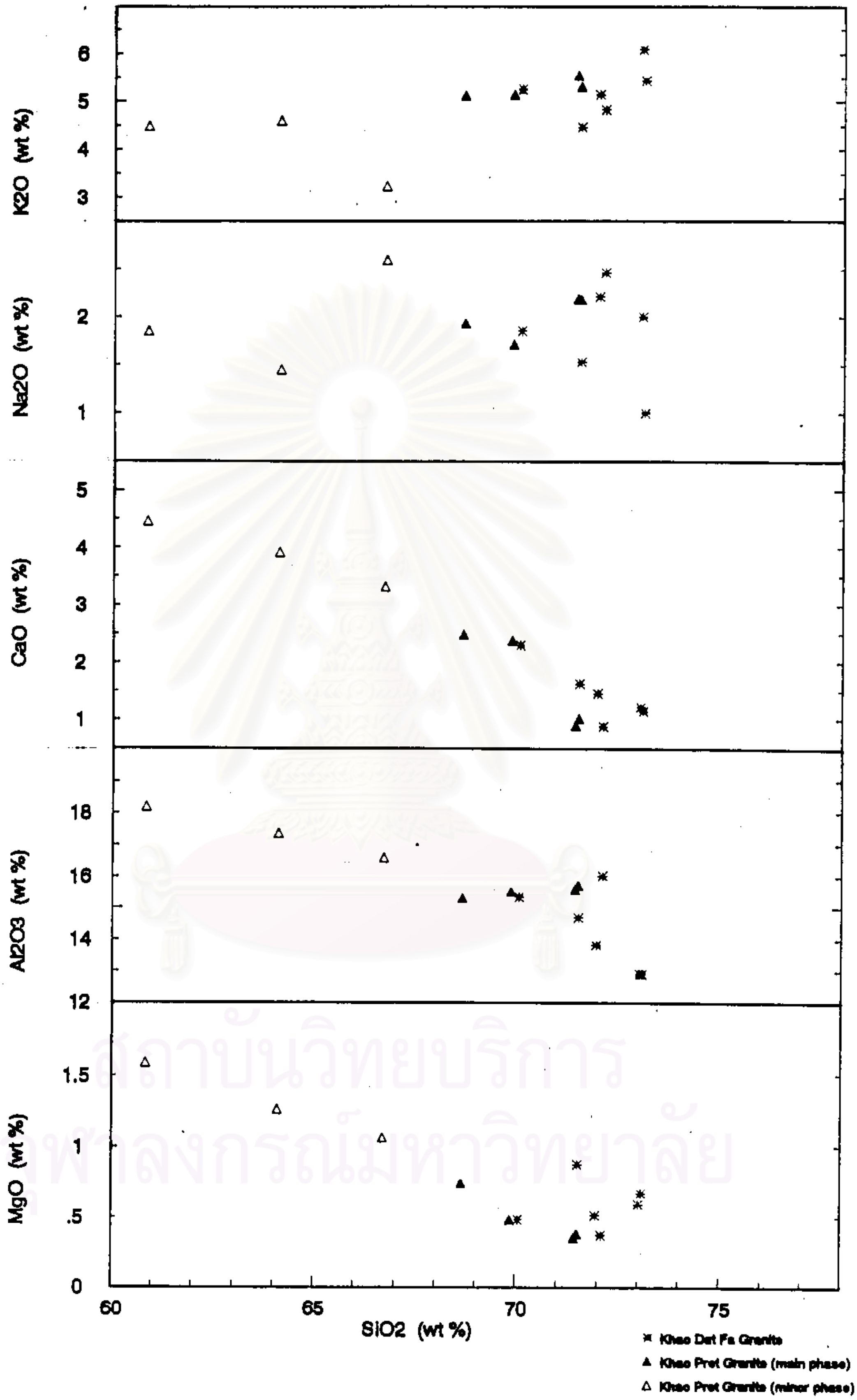


Figure 6.2b. Major oxide analyses of the Khanom granitic samples potted on MgO, Al_2O_3, Na_2O, K_2O and CaO versus Si_2O (as Harker variation diagram).

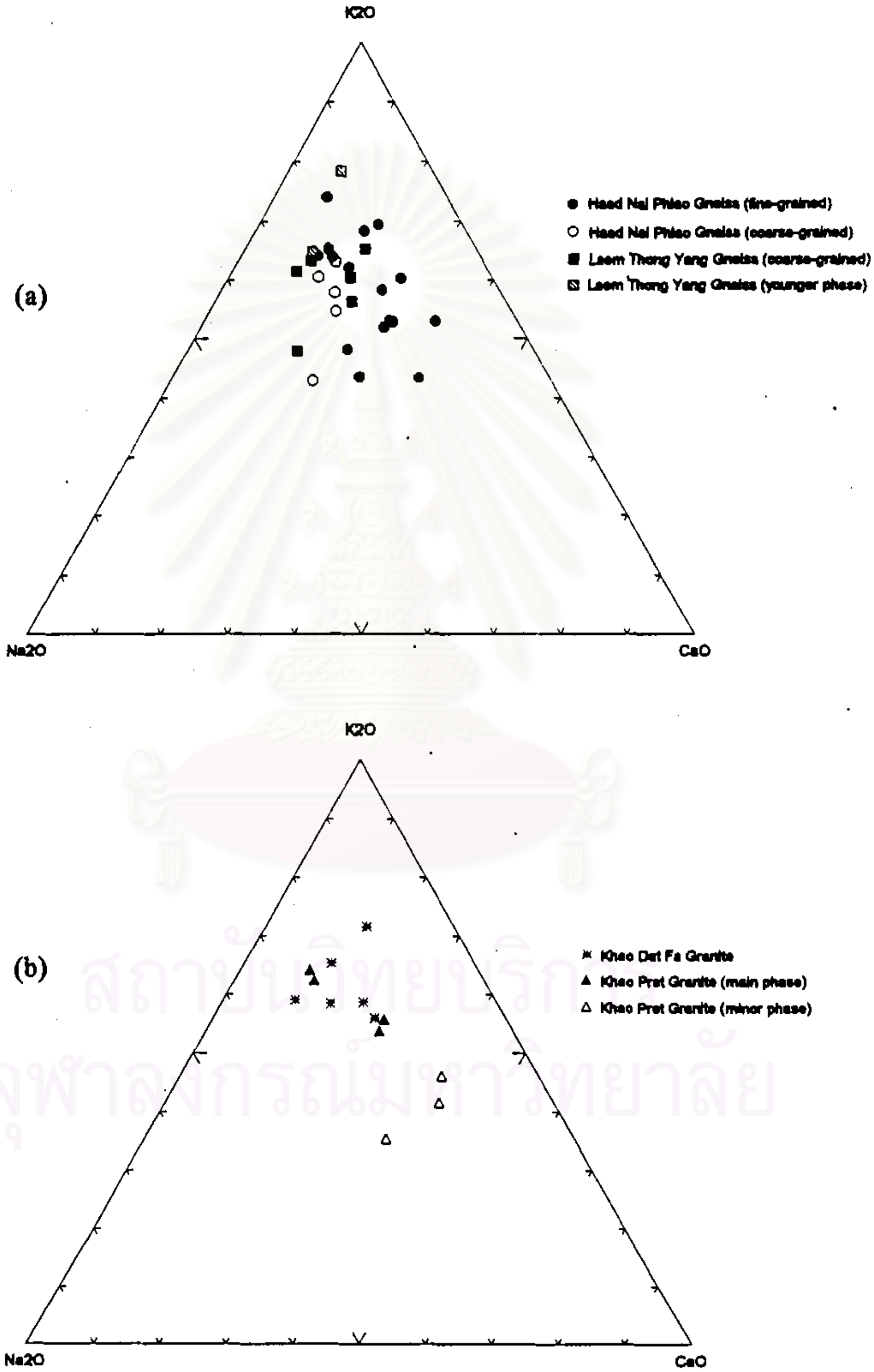


Figure 6.3. K_2O-Na_2O-CaO variation diagram of the Khanom gneiss (a) and granite (b).

