CHAPTER 4

GEOCHEMISTRY

4. 1 Granitic Rocks

A total of 25 samples of granites from the Mae Chedi Sn - W Mine and its vicinity were chemically analysed for their major and trace element concentrations. Table 4.1 presents the major element-oxides together with CIPW norms and differentiation index (D.I.) whereas Table 4.3 shows their trace elements and some certain elemental ratios. Range, mean and standard deviation of each of the major element-oxide together with D.I. and trace element from diverse rock types are summarized in Table 4.2 and 4.4, respectively. The differentiation index is computed as the sum of normative quartz, orthoclase and albite which recalculated after the total normative composition are normalized to 100 percent (Thornton and Tuttle, 1960).

4. 1. 1 Major element-oxide variations

Variation diagrams of the major element-oxides plot against silica (Figure 4.1) illustrates that there are two distinct trends. The first trend (GM-series) is composed of the GM-1, the GM-2, and the GM-3. The second trend (GM-series) consists of the GR-1, the GR-2, and the GR-3. It is noticeable that there are some differences of the same major element-oxides between these two series. The GM-series are relatively higher TiO_2 , Al_2O_3 , FeO (total), MnO, MgO, CaO, P_2O_5, H_2O^+ but lower SiO_2 contents than the GR-series. The Na_2O and K_2O contents in the GM-1, GM-2 and the GR-1, GR-2 show no significant dissimilarity. However, the GM-3 is distinctively lower

Table 4.1 Major element-oxide analyses, CIPW norms and Differentiation Index (D.I.) of the Mae Chedi granites

Rock Type	GM-1						GM-2	
Sample No.	(1)M1-13	(2)S-4B	(3)S-3	(4)M1-12	(5)M1-11-2	(6)S-2	(7)M1-18	(8)M1-11
Major element oxides. (wt.%)								
SiO_2	68.16	70.45	70.59	68.23	71.43	69.23	72.19	73.36
TiO_2	0.54	0.37	0.39	0.52	0.28	0.52	0.25	0.23
Al_2O_3	15.42	14.86	15.06	15.42	14.50	15.42	14.58	13.77
Fe_2O_3	1.51	1.03	1.26	1.22	1.05	1.31	1.04	0.88
FeO	1.87	1.26	1.34	2.13	0.82	1.83	0.65	0.49
MnO	0.09	0.06	0.06	0.10	0.04	0.05	0.03	0.02
MgO	1.91	1.21	1.25	1.88	0.76	1.67	0.61	0.57
CaO	1.39	1.34	1.09	1.76	1.39	1.59	0.95	0.33
Na_2O	2.96	2.71	2.69	2.89	2.94	3.01	3.01	3.23
K_2O	4.26	5.03	4.80	4.03	4.88	4.03	4.76	4.88
P_2O_5	0.18	0.11	0.12	0.18	0.12	0.19	0.12	0.12
H_2O^+	1.51	1.39	1.29	1.25	1.67	1.21	1.03	1.72
Total	99.80	99.82	99.94	99.61	99.88	100.06	99.22	99.60
CIPW norms								
Q	28.66	30.63	32.31	28.92	31.77	30.25	33.86	34.68
or	25.17	29.73	28.36	23.81	28.84	23.81	28.13	28.84
ab	25.05	22.93	22.76	24.46	24.88	25.47	25.47	27.33
an	5.72	5.93	4.62	7.55	6.11	6.65	3.93	0.85
C	3.84	2.78	3.75	3.53	2.14	3.67	3.04	2.86
hy en	4.76	3.01	3.11	4.68	1.89	4.16	1.52	1.42
hy fs	1.46	0.96	0.89	2.23	0.25	1.51	-	-
mt	2.19	1.49	1.83	1.77	1.52	1.90	1.47	0.98
hm	-	-	-	-	-	-	0.03	0.21
il	1.03	0.70	0.74	0.99	0.53	0.99	0.47	0.44
ap	0.42	0.25	0.28	0.42	0.28	0.44	0.28	0.28
Salic tot.	88.44	92.00	91.80	88.27	93.74	89.85	94.43	94.56
Femic tot.	9.86	6.41	6.85	10.09	4.47	9.00	3.77	3.33
D.I.	80.2	84.6	84.6	78.5	87.0	80.5	89.1	92.8

Table 4.1 - Continued

Rock Type	GM-2				GM-3			GR-1
Sample No.	(9)M1-15	(10)M1-9	(11)M1-7	(12)M1-4B	(13)M1-24	(14)M1-23	(15)M1-6	(16)MD11
Major element oxides (wt.%)								
SiO_2	72.72	72.59	72.90	72.23	74.34	74.72	74.14	73.05
TiO_2	0.23	0.22	0.22	0.30	0.15	0.11	0.14	0.24
Al_2O_3	14.21	14.50	14.26	13.73	14.50	14.21	14.21	14.25
Fe_2O_3	1.00	0.81	0.84	1.42	0.29	0.16	0.35	0.69
FeO	0.43	0.52	0.37	0.72	0.08	0.08	0.10	0.84
MnO	0.02	0.03	0.01	0.03	N.D.	N.D.	N.D	0.04
MgO	0.57	0.49	0.53	0.86	0.19	0.19	0.20	0.57
CaO	0.47	0.83	0.34	0.48	0.34	0.42	0.34	1.23
Na_2O	2.91	3.02	3.04	3.49	2.59	2.47	2.99	2.96
K_2O	5.53	5.50	5.50	4.25	5.61	5.78	5.50	4.84
P_2O_5	0.11	0.12	0.11	0.13	0.11	0.14	0.10	0.07
H_2O^+	1.49	1.12	1.52	1.78	1.17	1.04	1.66	0.76
Total	99.69	99.75	99.64	99.42	99.37	99.32	99.73	99.54
CIPW norms								
Q	33.08	31.81	32.96	33.72	37.10	37.45	34.96	33.72
or	32.68	32.50	32.50	25.12	33.15	34.16	32.50	28.60
ab	24.62	25.56	25.72	29.53	21.92	20.90	25.30	25.05
an	1.62	3.33	0.97	1.53	0.97	1.17	1.04	5.65
C	2.84	2.36	2.95	2.83	3.81	3.46	2.96	2.07
hy en	1.42	1.22	1.32	2.14	0.47	0.47	0.50	1.42
hy fs	-	-	-	-	-	-	-	0.65
mt	0.78	1.14	0.59	1.55	-	-	-	1.00
hm	0.46	0.03	0.43	0.35	0.29	0.16	0.35	-
il	0.44	0.42	0.42	0.57	0.17	0.17	0.21	0.46
ru	-	-	-	-	0.06	0.02	0.03	-
ap	0.25	0.28	0.25	0.30	0.25	0.33	0.23	0.16
Salic tot.	94.84	95.56	95.10	92.73	96.95	97.14	96.76	95.09
Femic tot.	3.35	3.09	3.01	4.91	1.24	1.15	1.32	3.69
D.I.	92.0	91.1	92.9	90.5	93.9	94.1	94.6	88.4