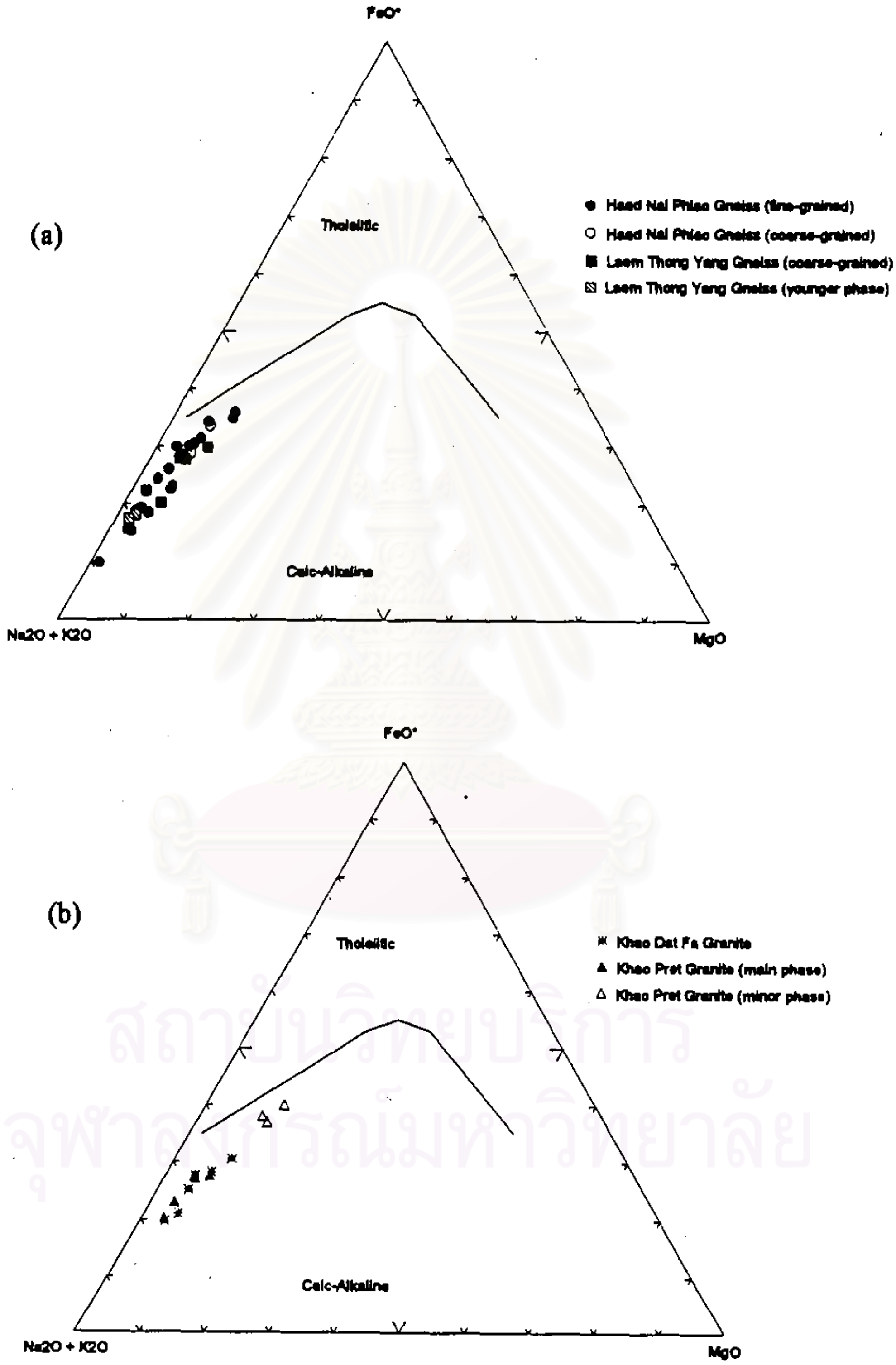


Figure 6.4. Na_2O+K_2O - FeO^* - MgO ternary diagrams can be divided between tholeiitic and calc-alkaline suites of the Khanom gneiss (a) and granite (b) after Irvine and Baragar (1971).

Table 6.2. Summary of mainly chemical geocharacteristics (mean) of the Khanom Gneissic Complex.

Haad Nai Phlao Gneiss	Laem Thong Yang Gneiss	Khao Dat Fa Granite	Khao Pret Granite
Relative Na/K 0.258	Relative Na/K 0.296	Relative Na/K 0.265	Relative Na/K 0.277
Fe^{3+}/Fe^{2+} ratios 0.324	Fe^{3+}/Fe^{2+} ratios 0.315	Fe^{3+}/Fe^{2+} ratios 0.220	Fe^{3+}/Fe^{2+} ratios 0.580
A/CNK 1.356	A/CNK 1.343	A/CNK 1.230	A/CNK 1.270
Normative Corundum 3.27	Normative Corundum 4.49	Normative Corundum 3.36	Normative Corundum 4.23

display strong negative correlation with CaO, Al_2O_3 and MgO. The Haad Nai Phlao Gneiss shows a wide variation of the K_2O/Na_2O ratios from 1.20 to 4.44 with a mean of 2.94. The Laem Thong Yang Gneiss shows most variation of the K_2O/Na_2O ratios from 1.34 to 5.70 with a mean of 2.92. The K_2O/Na_2O ratios of the Khao Dat Fa Granite range from 1.96 to 5.43 with an average of 3.09. The Khao Pret Granite range show less variable ratios as 2.44-3.01 (mean = 2.66). The plots of variation triangular diagram depict that there is quite distinction between Haad Nai Phlao Gneiss and Laem Thong Yang Gneiss, and also Khao Dat Fa Granite and Khao Pret Granite in K_2O - Na_2O - CaO diagram. Mild distinction occurs when these types of granites and gneisses are plotted in FeO - Na_2O + K_2O - MgO diagram. Table 6.2 shows the summary of geochemical characteristic of the Khanom Gneissic Complex.

Trace Elements

Trace element determinations of the Khanom gneissic and granitic rocks are given in Table 6.3. The average Rb/Sr ratios are generally higher in the Laem Thong Yang Gneiss (5.63$\pm$3.96), Haad Nai Phlao Gneiss (3.81$\pm$3.39) and Khao Dat Fa Granite (2.42$\pm$2.40) than in the Khao Pret Granite (2.54$\pm$2.50). The high Rb/Sr ratio may be explained by either strong fractionation of Rb-poor and Sr-enriched plagioclase or plagioclase may not be involved in the melt phase retaining at the unmelted restite during low degree of partial melting (Hong, 1992). The K/Rb ratios of the Khanom samples fall in a quite wide range, 140-340 (mean = 254) in the Khao Dat Fa Granite, 90-313 (mean = 222) in the Haad Nai Phlao Gneiss, 140-246 (mean = 186) in the Khao Pret Granite and 132-218 (mean = 151) in the Laem Thong Yang Gneiss.

The Khao Pret Granite displays higher in Sr, Pb and Zn contents whereas the Khao Dat Fa Granite shows higher in Cr and Ni contents, the Laem Thong Yang Gneiss are enriched in Rb and Co contents and the Haad Nai Phlao Gneiss shows higher in Ba and Cu contents.