N.D. = not detected

Table 4.1 -- Continued

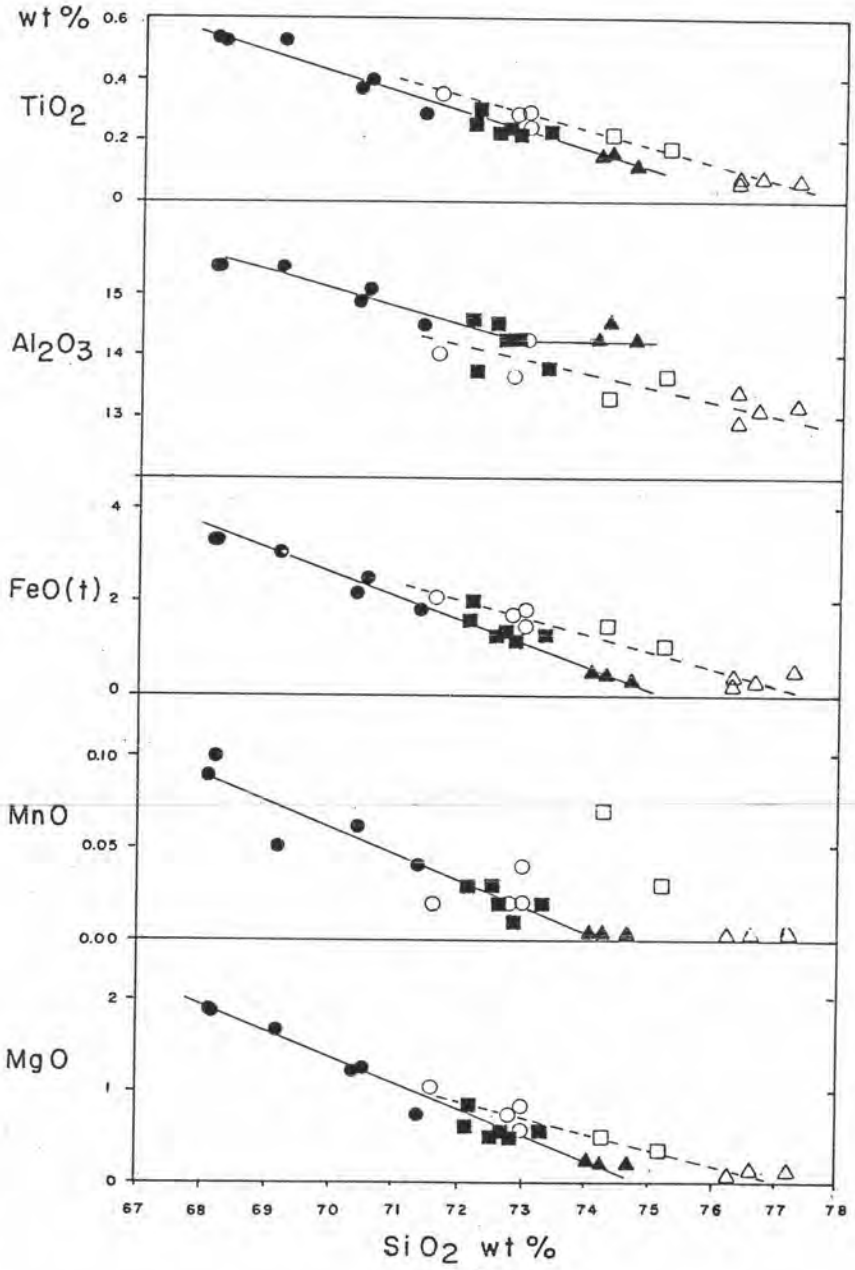
Rock Type	GR-1			GR-2		GR-3			
Sample No.	(17)MD10	(18)MD6	(19)MD7	(20)MD22	(21)MD24	(22)MD35	(23)MD16	(24)MD13	(25)MD21
Major element oxides (wt.%)									
SiO_2	71.65	72.85	73.05	74.34	75.24	76.32	76.32	77.26	76.68
TiO_2	0.35	0.28	0.29	0.22	0.17	0.07	0.06	0.06	0.07
Al_2O_3	14.01	13.65	14.25	13.29	13.65	12.88	13.36	13.12	13.05
Fe_2O_3	0.96	1.06	0.81	0.98	0.92	0.24	TR.	0.33	0.16
FeO	1.23	0.77	1.08	0.58	0.22	0.09	0.05	0.12	0.12
MnO	0.02	0.02	0.02	0.07	0.03	N.D.	N.D.	N.D.	N.D.
MgO	1.04	0.75	0.83	0.49	0.36	0.06	0.03	0.09	0.13
CaO	1.52	1.12	1.31	0.46	0.76	0.68	0.17	0.31	0.21
Na_2O	2.88	2.84	2.67	2.79	3.14	3.23	3.52	3.59	3.09
K_2O	4.65	4.87	4.87	4.98	4.75	4.98	4.91	4.24	5.17
P_2O_5	0.11	0.07	0.09	0.05	0.05	0.01	0.01	0.05	0.05
H_2O^+	1.34	1.06	0.83	1.53	1.14	1.05	0.96	0.59	0.89
Total	99.76	99.34	100.10	99.78	100.43	99.61	99.39	99.76	99.62
CIPW norms									
Q	32.18	34.32	34.69	37.47	36.78	36.96	36.68	39.49	38.42
or	27.48	28.78	28.78	29.43	28.07	29.43	29.01	25.06	30.55
ab	24.37	24.03	22.59	23.61	26.57	27.33	29.78	30.38	26.15
an	6.83	5.10	5.91	1.96	3.44	3.31	0.78	1.21	0.72
C	1.74	1.84	2.42	2.59	2.08	0.96	1.97	2.18	2.11
hy en	2.59	1.87	2.07	1.22	0.90	0.15	0.07	0.22	0.32
hy fs	0.92	0.11	0.87	0.02	-	-	-	-	-
mt	1.39	1.54	1.17	1.42	0.31	0.09	-	0.21	0.19
hm	-	-	-	-	0.70	0.18	-	0.18	0.03
il	0.66	0.53	0.55	0.42	0.32	0.13	0.11	0.11	0.13
ap	0.25	0.16	0.21	0.12	0.12	0.02	0.02	0.12	0.12
Salic tot.	92.60	94.07	94.39	95.06	96.94	97.99	98.22	98.32	97.95
Femic tot.	5.81	4.21	4.87	3.20	2.35	0.57	0.20	0.84	0.79
D.I.	85.4	88.7	86.7	92.1	92.1	95.1	97.0	95.7	96.3

TR. = trace, N.D. = not detected

Table 4.2 Values of major element-oxides (wt.%) and differentiation index of the Mae Chedi granites showing range, mean and standard deviation

Rock Type	GM-1			GM-2			GM-3			GR-1			GR-2			GR-3		
No.of analyses	6			6			3			4			2			4		
	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD
SiO_2	68.16-71.43	69.68	1.35	72.19-73.36	72.67	0.44	74.14-74.72	74.40	0.29	71.65-73.05	72.65	0.67	74.34-75.24	74.79	0.64	76.33-77.26	76.65	0.44
TiO_2	0.28- 0.54	0.44	0.11	0.22- 0.30	0.24	0.03	0.11- 0.15	0.13	0.02	0.24- 0.35	0.29	0.05	0.17- 0.22	0.20	0.04	0.06- 0.07	0.07	0.01
Al_2O_3	14.50-15.42	15.11	0.38	13.73-14.58	14.18	0.36	14.21-14.50	14.31	0.17	13.65-14.25	14.04	0.28	13.29-13.65	13.47	0.25	12.88-13.36	13.10	0.20
Fe_2O_3	1.03- 1.51	1.23	0.18	0.81- 1.42	1.00	0.23	0.16- 0.35	0.27	0.10	0.69- 1.06	0.88	0.16	0.92- 0.98	0.95	0.04	TR. - 0.33	0.18	0.14
FeO	0.82- 1.87	1.54	0.49	0.37- 0.72	0.53	0.13	0.08- 0.10	0.09	0.01	0.77- 1.23	0.98	0.21	0.22- 0.58	0.40	0.25	0.05- 0.12	0.10	0.03
MnO	0.04- 0.10	0.07	0.02	0.01- 0.03	0.02	0.01	N.D.	-	-	0.02- 0.04	0.03	0.01	0.03- 0.07	0.05	0.03	N.D.	-	-
MgO	0.76- 1.91	1.45	0.45	0.49- 0.86	0.61	0.13	0.19- 0.20	0.19	0.01	0.57- 1.04	0.80	0.19	0.36- 0.49	0.43	0.09	0.03- 0.13	0.08	0.04
CaO	1.09- 1.76	1.43	0.23	0.33- 0.95	0.57	0.26	0.34- 0.42	0.37	0.05	1.12- 1.52	1.30	0.17	0.46- 0.76	0.61	0.21	0.17- 0.68	0.34	0.23
Na_2O	2.69- 3.01	2.87	0.13	2.91- 3.49	3.12	0.21	2.47- 2.99	2.68	0.27	2.67- 2.96	2.84	0.12	2.79- 3.14	2.97	0.25	3.09- 3.59	3.36	0.24
K_2O	4.03- 5.03	4.51	0.45	4.25- 5.53	5.07	0.53	5.50- 5.78	5.63	0.14	4.65- 4.87	4.81	0.11	4.75- 4.98	4.87	0.16	4.24- 5.17	4.83	0.41
P_2O_5	0.11- 0.19	0.15	0.04	0.11- 0.13	0.12	0.01	0.10- 0.14	0.12	0.02	0.07- 0.11	0.09	0.02	0.05	0.05	0.00	0.01- 0.05	0.03	0.02
H_2O^+	1.21- 1.67	1.39	0.18	1.03- 1.78	1.44	0.31	1.04- 1.66	1.29	0.33	0.76- 1.34	1.00	0.26	1.14- 1.53	1.34	0.28	0.59- 1.05	0.87	0.20
D.I.	78.5 -87.0	82.6	3.3	89.1 -92.9	91.4	1.5	93.9 -94.6	94.2	0.4	85.4 -88.7	87.3	1.5	92.1	92.1	0.00	95.1 -97.0	96.0	0.8

$\bar{X}$ = mean, SD = standard deviation, D.I. = differentiation index, TR. = trace, N.D. = not detected


wt %
TiO2
0.6
0.4
0.2
0
Al2O3
15
14
13
FeO(t)
4
2
0
MnO
0.10
0.05
0.00
MgO
2
1
0
67
68
69
70
71
72
73
74
75
76
77
78
SiO2 wt %

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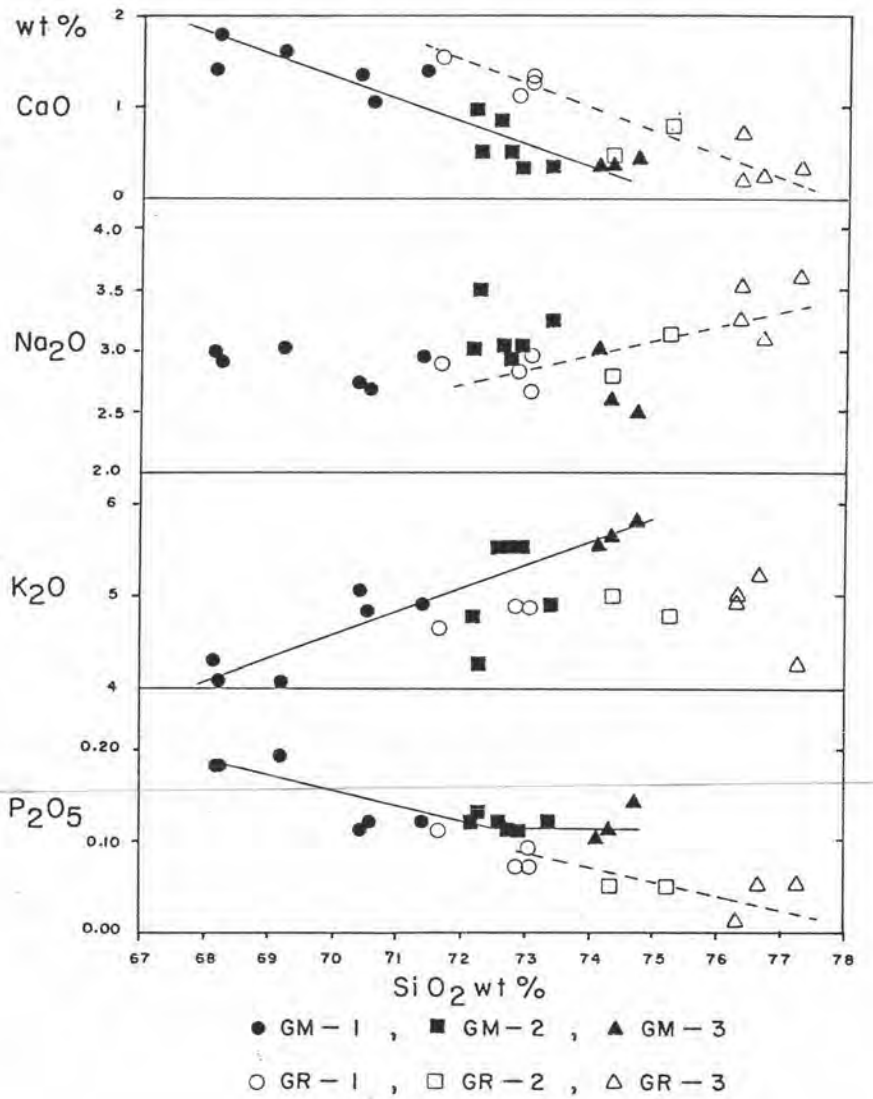


Figure 4.1 Variation of major element-oxides against silica for the Mae Chedi granites.

in Na_2O and higher in K_2O than the GR-3.

SiO_2 : The ranges of the SiO_2 contents of each granite series are relatively restricted. The SiO_2 contents of the GM-series range from 68.16 to 74.72 while those of the GR-series range from 71.65 to 77.26. It gradually increases from the GM-1 to the GM-3 and the GR-1 to the GR-3. However, the GR-series tend to be more silicic than the GM-series.

TiO_2 : The TiO_2 contents of the GM- and the GR-series decrease sharply from the GM-1 to the GM-3 and the GR-1 to the GR-3, respectively, by being correlated with the increasing of the SiO_2 contents. Plots of the TiO_2 contents of both series display more or less the same trend.

Al_2O_3 : The Al_2O_3 contents of the GM-series decrease from the GM-1 to the GM-2 but remain at approximately the same value from the GM-2 to the GM-3 whilst those of the GR-series decrease gradually from the GR-1 to the GR-3 with the increasing of the SiO_2 contents.

FeO (total) and MgO : It is evident that the FeO (total) and the MgO contents of the GM-series from the GM-1 to the GM-3 tend to distinctively decrease with a higher gradient than those of the GR-series (from the GR-1 to the GR-3) as the increase of the SiO_2 contents. It indicates that the concentrations of the FeO (total) and MgO in the GM-series are depleted at the faster rate than those of the GR-series.

MnO : The variation plots of the MnO against the SiO_2 of the GM-series tend to uniformly decrease from the GM-1 to the GM-3

but those of the GR-series appear to be sacattered. However, the average MnO contents of the GR-series (Table 4.2) seem to increase slightly from the GR-1 to the GR-2 and deplete from the GR-2 to the GR-3. It should be noted that the MnO content of both the GM-3 and the GR-3 samples are not detected.

CaO : The CaO contents of the GM-series decrease distinctively from the GM-1 to the GM-2, however, they tend to decrease slightly from the GM-2 to the GM-3 whilst those of the GR-series decrease gradually from the GR-1 to the GR-3 with the increasing of the SiO_2 contents. The variation diagram shows two separate trends which seem to be parallel to each other.

Na_2O : The Na_2O contents of the GM-series do not exhibit a clear trend. Conversely, those of the GR-series show a tendency to increase slightly from the GR-1 to the GR-3 as the SiO_2 contents increase.

K_2O : It can be pointed out that the K_2O contents of the GM-series increase gradually from the GM-1 to the GM-3 whereas those of the GR-series seem to be unchanged as the SiO_2 contents increase.

P_2O_5 : The P_2O_5 contents of the GM-series show to be slightly decreasing from the GM-1 to the GM-2 and to be unchanged from the GM-2 to the GM-3 while those of the GR-series appear to be slightly decreasing from the GR-1 to the GR-3 with the increasing of the SiO_2 contents.

The A F M (A = total alkalis ($Na_2O + K_2O$), F = total Fe as FeO, M = MgO) diagram shows another well defined variation of

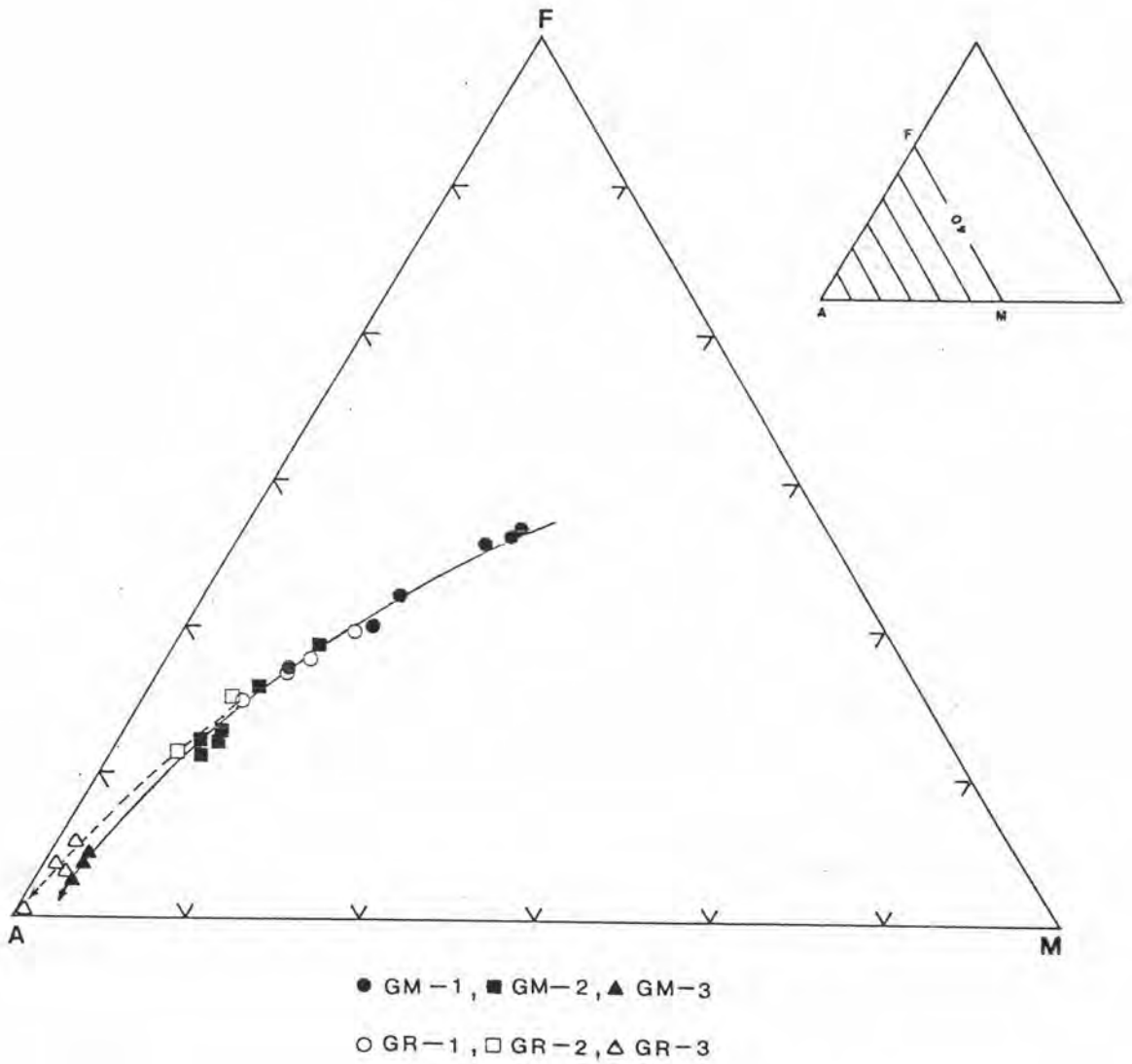


Figure 4.2 A ($Na_2O + K_2O$) - F (FeO total) - M (MgO) diagram for the Mae Chedi granites showing chemical variation trends

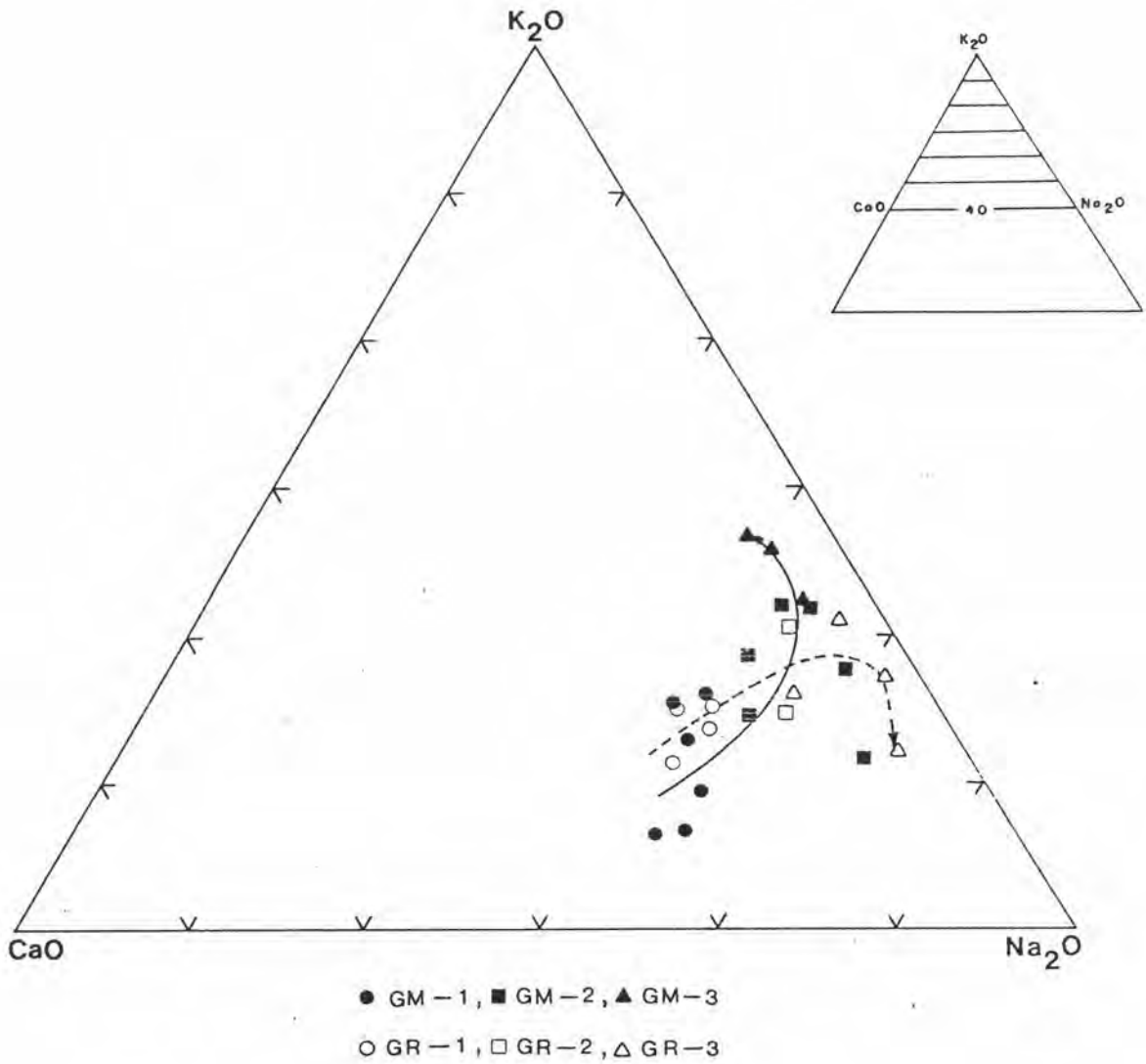


Figure 4.3 K_2O - Na_2O - CaO diagram for the Mae Chedi granites showing chemical variation trends