Table 6.3. The characteristics of the trace element (ppm) in the Khanom Gneissic Complex.

Units	Haad Nai Phlao Gneiss																				
Sample No.	KN1-2	KN2-2	KN2-3	KN12-1	KN18-1	KN18-2	KN18-3	KN18A	KN19-1	KN19-2	KN19-3	KN24-1	KN24-2	KN24-3	KN54-1	KN54-2	KN54-3	KN54-4	KN54-5	KN68	KN72
Symbols	●	○	○	○	●	●	●	●	●	●	○	●	●	●	●	○	●	●	●	●	●
Ba	160	415	542	598	952	458	689	1035	3017	1008	540	1209	1177	482	1113	479	1342	706	508	98	929
Cr	12	12	42	37	87	27	62	179	77	7	20	122	185	36	8	60	263	44	308	23	59
Cu								32				28	23				28		31		
Ni								109				59	93				134		162		
Pb	13	14	16	15	6	6	6	5	25	19	18	7	7	6	10	11	12	6	13	23	11
Rb	322	343	312	314	118	123	118	165	171	159	281	161	163	159	129	229	116	153	188	241	152
Sr	23	43	61	72	67	57	64	42	451	529	65	45	33	29	626	52	586	67	52	27	641
Zn	30	35	42	55	10	10	8	10	37	49	40	24	5	7	49	26	49	13	27	11	52
Co	62	30	87	91	81	78	63		60	33	43			40	47	56		84		124	71
Rb/Sr	14.00	7.98	5.11	4.36	1.76	2.16	1.84	3.93	0.38	0.30	4.32	3.58	4.94	5.48	0.21	4.40	0.20	2.28	3.62	8.93	0.24
K/Rb	131.48	259.47	106.24	89.62	313.05	219.34	256.77	240.98	240.78	249.55	146.82	265.20	259.34	248.52	251.60	179.07	288.39	214.81	248.15	175.66	286.17

Units	Laem Thong Yang Gneiss								Khao Dat Fa Granite						Khao Pret Granite						
Sample No.	KN22-1	KN30	KN30-2	KN70-2	KN70-3	KN71	KS84A	KS157-1	KN59	KN63	KN74	KS116B	KS153	KS156	KN21-4	KN21-5	KN21-6	KN21-7	KN22	KN49	KN58
Symbols	■	■	⊠	■	■	⊠	■	■	✱	✱	✱	✱	✱	✱	△	△	△	▲	▲	▲	▲
Ba	136	964	195	360	612	241	401	643	466	379	729	915	860	788	1732	854	565	614	880	303	355
Cr	15	93	26	29	15	28	66	103	224	202	5	153	106	521	31	11	53	41	208	240	146
Cu		32						16	19	21			26	42					35	19	19
Ni		73						44	116	104			51	278					115	126	73
Pb	16	12	17	20	22	23	12	41	7	22	14	13	7	24	17	11	8	19	21	49	36
Rb	312	326	297	217	207	321	351	246	118	285	147	313	132	160	159	118	206	173	203	339	313
Sr	25	104	30	54	73	42	348	61	19	67	487	406	52	351	571	699	480	430	500	65	76
Zn	28	38	28	43	44	36	10	49	11	23	50	10	53	37	56	84	58	41	44	41	45
Co	67		83	86	44	57					43				49	40	50	99			
Rb/Sr	12.48	3.13	9.90	4.02	2.84	7.64	1.01	4.03	6.21	4.25	0.30	0.77	2.54	0.46	0.28	0.17	0.43	0.40	0.41	5.22	4.12
K/Rb	131.96	132.66	136.95	175.20	218.95	168.09	120.61	124.18	314.45	140.68	296.46	161.51	341.47	266.67	239.63	316.56	129.75	246.63	209.36	147.66	140.83

Detailed description of individual elements of granitic rocks in the Khanom Complex area are given below.

Ba values range from 98 to 3017 ppm (average 831 ppm) for the Haad Nai Phlao Gneiss, 303 to 880 ppm (average 538 ppm) for the Khao Pret Granite, 379 to 915 ppm (average 689 ppm) for the Khao Dat Fa Granite and 136 to 964 ppm (average 444 ppm) for the Laem Thong Yang Gneiss. The remainder of samplers shows a scatter against SiO_2 with a broad negative correlation.

The mean Cr content is 201 ppm with a range of 5 to 521 ppm for the Khao Dat Fa Granite, 158 ppm with a range of 41 to 240 ppm for the Khao Pret Granite, 79 ppm with a range of 7 to 308 ppm for the Haad Nai Phlao Gneiss and 46 ppm with a range 15 to 103 ppm of the Laem Thong Yang Gneiss. Cr shows scatter with negative correlation with SiO_2.

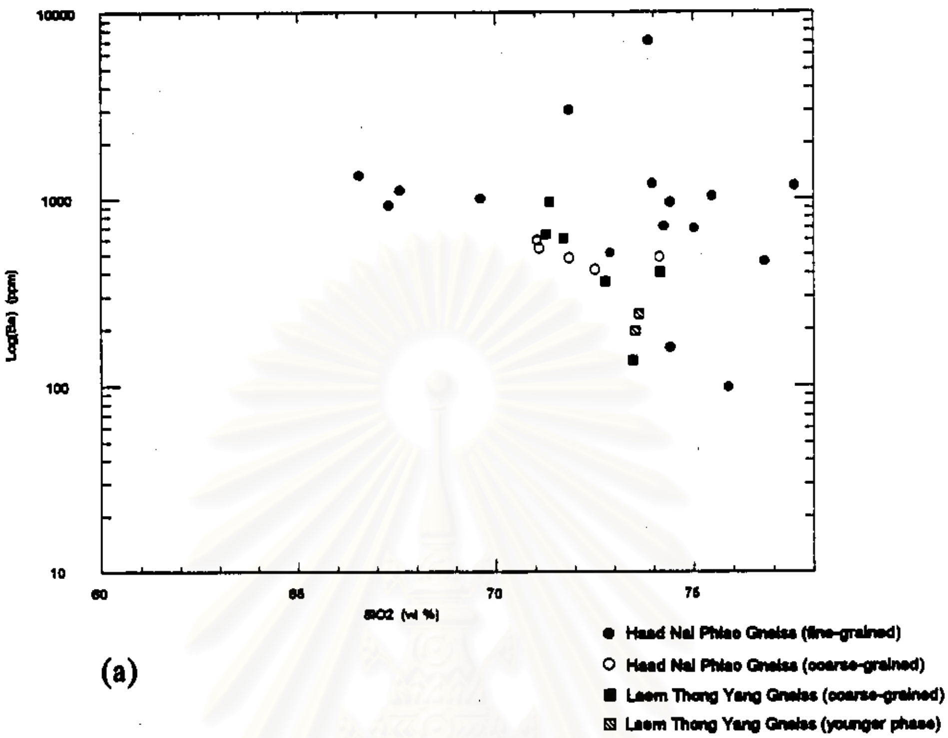
Pb has a broad range in abundance. Pb ranges from 19 to 49 ppm (average 31 ppm) for the Khao Pret Granite, 12 to 41 ppm (average 20 ppm) for the Laem Thong Yang Gneiss, 7 to 24 ppm (average 15 ppm) for the Khao Dat Fa Granite and 5 to 25 ppm (average 12 ppm) for the Haad Nai Phlao Gneiss. It shows scatter with no correlation with SiO_2.

Rb value ranges from 207 to 351 ppm (average 284 ppm) for the Laem Thong Yang Gneiss, 173 to 339 ppm (average 257 ppm) for the Khao Pret Granite, 116 to 343 ppm (average 196 ppm) for the Haad Nai Phlao Gneiss and 118 to 313 ppm (average 192 ppm) for the Khao Dat Fa Granite. Rb displays a broad positive correlation with SiO_2.

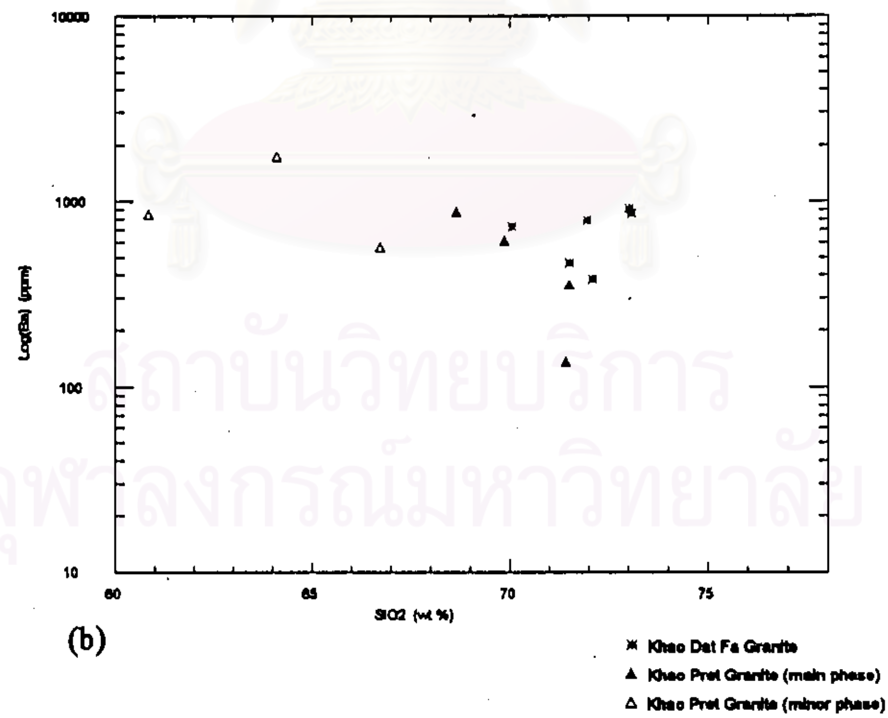
The mean Sr content is 267 ppm with a wide range of 65 to 500 ppm for the Khao Pret Granite, 230 ppm with a range of 19 to 487 ppm for the Khao Dat Fa Granite, 172 ppm with a range of 23 to 641 ppm for the Haad Nai Phlao Gneiss and 92 ppm with a range of 25 to 348 ppm. Sr shows a scatter with a broad negative correlation with SiO_2.

Zn ranges from 41 to 45 ppm (average 42 ppm) for the Khao Pret Granite, 10 to 49 ppm (average 34 ppm) for the Laem Thong Yang Gneiss, 10 to 53 ppm (average 30 ppm) for the Khao Dat Fa Granite and 5 to 55 ppm (average 28 ppm) for the Haad Nai Phlao Gneiss.

Plots of SiO_2 versus some trace elements of granitic rocks in the Khanom Complexes (Figures 6.5a to f) indicate that there are some geochemical distinctions between these types of granites and gneisses. The trace element geochemistry shows more regnizable contrast in the different granites (Khao Pret and Khao Dat Fa) than in the different gneisses (Haad Nai Phlao and Laem Thong Yang).

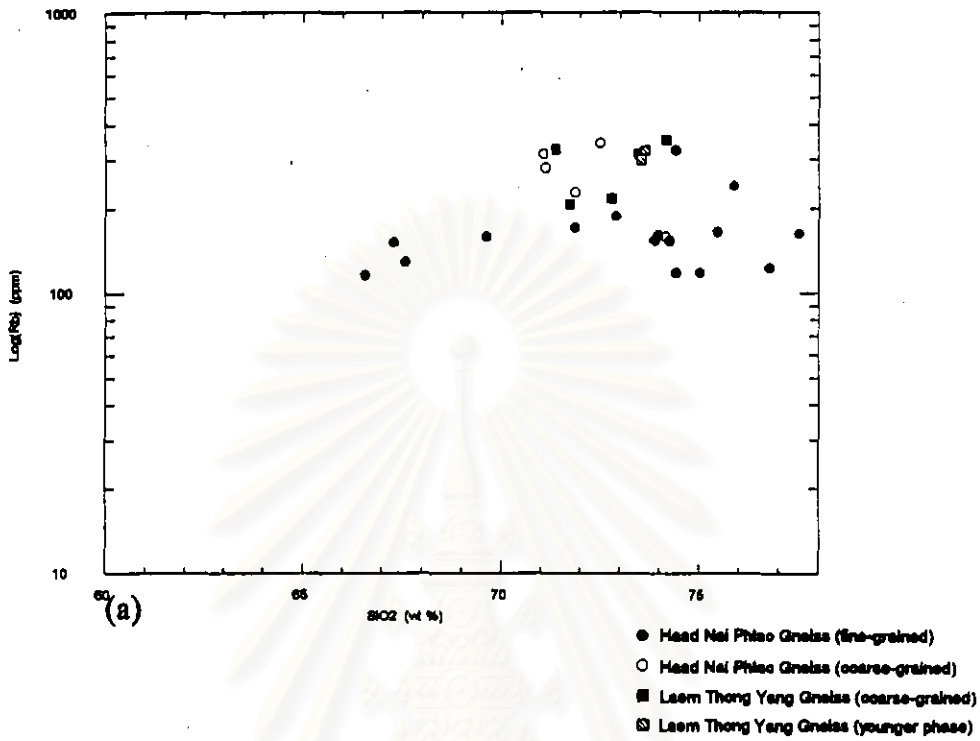


(a)



(b)

Figure 6.5a. Plot of barium against silica for the Khanom gneiss (a) and granite (b).