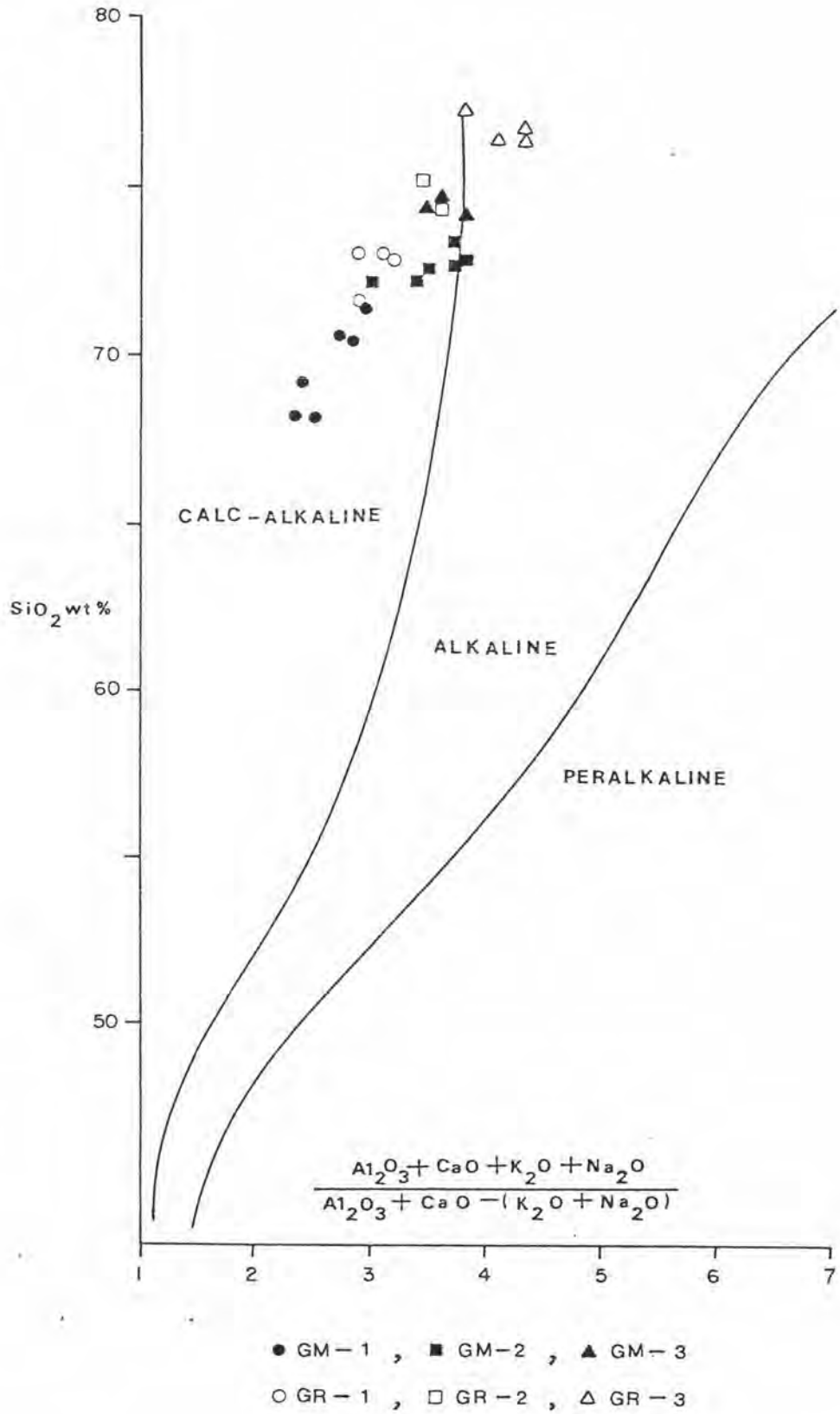


Figure 4.4 Alkalinity ratio variation diagram for the Mae Chedi granites. The alkalinity fields are from Wright (1969, cited in Sheraton and Labonne, 1978).

the GM- and the GR-series (Figure 4.2). Both variation trends are close to the F - A join and move toward the A apex. The decreasing total iron as well as MgO and enrichment of total alkalis are characteristic of both trends. These characteristics are generally similar to the granites of Phuket Pluton (Charusiri, 1980; Charusiri and Pongsapich, 1982) and the Thong-Lang granites (Nakapadungrat, 1982). The diagram (Figure 4.2) shows that the GM- and the GR-series align within the same trend when having high total iron and MgO contents (GM-1 and GR-1), and appear to branch out, slightly apart, into two trends, from the GM-2 toward the GM-3 and the GR-2 toward the GR-3, at lower total iron and MgO contents.

The K_2O - Na_2O - CaO diagram also shows increasing alkalis for both series (Figure 4.3). However, the trend of the GM-series has a tendency to move toward the K_2O whereas the trend of the GR-series has a tendency to move toward the Na_2O. The plotting of the alkalinity ratio proposed by Wright (1969, cited in Sheraton and Labonne, 1978) against SiO_2 shows that majority of samples of the GM- and the GR-series fall in the calc-alkaline field, although some of the high silicic samples, especially the GR-3, fall in the alkaline field (Figure 4.4). This appears to be the characteristic of many common calc-alkaline associations (Sheraton and Labonne, 1978).

4. 1. 2 Trace element variations

Most of the variations constructed from plots of the trace elements (Table 4.3) against SiO_2, again, tend to show two distinct trends of the GM- and the GR-series (Figure 4.5). There are

Table 4.3 Trace element analyses and elemental ratios of the Mae Chedi granites

Rock Type	GM-1						GM-2	
Sample No.	(1)M1-13	(2)S-4B	(3)S-3	(4)M1-12	(5)M1-11-2	(6)S-2	(7)M1-18	(8)M1-11
Trace elements (ppm)								
Li	50	38	34	55	36	55	19	15
F	1188	1665	1476	1483	1012	1217	522	463
Rb	401	388	431	364	392	344	387	419
Sr	157	88	68	101	62	117	74	87
Ba	812	527	516	768	565	667	563	555
Zr	176	124	126	155	97	162	109	98
Sn	6.0	6.0	6.5	7.5	10.0	3.0	1.0	17.5
W	15.6	6.9	6.4	7.6	7.6	18.2	6.1	23.3
Cu	60	29	26	60	70	18	28	18
Pb	50	72	68	56	85	68	560*	56
Zn	113	56	77	99	260*	90	278*	38
Ni	38	20	20	40	105*	25	195*	25
La	57	53	43	66	44	69	58	25
Ce	144	91	73	166	80	110	90	58
U	10.5	21.2	22.6	14.1	15.1	13.9	20.2	15.6
Elemental ratios								
K/Rb	88.2	107.6	92.5	91.9	103.4	97.3	102.1	96.7
Ba/Rb	2.0	1.4	1.2	2.1	1.4	1.9	1.5	1.3
K/Ba	43.6	79.2	77.2	43.6	71.7	50.2	70.2	73.0
Rb/Sr	2.6	4.4	6.3	3.6	6.3	2.9	5.2	4.8
Ca/Sr	63.3	108.8	114.6	124.5	160.2	97.1	91.8	27.1
Zr/Sn	29.3	20.7	19.4	20.7	9.7	54.0	109.0	5.6
Zn/Pb	2.3	0.8	1.1	1.8	3.1	1.3	0.5	0.7
F/Li	23.8	43.8	43.4	27.0	28.1	22.1	27.5	30.9
100Li/Mg	0.4	0.5	0.5	0.5	0.8	0.6	0.5	0.4
1000Li/K	1.4	0.9	0.9	1.6	0.9	1.6	0.5	0.4