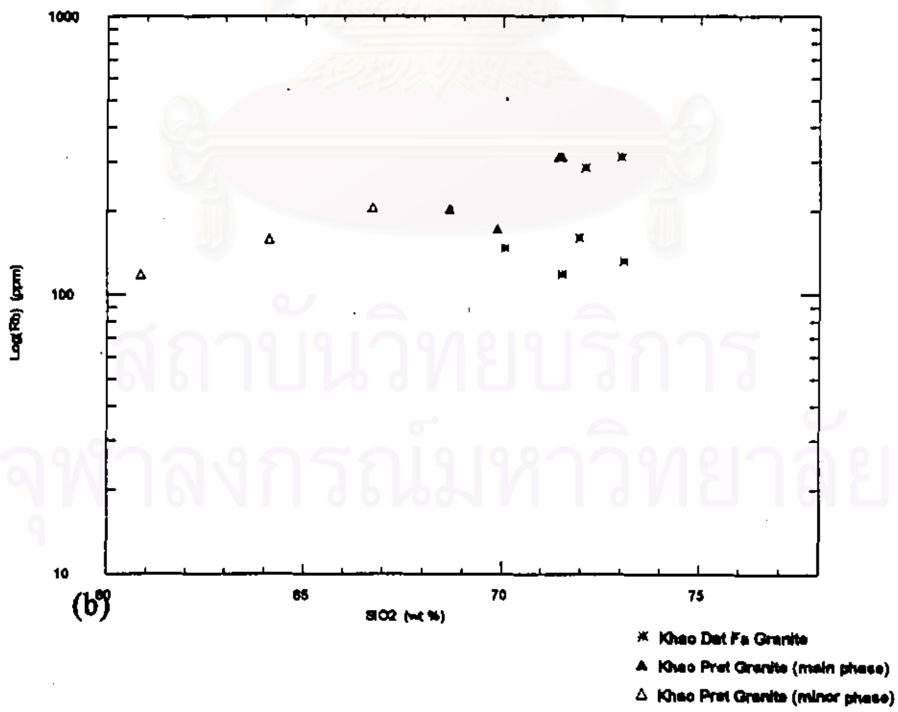
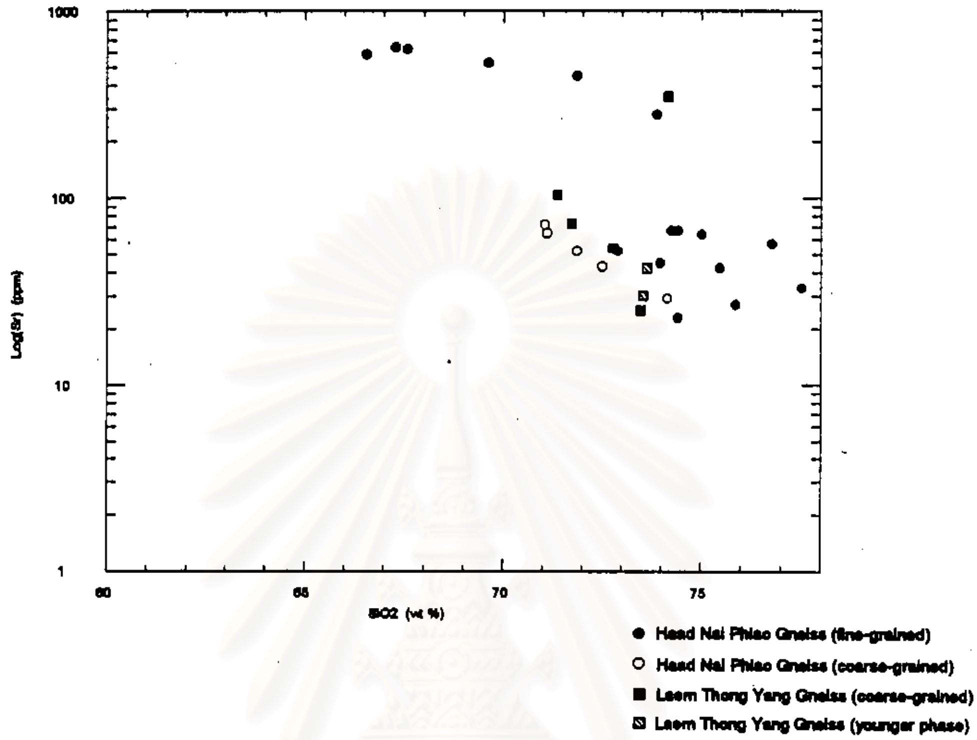


Figure 6.5b. Plot of rubidium against silica for the Khanom gneiss (a) and granite (b).



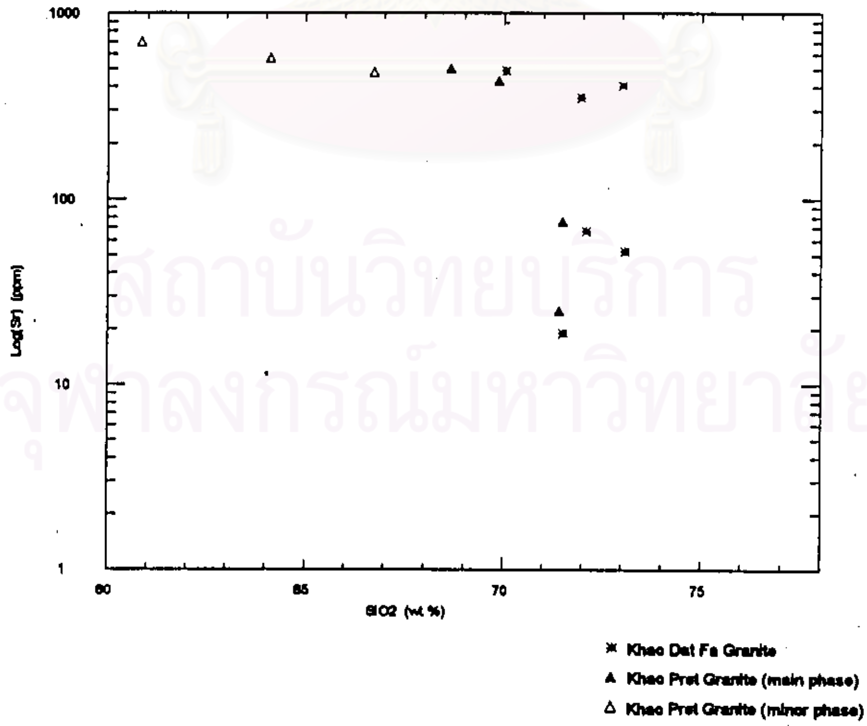


Figure 6.5c. Plot of strontium against silica for the Khanom gneiss (a) and granite (b).

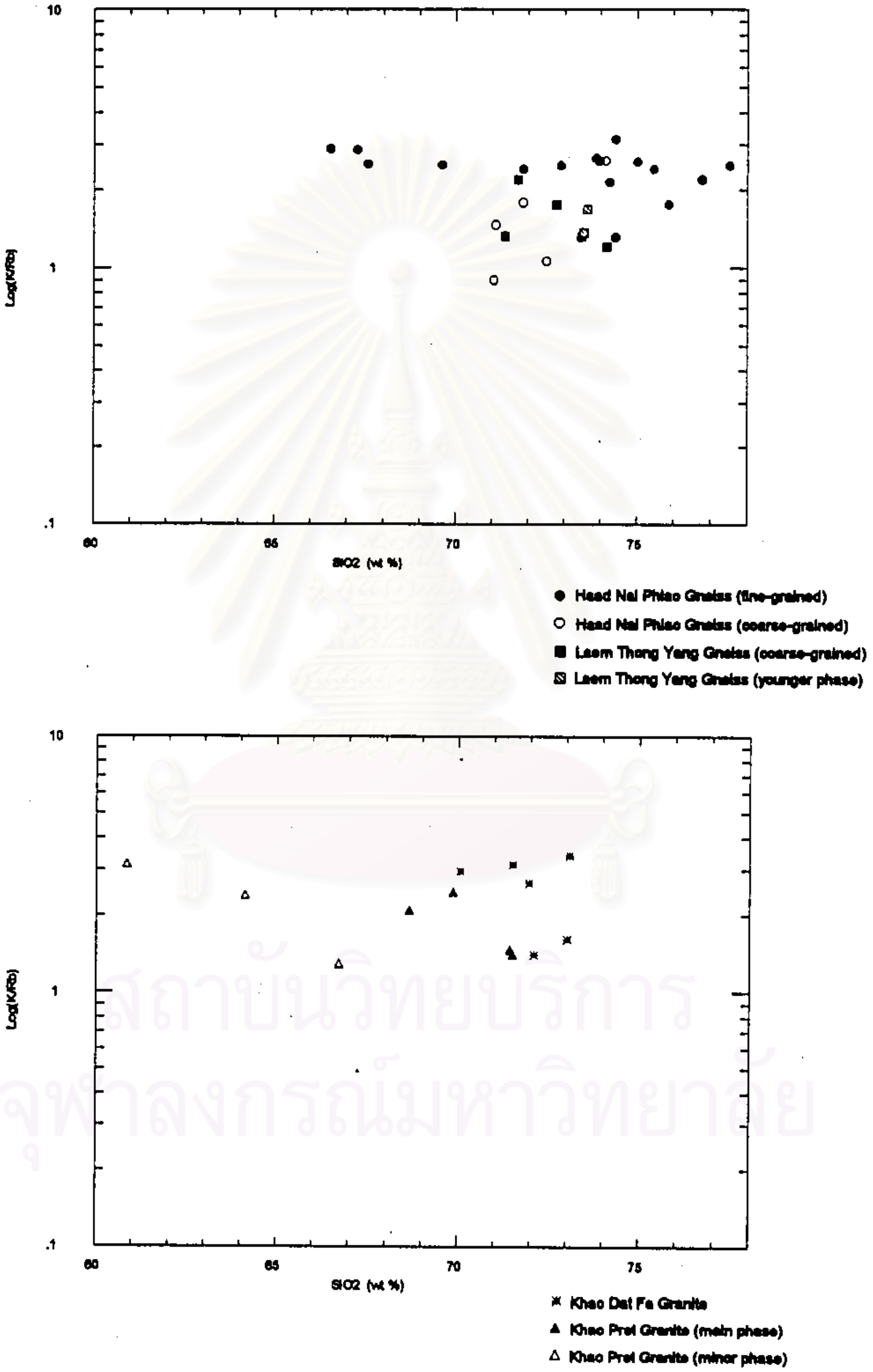
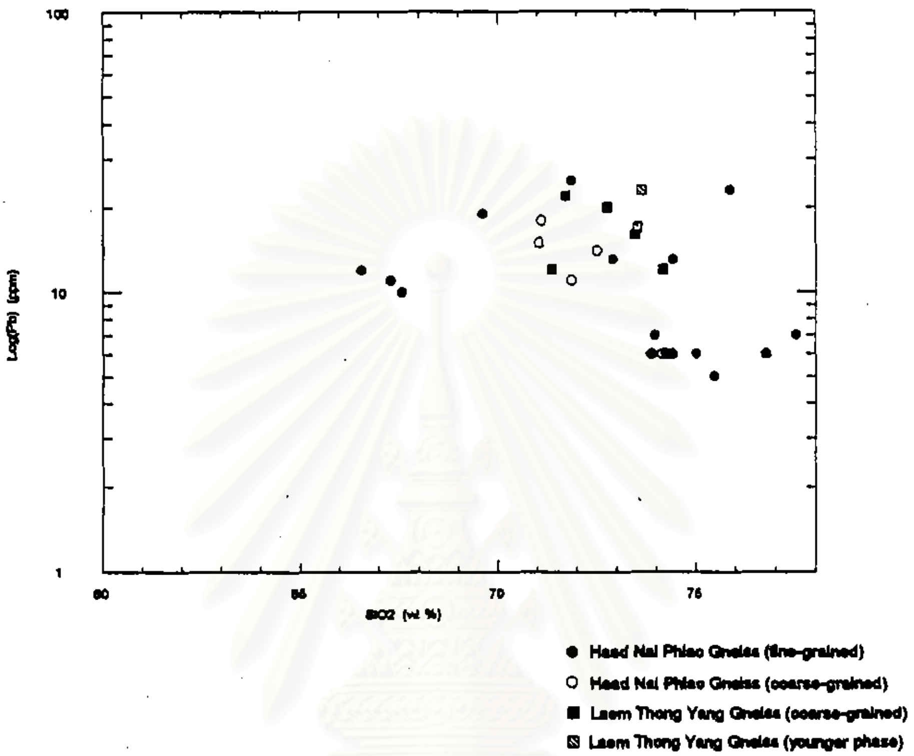


Figure 6.5d. Plot of potassium/rubidium ratio against silica for the Khanom gneiss (a) and granite (b).



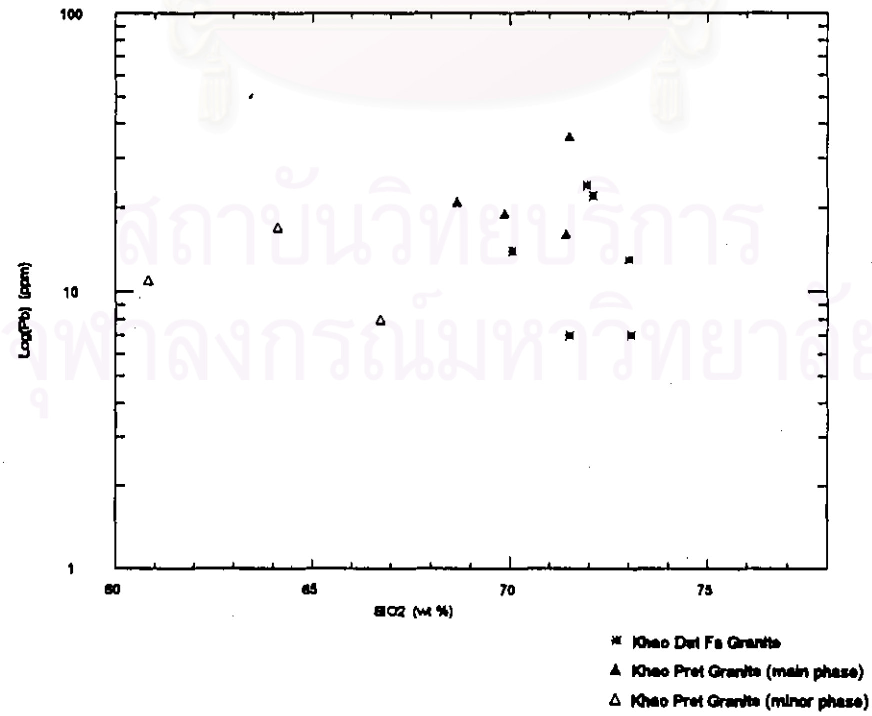
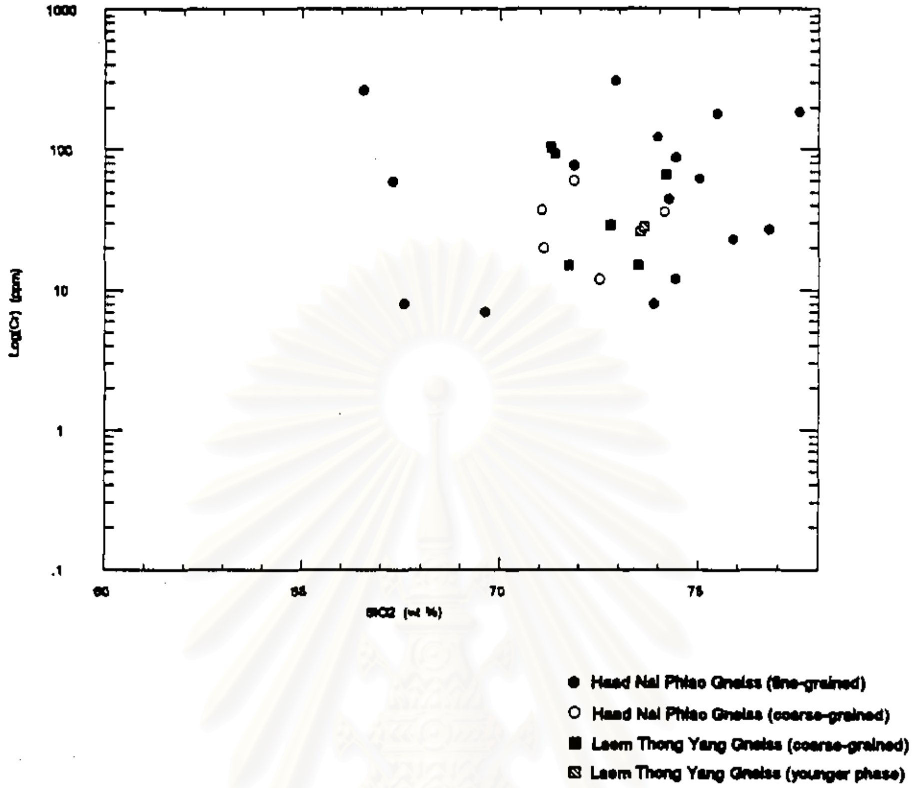


Figure 6.5e. Plot of lead against silica for the Khanom gneiss (a) and granite (b).