* highly erratic values are excluded from Table 4.4

Table 4.3 - Continued

Rock Type	GM-2				GM-3			GR-1
Sample No.	(9)M1-15	(10)M1-9	(11)M1-7	(12)M1-4B	(13)M1-24	(14)M1-23	(15)M1-6	(16)MD11
Trace elements (ppm)								
Li	19	15	15	18	6	6	9	50
F	474	585	538	454	623	488	508	585
Rb	527	476	441	320	475	445	644	469
Sr	81	81	123	81	86	70	64	40
Ba	371	530	495	390	495	400	442	338
Zr	93	85	109	93	103	73	77	77
Sn	7.5	15.0	12.5	12.5	3.5	5.0	10.0	2.0
W	7.6	14.4	9.2	13.3	9.0	7.9	12.2	7.6
Cu	50	127	38	50	195	207	31	N.D.
Pb	80	80	60	56	72	80	56	80
Zn	39	48	30	39	13	13	19	36
Ni	16	6	16	25	6	10	20	6
La	45	38	28	24	32	26	18	56
Ce	48	75	50	48	49	36	37	76
U	20.0	17.5	15.9	14.9	22.7	19.1	15.7	19.3
Elemental ratios								
K/Rb	87.1	95.9	103.5	110.3	98.1	107.8	70.9	85.7
Ba/Rb	0.7	1.1	1.1	1.2	1.0	0.9	0.7	0.7
K/Ba	123.7	86.2	92.2	90.5	94.1	120.0	103.3	118.9
Rb/Sr	6.5	5.9	3.6	4.0	5.5	6.4	10.1	11.7
Ca/Sr	41.5	73.2	19.8	42.4	28.3	42.9	38.0	219.8
Zr/Sn	12.4	5.7	8.7	7.4	29.4	14.6	7.7	38.5
Zn/Pb	0.5	0.6	0.5	0.7	0.2	0.2	0.3	0.5
F/Li	25.0	39.0	35.9	25.2	103.8	81.3	56.4	11.7
100Li/Mg	0.6	0.5	0.5	0.4	0.5	0.5	0.8	1.5
1000Li/K	0.4	0.3	0.3	0.5	0.1	0.1	0.2	1.2

N.D. = not detected

Table 4.3 -- Continued

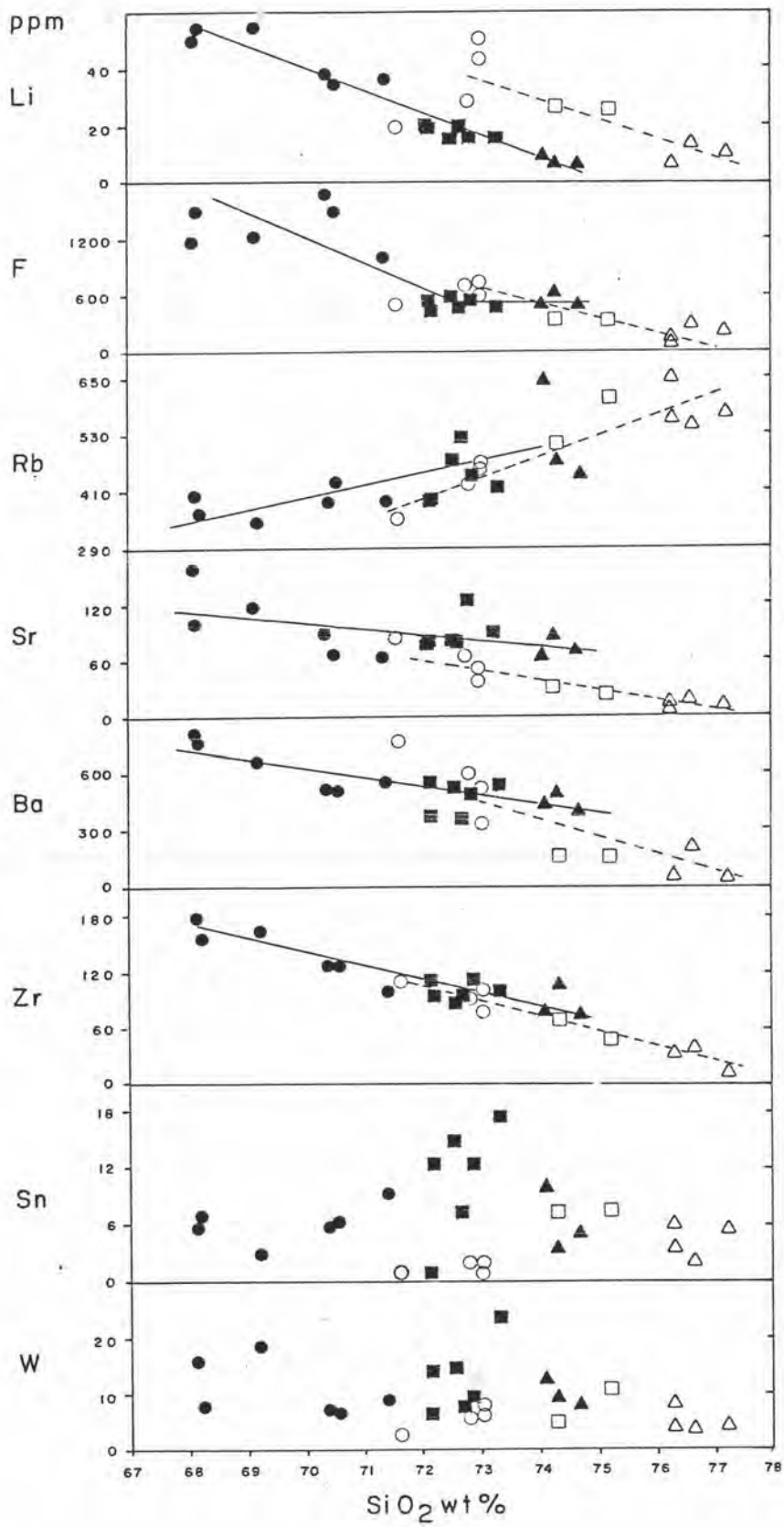
Rock Type	GR-1			GR-2		GR-3			
Sample No.	(17)MD10	(18)MD6	(19)MD7	(20)MD22	(21)MD24	(22)MD35	(23)MD16	(24)MD13	(25)MD21
Trace elements (ppm)									
Li	19	28	43	26	25	6	6	10	13
F	513	717	745	324	319	105	139	187	265
Rb	353	423	456	514	611	564	648	574	550
Sr	84	65	51	30	22	14	7	11	19
Ba	783	606	531	164	152	58	54	45	208
Zr	109	91	101	68	45	35	34	13	40
Sn	1.0	2.0	1.0	7.5	7.5	6.0	3.5	5.5	2.0
W	2.6	5.4	6.1	4.7	10.7	7.8	3.6	4.0	3.3
Cu	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pb	68	85	85	202	72	105	80	56	60
Zn	42	39	37	35	28	13	7	14	10
Ni	20	20	16	6	16	6	10	10	N.D.
La	64	51	53	27	23	31	28	17	N.D.
Ce	103	94	92	31	48	28	42	15	23
U	13.9	8.6	20.1	20.9	23.1	20.1	9.3	3.4	22.1
Elemental ratios									
K/Rb	109.4	95.6	88.7	80.4	64.5	73.3	62.9	61.3	78.0
Ba/Rb	2.2	1.4	1.2	0.3	0.3	0.1	0.1	0.1	0.4
K/Ba	49.3	66.7	76.1	252.1	259.4	712.8	754.8	782.2	206.3
Rb/Sr	4.2	6.5	8.9	17.1	27.8	40.3	92.6	52.2	29.0
Ca/Sr	129.3	123.2	183.6	109.6	246.9	347.1	173.6	201.4	79.0
Zr/Sn	109.0	45.5	101.0	9.1	6.0	5.8	9.7	2.4	20.0
Zn/Pb	0.6	0.5	0.4	0.2	0.4	0.1	0.1	0.3	0.2
F/Li	27.0	25.6	17.3	12.5	12.8	17.5	23.2	18.7	20.4
100Li/Mg	0.3	0.6	0.9	0.9	1.2	1.7	3.3	1.8	1.7
1000Li/K	0.5	0.7	1.1	0.6	0.6	0.2	0.2	0.3	0.3

N.D. = not detected

Table 4.4 Values of trace elements (ppm) of the Mae Chedi granites showing range, mean and standard deviation

Rock Type	GM-1			GM-2			GM-3			GR-1			GR-2			GR-3		
No. of analyses	6			6			3			4			2			4		
	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD	Range	$\bar{X}$	SD
Li	34-55	45	10	15-19	17	2	6-9	7	2	19-50	35	14	25-26	26	1	6-13	9	3
F	1012-1665	1340	241	454-585	506	51	488-623	540	73	513-745	640	110	319-324	322	4	105-265	174	69
Rb	344-431	387	30	320-527	428	72	445-644	521	107	353-469	425	52	514-611	563	69	550-648	584	44
Sr	62-157	99	35	74-123	88	18	64-86	73	11	40-84	60	19	22-30	26	6	7-19	13	5
Ba	516-812	643	127	371-563	484	84	400-495	446	48	338-783	565	184	152-164	158	8	45-208	91	78
Zr	97-176	140	29	85-109	98	10	73-103	84	16	77-109	95	14	45-68	57	16	13-40	31	12
Sn	3.0-10.0	6.5	2.3	1.0-17.5	11.0	6	3.5-10.0	6.2	3.4	1.0-2.0	1.5	0.6	7.5	7.5	0	2.0-6.0	4.3	2
W	6.4-18.2	10.4	5.1	6.1-23.3	12.3	6.3	7.9-12.2	9.7	2.2	2.6-7.6	5.4	2.1	4.7-10.7	7.7	4.2	3.3-7.8	4.7	2.1
Cu	18-70	44	22	18-127	52	39	31-207	144	98	N.D.	-	-	N.D.	-	-	N.D.	-	-
Pb	50-85	67	12	56-80*	66	13	56-80	69	12	68-85	80	8	72-202	137	92	56-105	75	22
Zn	56-113*	87	22	30-48*	39	6	13-19	15	3	36-42	39	3	35-28	32	5	7-14	11	3
Ni	20-40*	29	10	6-25*	18	8	6-20	12	7	6-20	16	7	6-16	11	7	N.D.-10	7	5
La	43-69	55	11	24-58	36	13	18-32	25	7	51-64	56	6	23-27	25	3	N.D.-31	19	14
Ce	73-166	111	37	48-90	62	17	36-49	41	7	76-103	91	11	31-48	40	12	15-42	27	11
U	10.5-22.6	16.2	4.7	14.9-20.2	17.4	2.3	15.7-22.7	19.2	3.5	8.6-20.1	15.5	5	20.9-23.1	22.0	1.6	3.4-22.1	13.7	8.9