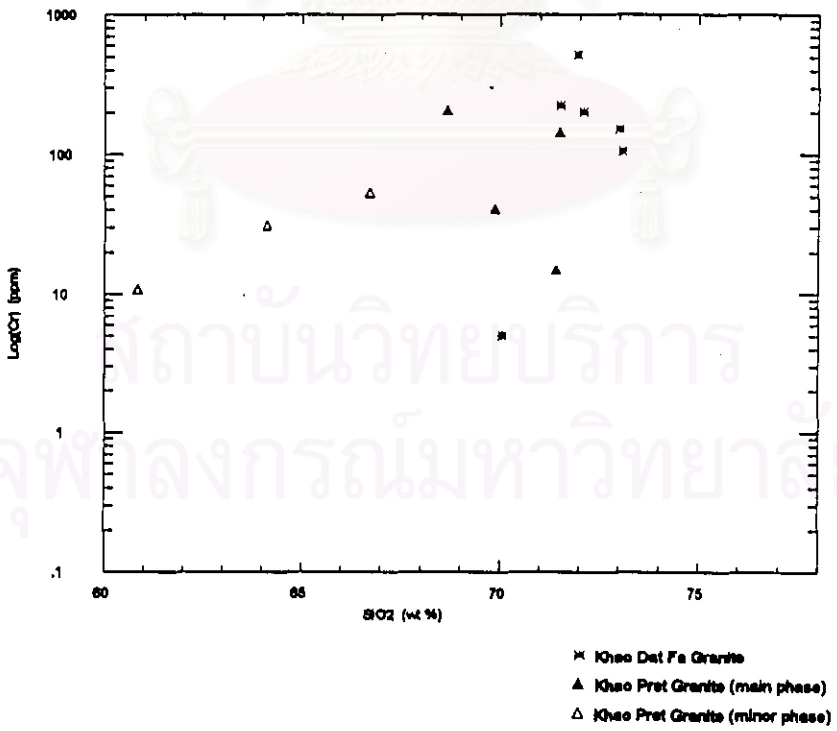


Figure 6.5f. Plot of chromium against silica for the Khanom gneiss (a) and granite (b).

Rare Earth Elements

The rare earth elements (REE) have generally been considered to be immobile during secondary or non-magmatic geochemical processes. Most studies of many rocks in high-grade metamorphic terrain of Precambrian age of Collerson & Fryer (1978) and Collerson & Bridgwater (1979), assume that metamorphism has not affected REE distributions although many other elements have been shown to be mobile. The overall slope of REE abundance patterns also gives important information on the behavior of REE during weathering. For example, minerals such as monazite, allanite and florencite, have light REE (LREE) enriched abundance patterns, on the other hand, xenotime, garnet, and zircon are heavy REE (HREE) enriched (Kamioka et al., 1994).

The REE data of granitic rocks of the Khanom Complex are presented in Table 6.4, and further displayed as chondrite-normalized patterns in Figures 6.6a, b, c and d. Chondrite normalized pattern of the total samples shows right hanging-down feature, from light REE enrichment to heavy REE depletion.

In Figures 6.6a, b and c, the ranges of REE content found in three granites are compared with ranges of REE contents in monzogranites (adamellites) and syeno-granites (granites) of Cullers and Graf (1984). It is illustrated that the Laem Thong Yang Gneiss contains moderate to large negative Eu anomalies, the Khao Pret Granite containing small to moderate negative anomalies, whereas the Khao Dat Fa Granite containing little to no Eu anomalies and similar to REE characters of the Haad Nai Phlao Gneiss.

The Khao Pret Granite contains the most total REE content with an average value of 337.62 (± 73.99) ppm, as compared with those of the Khao Dat Fa Granite with an average value of 218.77 (±36.78) ppm the Haad Nai Phlao Gneiss with an average 202.43 (± 31.67) ppm, and the Laem Thong Yang Gneiss with the least average value of 185.36 (± 59.83) ppm.

Table 6.4. REE characteristics (in ppm) of the Khanom Gneissic Complex, showing the average value with standard deviation (±).

Units	Haad Nai Phlao Gneiss			Laem Thong Yang Gneiss			Khao Dat Fa Granite				Khao Pret Granite		Chondrite
Sample No.	KN2-3	KN18-2	KN24-1	KN22-1	KN30-2	KN70-2	KN59	KN63	KS153	KS156	KN49	KN58	(Sun,1982)
La	56.94±5.47	38.69±0.56	50.54±2.16	37.65±0.94	27.29±1.25	66.85±2.83	56.57±1.11	70.34±2.46	58.27±4.49	41.51±0.70	76.86±2.80	104.48±1.55	0.329
Ce	117.08±10.08	73.89±7.12	89.79±1.28	62.73±0.39	62.56±0.05	118.74±1.66	100.12±3.13	129.13±4.53	99.11±3.41	78.57±2.90	126.82±1.13	185.32±8.76	0.865
Nd	29.04±2.72	32.88±0.72	40.00±0.41	31.61±0.49	29.55±2.92	50.93±3.61	35.03±3.30	51.00±0.85	47.63±1.93	33.69±0.97	55.78±1.01	77.02±4.95	0.629
Sm	10.99±1.09	6.62±0.55	7.47±0.24	8.09±0.08	5.97±0.12	11.15±0.34	7.50±0.57	8.44±0.65	8.32±0.11	5.91±0.27	10.11±0.94	12.22±0.81	0.203
Eu	1.06±0.02	1.14±0.11	1.06±0.00	0.63±0.01	0.25±0.01	0.70±0.05	1.76±0.00	0.84±0.00	1.85±0.05	1.38±0.13	0.57±0.01	1.24±0.07	0.077
Tb	1.32±0.13	0.48±0.03	0.92±0.06	0.68±0.01	0.80±0.08	1.44±0.08	0.69±0.01	0.98±0.09	1.06±0.07	0.93±0.05	1.01±0.07	0.73±0.05	0.0498
Dy	13.91±1.34	5.66±0.12	5.88±0.13	5.97±0.27	6.43±0.56	16.78±1.04	6.99±0.56	8.28±0.79	6.16±0.39	4.18±0.12	7.31±0.70	7.45±0.39	0.343
Yb	10.92±0.29	4.35±0.30	6.38±0.60	1.38±0.11	4.64±0.34	3.05±0.19	2.22±0.20	1.34±0.04	3.68±0.13	1.32±0.08	6.74±0.56	1.40±0.07	0.219
Lu	0.11±0.01	0.07±0.01	0.10±0.00	0.05±0.00	0.07±0.01	0.10±0.01	0.05±0.00	0.10±0.00	0.08±0.00	0.05±0.00	0.09±0.01	0.08±0.00	0.0339
Total REE	241.36	163.78	202.14	148.79	137.56	269.74	210.93	270.45	226.16	167.54	285.29	389.94	2.749
Ce/Yb	10.72	16.98	14.07	45.45	13.48	38.93	45.4	96.36	26.93	59.52	18.82	132.37	
(La/Lu)cn	53.49	57.12	52.23	77.82	40.29	69.08	116.92	72.29	75.27	85.79	88.25	134.96	
Hf	6.04±0.43	4.57±0.12	5.27±0.06	3.45±0.21	4.08±0.25	6.49±0.39	5.44±0.29	6.54±0.22	5.84±0.48	3.89±0.11	5.6±0.23	7.02±0.10	

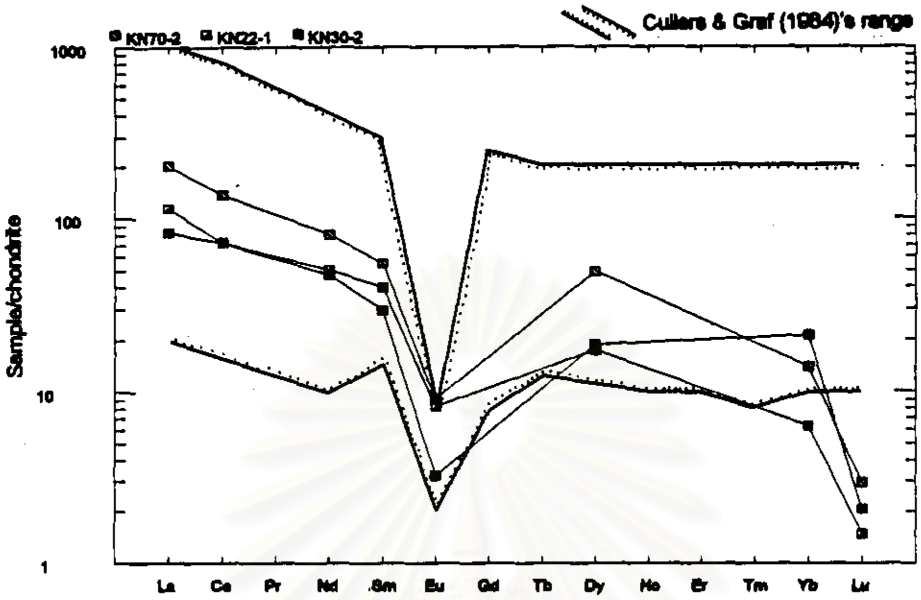


Figure 6.6. Chondrite-normalized REE patters for (a) Laem Thong Yang Gneiss, in compare to a range of REE content of Cullers and Graf (1984)'s granites contain moderate to large Eu anomalies.

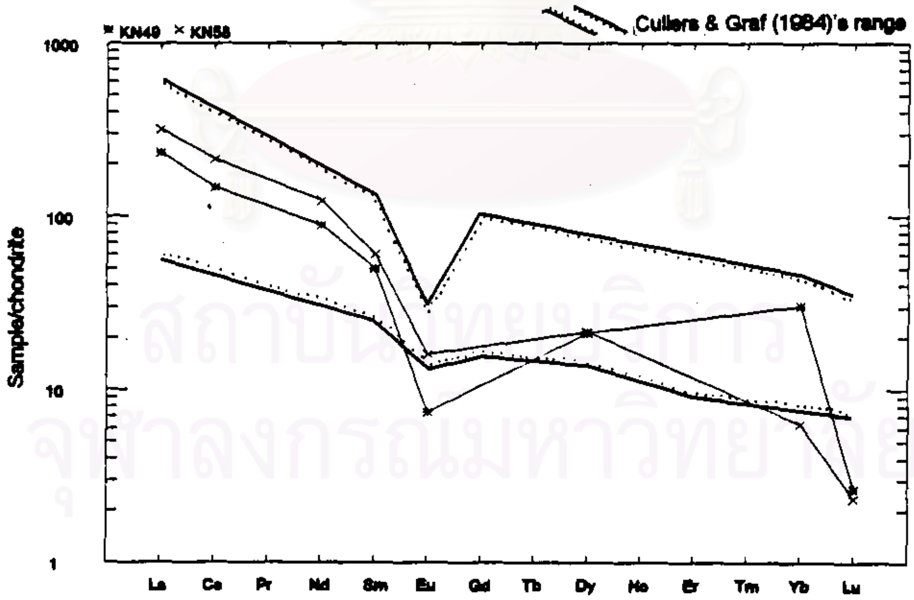


Figure 6.6. (continue) (b) Khao Pret Granite (western terrane), in compare to a range of REE content of Cullers and Graf (1984)'s granites contain small to moderate negative Eu anomalies.

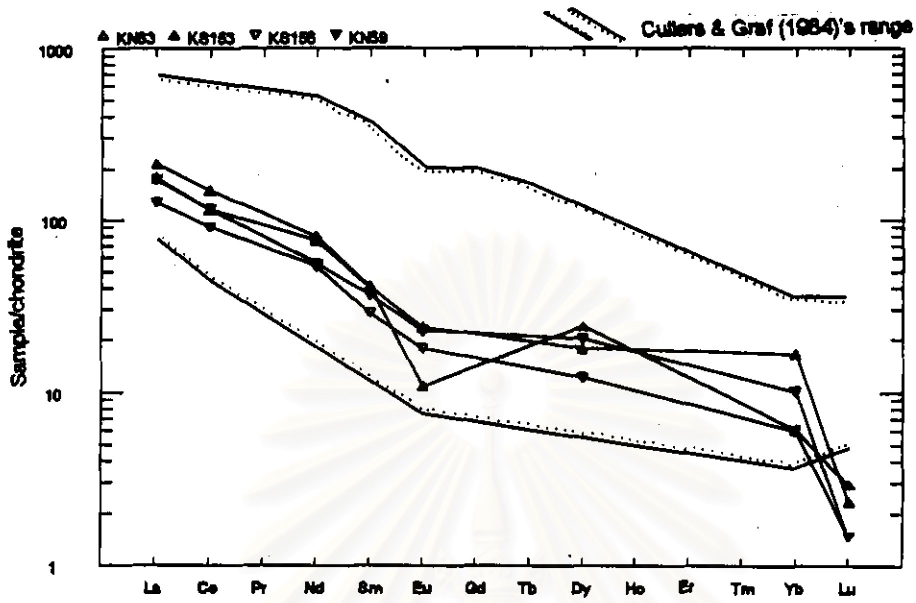


Figure 6.6. (continue) (c) Khao Dat Fa Granite, in compare to a range of REE content of Cullers and Graf (1984)'s granites contain little or no Eu anomalies.

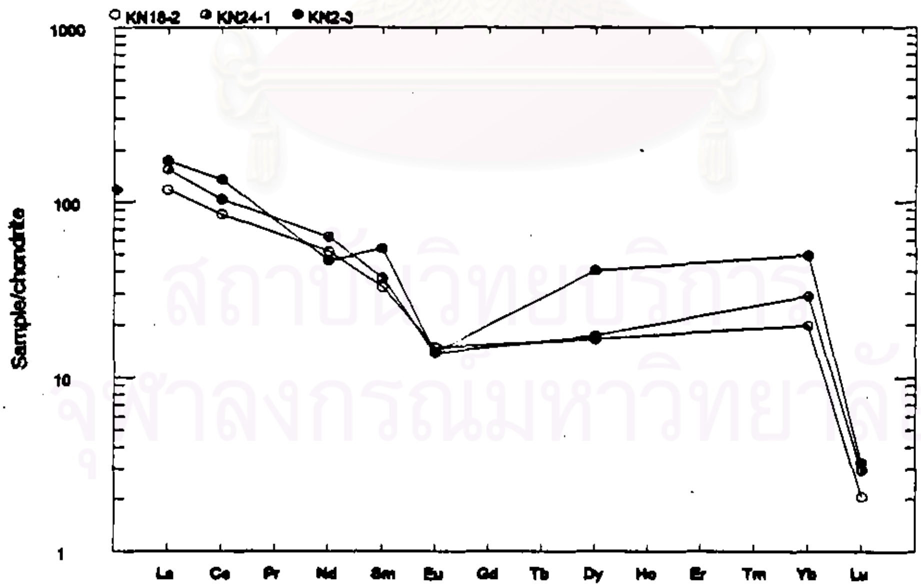


Figure 6.6. (d) Haad Nai Phlao Gneiss.