$\bar{X}$ = mean, SD = standard deviation, N.D. = not detected, * from 5 samples of analyses (see Table 4.3)


ppm
Li
40
20
0
F
1200
600
0
Rb
650
530
410
290
Sr
120
60
0
Ba
600
300
0
Zr
180
120
60
0
Sn
18
12
6
0
W
20
10
0
67
68
69
70
71
72
73
74
75
76
77
78
SiO2 wt%

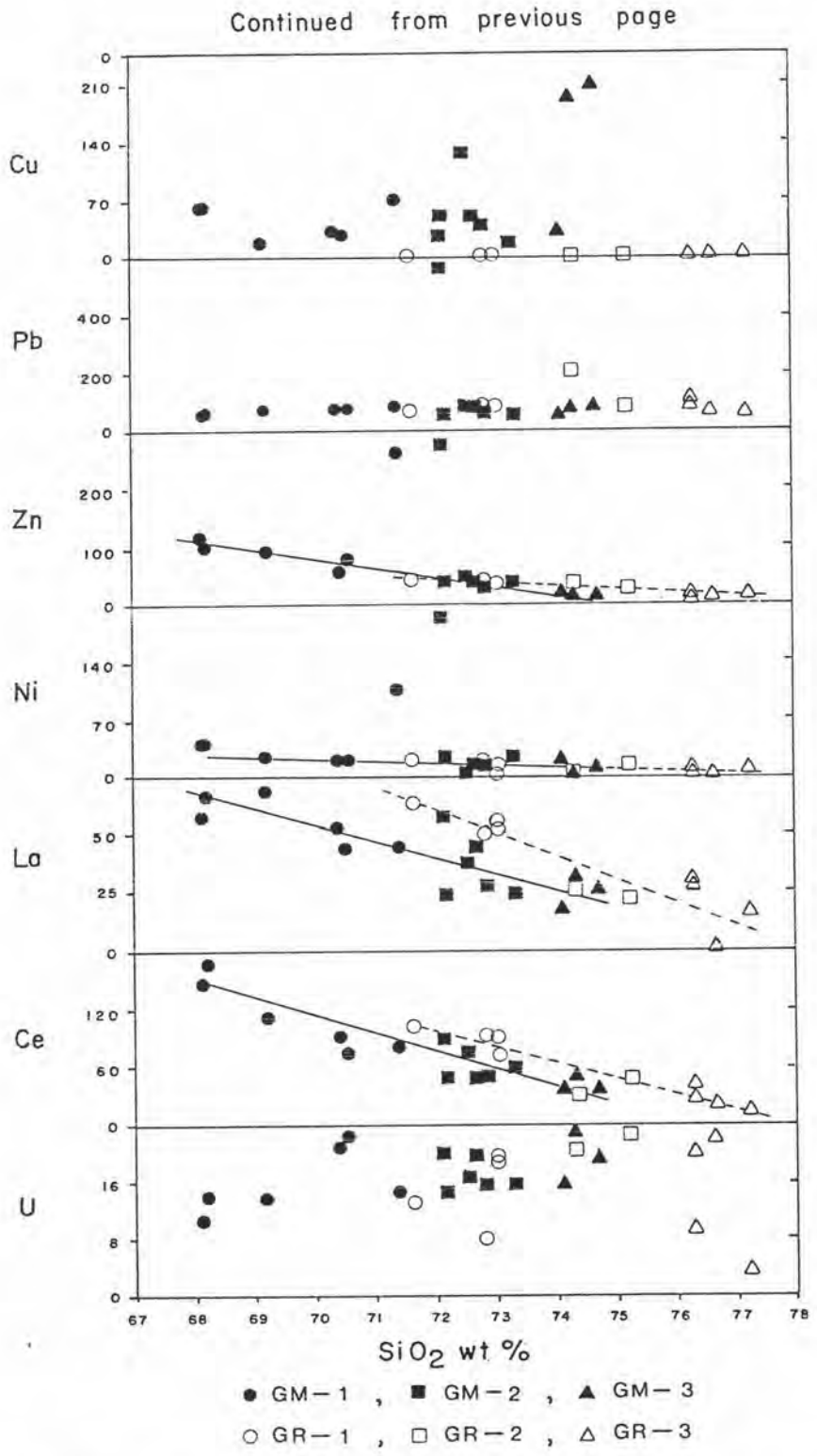


Figure 4.5 Variation of trace elements against silica for the Mae Chedi granites

also some differences of the same trace element between the GM- and the GR-series, the former is notably higher in Li, F, Sr, Ba, Zr, Sn, W, Cu, Zn, Ni, Ce, and lower in Rb contents than the latter. No significant difference of Pb, La, and U is known from these two granitic series.

Lithium (Li) : The Li concentration of the GM- and the GR-series decreases as the SiO_2 content increases. It can be seen that the variation diagram clearly shows two separate trends and the Li content of the GM-1 samples are relatively higher than that of the GR-1 samples.

Fluorine (F) : The F concentration of the GM-series strongly decreases from the GM-1 to the GM-2 and shows no distinct differences from the GM-2 to the GM-3 while that of the GR-series gradually decreases from the GR-1 to the GR-3 with an increasing of the SiO_2 concentrations.

Rubidium (Rb) : The Rb content of both the GM- and the GR-series increase from the GM-1 to the GM-3 and from the GR-1 to the GR-3, respectively, with the increasing of the SiO_2. However the increase of the Rb value of the GR-series is greater than that of the GM-series.

Strontium (Sr) and Barium (Ba) : Both Sr and Ba contents of the GM-series slightly decrease from the GM-1 to the GM-3 whereas those of the GR-series distinctively decrease from the GR-1 to the GR-3 with the increasing of the SiO_2 contents.

Zirconium (Zr) : The Zr contents of the GM- and the GR-series sharply decrease from the GM-1 to the GM-3 and from the

GR-1 to the GR-3, respectively, by being correlated with the increasing of the SiO_2 contents. Both of the variation trends appear to be more or less the same attitude.

Tin (Sn) and Tungsten (W) : The Sn and W variation plots of the GM- and the GR-series against the SiO_2 appear to be scattered. However, they seem to increase from the GM-1 to the GM-2 and from the GR-1 to the GR-2 and then decrease to the GM-3 and the GR-3, respectively, with and increasing of the SiO_2 contents. It can be seen that both Sn and W values of the GM-series are generally higher than those of the GR-series.

Copper (Cu) : The Cu contents of the GM-series vary from 18 to 207 ppm in the GM-1 to the GM-3 (see also Tables 4.3, 4.4) whereas the Cu contents of the GR-series are not detected. The trend of Cu apparently increases with small amounts from the GM-1 to the GM-2 and with large amounts from the GM-2 to the GM-3.

Lead (Pb) : The Pb contents of both the GM- and the GR-series appear to be uniform with an increasing of the SiO_2. They also show no significant difference between the two series. However, the average Pb values of the GR-series (Table 4.4) are relatively higher than those of the GM-series except for the sample (7) M1-18 of the GM-2 which contains up to 560 ppm Pb. This may suggest that it is an erratic sampling.

Zinc (Zn) : It is clearly seen that the Zn contents of the GM-series distinctively decrease from the GM-1 to the GM-3 while those of the GR-series slightly decrease from the GR-1 to the GR-3 as the SiO_2 contents increase except for samples (5) M1-11-2 of

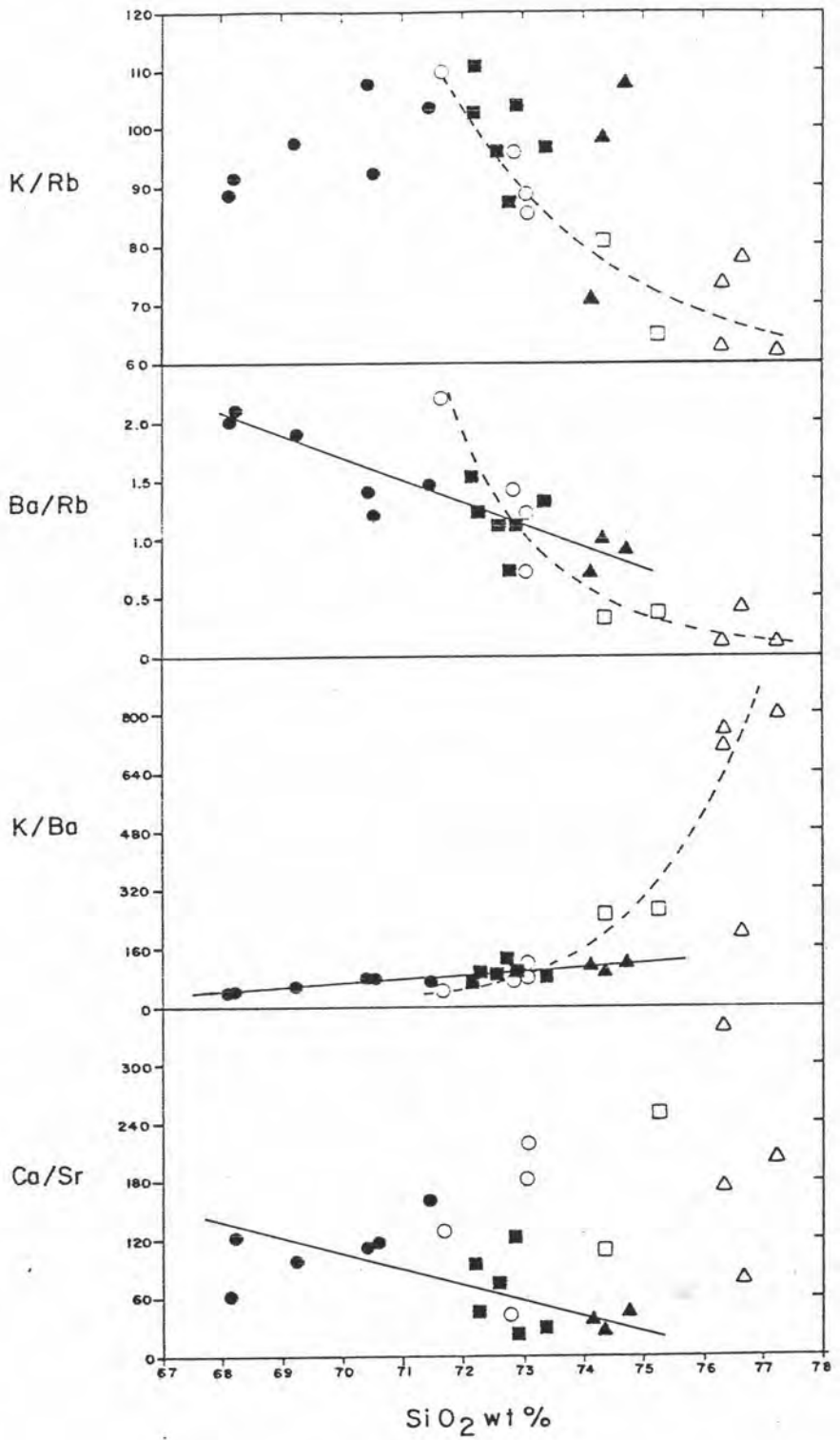
the GM-1 and (7) M1-18 of the GM-2, which contain up to 260 and 278 ppm Zn, respectively. These may be due to erratic sampling. It can be noted, however, that all of the GM-1 samples have the higher Zn concentration than those of the GR-1 samples.

Nickel (Ni) : Both Ni contents of the GM- and the GR-series slightly decrease from the GM-1 to the GM-3 and from the GR-1 to the GR-3, respectively, with the increasing of the SiO_2. The variation trends exactly confine to the same trend, except the erratic samples (5) M1-11-2 and (7) M1-18 which contain up to 105 and 195 ppm Ni, respectively.

Lanthanum (La) and Cerium (Ce) : Both La and Ce contents of the GM- and the GR-series gradually decrease from the GM-1 to the GM-3 and from the GR-1 to the GR-3 respectively. The difference of the La contents between the GM- and the GR-series are not significant. However, the GM-series are notably higher in Ce than the GR-series.

Uranium (U) : The U variation plots of the GM- and the GR-series against the SiO_2 appear to be scattered and show no significant difference.

Some selected elemental ratios (K/Rb, Ba/Rb, K/Ba, Ca/Sr, Rb/Sr, F/Li, 100 Li/Mg) plotted against SiO_2 content are shown in Figure 4.6. The K/Rb and Ba/Rb ratios of the GR-series distinctively decrease from the GR-1 to the GR-3 whereas the K/Rb ratios of the GM-series seem to be scattered and show just slightly increase, but the Ba/Rb ratios appear to decrease gradually from the GM-1 to the GM-3 with an increasing of the SiO_2 content. The concentration of the K/Ba, Rb/Sr and 100 Li/Mg ratios of the GR-series


K/Rb
Ba/Rb
K/Ba
Ca/Sr
SiO2 wt %

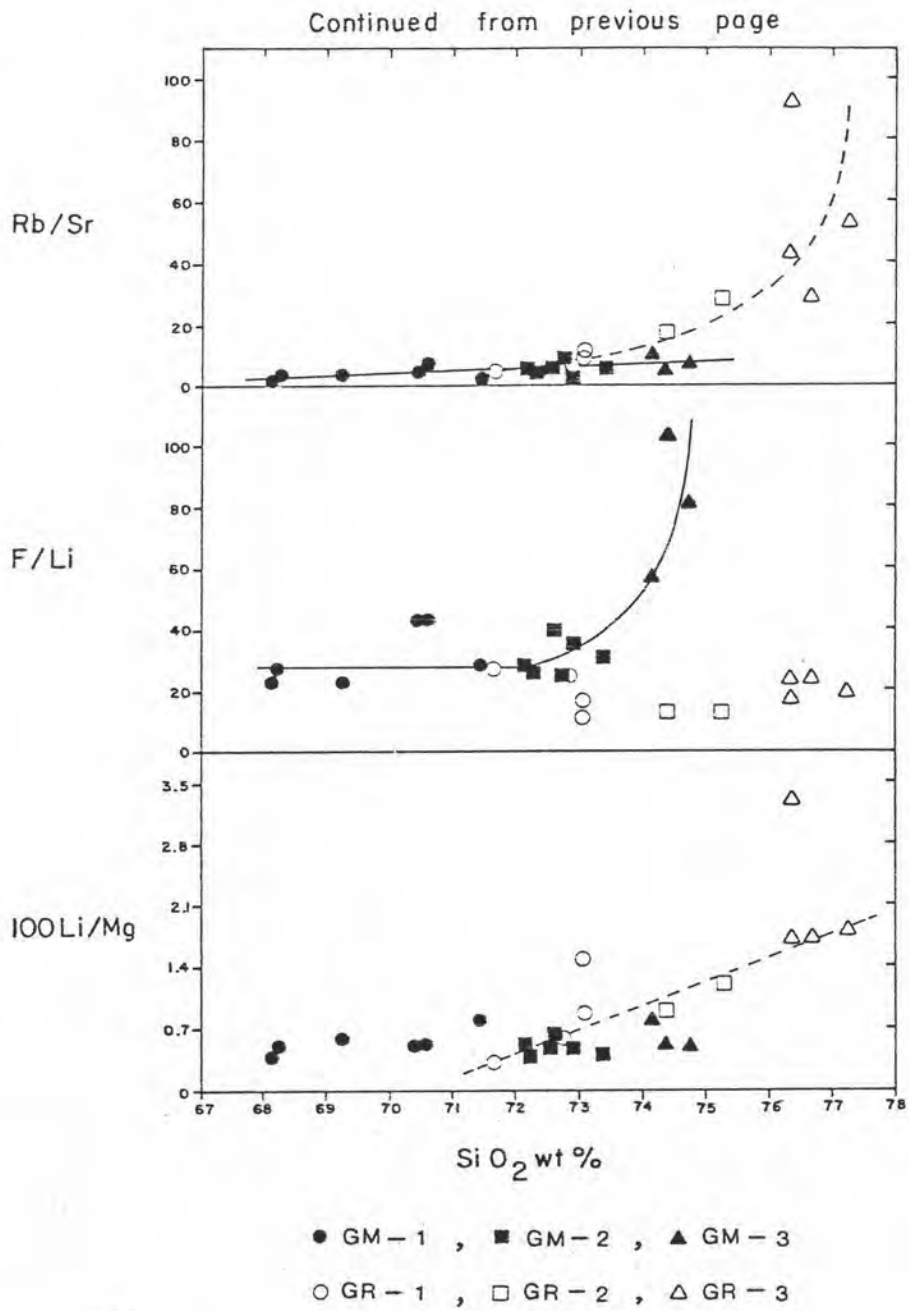
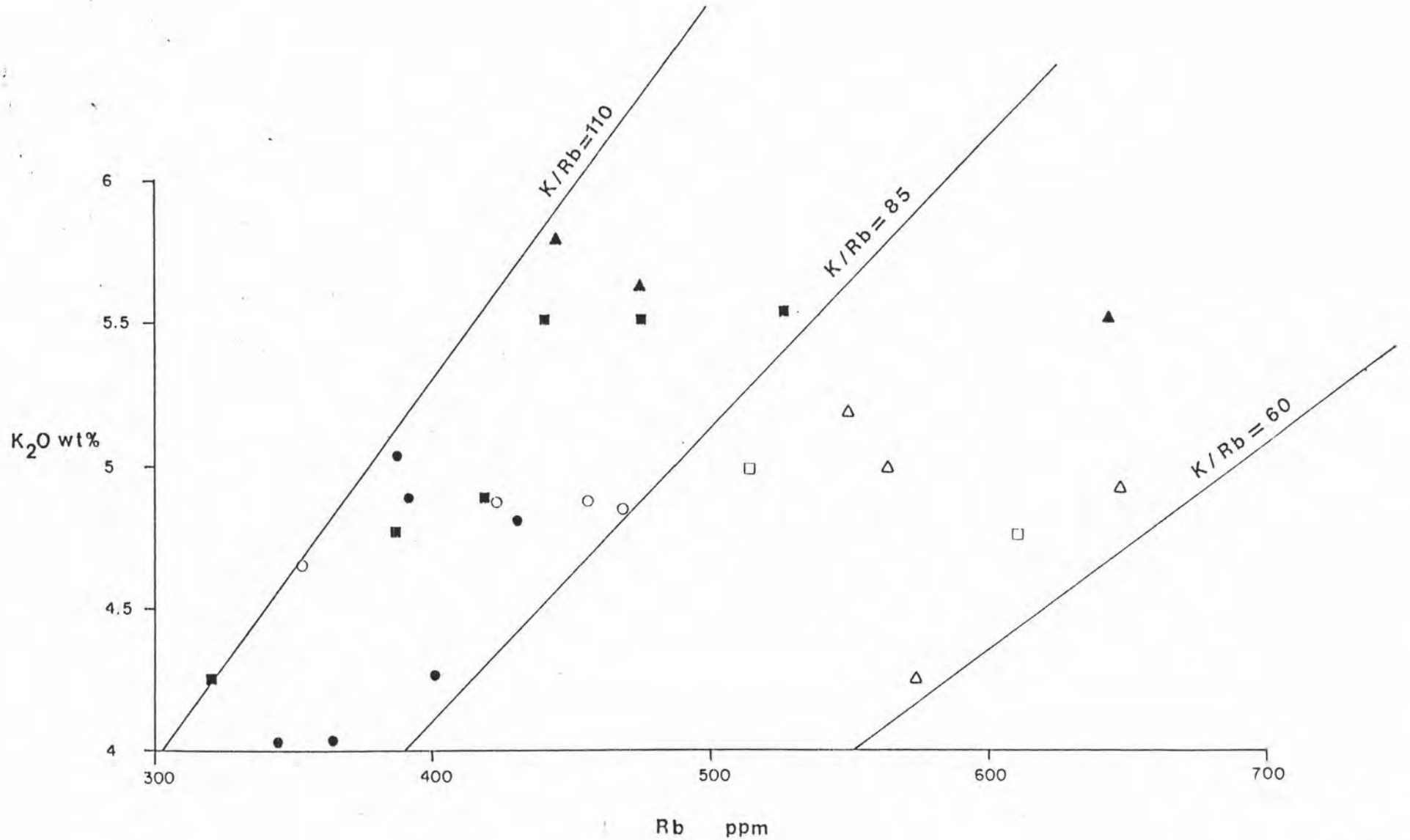


Figure 4.6 Variation of the K/Rb, Ba/Rb, K/Ba, Ca/Sr, Rb/Sr, F/Li and 100 Li/Mg ratios against SiO_2 for the Mae Chedi granites


K/Rb=110
K/Rb=85
K/Rb=60
6
5.5
5
4.5
4
K_2O wt%
300
400
500
600
700
Rb ppm

Continued from previous page

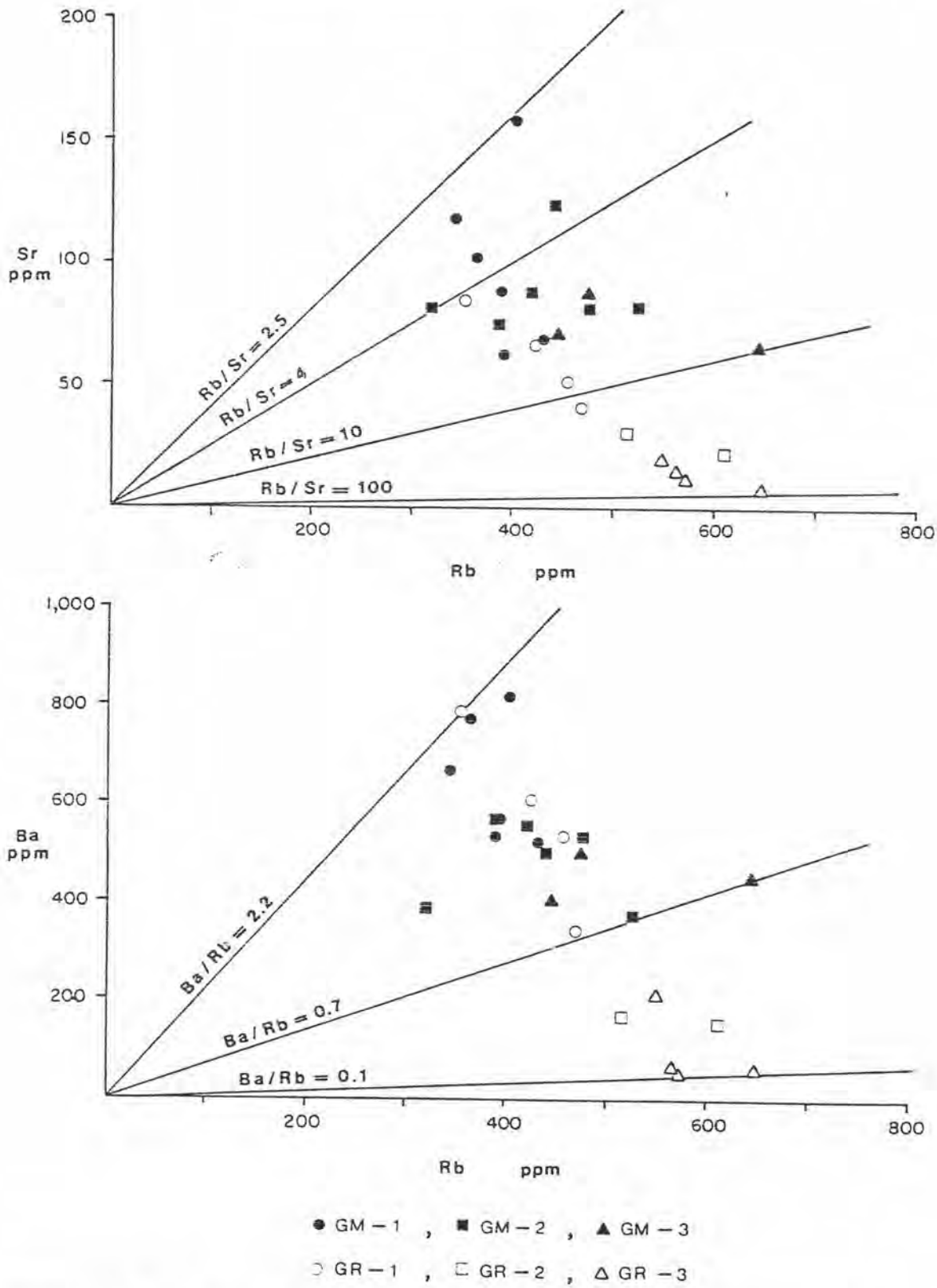


Figure 4.7 Plots of K_2O, Ba and Sr contents against Rb content for the Mae Chedi granites

distinctively increase from the GR-1 to the GR-3 while the K/Ba and the Rb/Sr ratios of the GM-series slightly increase from the GM-1 to the GM-3 with an increasing of the SiO_2, but the 100 Li/Mg ratios of the GM-series show unchanged amounts. The Ca/Sr ratios of the GM-series decrease from the GM-1 to the GM-3 while those of the GR-series seem to be scattered. Although the average values of Ca/Sr ratio of the GR-series in Table 4.3 appear to increase from the GR-1 to the GR-3 as the silica content increase. It should be noticed that the F/Li ratios of the GM-series appear to be unchanged from the GM-1 to the GM-2 but abruptly increase from the GM-2 to the GM-3 while those of the F/Li ratios of GR-series show no significant trend.

Plots of the K_2O, Ba and Sr contents against the Rb content (Figure 4.7) show that the GM-3 has higher K/Rb and Ba/Rb and lower Rb/Sr ratios than the GR-3. It is important to note that the K/Rb, Ba/Rb and Rb/Sr ratios of the GM-series are relatively restricted, i.e. ranging from 70.9 to 110.3 (87.1 to 110.3, except for the sample (15) M1-6), 0.7 to 2.1 and 2.6 to 10.1 whereas those of the GR-series are relatively wider ranges, i.e. verying from 61.3 to 109.4, 0.1 to 2.2 and 4.2 to 92.6, respectively (see Table 4.3).

4. 2 Metabasites

The chemical analyses and C I P W norm together with differentiation index (Thornton and Tuttle, 1960) of a total of 7 samples of metabasites from the Mae Chedi area are given in Table 4.5 and 4.6 respectively. The location of analysed metabasite specimens are shown in Figures 2.2, 2.3. Plots of the $Na_2O + K_2O$ against the

Table 4.5 Chemical analyses of metabasites, Mae Chedi, Wiang Pa Pao, Chiang Rai

Sample No.	B1 (M1-5)	B2 (V1-1)	B3 (V1-2)	B4 (M2-1)	B5 (M2-2)	B6 (MD31)	B7 (MD26)
Grid Ref.	499142	499141	499141	501138	501138	496159	479186
Major elements (wt.%)							
SiO_2	45.21	47.90	44.37	46.90	44.57	46.46	41.79
TiO_2	3.04	2.43	2.53	2.46	2.72	3.16	2.46
Al_2O_3	16.67	16.93	11.59	16.31	16.67	16.67	10.99
Fe_2O_3	2.99	2.57	2.33	2.52	2.62	2.95	2.01
FeO	8.56	6.69	9.71	8.15	9.07	8.77	9.62
MnO	0.20	0.35	0.27	0.15	0.20	0.15	0.13
MgO	7.05	6.68	14.05	6.49	6.69	5.26	18.70
CaO	9.80	8.35	10.85	10.90	11.30	9.20	9.05
Na_2O	2.53	3.16	1.21	2.61	2.27	3.22	0.45
K_2O	1.00	2.31	0.71	1.74	1.40	1.71	0.15
P_2O_5	0.51	0.34	0.34	0.37	0.37	0.51	0.31
S	0.97	0.05	0.11	0.18	0.30	0.51	N.D.
H_2O^+	1.04	1.67	1.26	1.06	1.11	1.21	3.78
Total	99.57	99.43	99.33	99.84	99.29	99.78	99.44
Trace elements (ppm)							
Li	18	26	21	39	40	35	6
F	1611	3276	3774	1355	1974	1124	510
Sn	2.5	<1	1.5	2.5	1.5	<1	<1
W	6.9	2.9	1.8	3.7	1.5	2.9	0.9
Cu	456	71	50	185	29	50	93
Pb	35	50	50	35	35	35	30
Zn	122	126	127	113	129	126	124
Ni	100	80	650	70	100	50	900
U	2.0	1.2	1.1	1.1	0.9	1.7	1.3

N.D. = not detected

Table 4.6 CIPW norms and Differentiation Index (D.I.) of metabasites, Mae Chedi, Wiang Pa Pao, Chiang Rai

Sample No.	B1 (M1-5)	B2 (V1-1)	B3 (V1-2)	B4 (M2-1)	B5 (M2-2)	B6 (MD31)	B7 (MD26)
Or	5.91	13.65	4.20	10.28	8.27	10.10	0.89
ab	21.41	24.03	10.24	18.84	14.97	25.07	3.81
an	31.17	25.19	24.10	27.65	31.16	25.98	27.53
ne	-	1.47	-	1.76	2.30	1.18	-
di wo	5.90	5.85	11.49	10.02	9.39	6.82	6.41
di en	3.96	3.87	7.87	6.14	5.61	4.08	4.62
di fs	1.49	1.56	2.70	3.32	3.29	2.39	1.21
hy en	4.86	-	5.54	-	-	-	14.01
hy fs	1.83	-	1.90	-	-	-	3.67
Ol fo	6.13	8.95	15.12	7.02	7.74	6.32	19.58
Ol fa	2.54	3.97	5.72	4.18	5.00	4.09	5.65
mt	4.33	3.73	3.38	3.65	3.80	4.28	2.92
il	5.77	4.61	4.81	4.67	5.17	6.00	4.67
pr	1.82	0.09	0.21	0.34	0.56	0.96	-
ap	1.18	0.79	0.79	0.86	0.86	1.18	0.72
Salic tot.	58.49	64.34	38.54	58.53	56.70	62.33	32.23
Femic tot.	39.81	33.42	59.53	40.20	41.42	36.12	63.46
D.I.	27.8	40.0	14.7	31.3	26.0	36.9	4.9

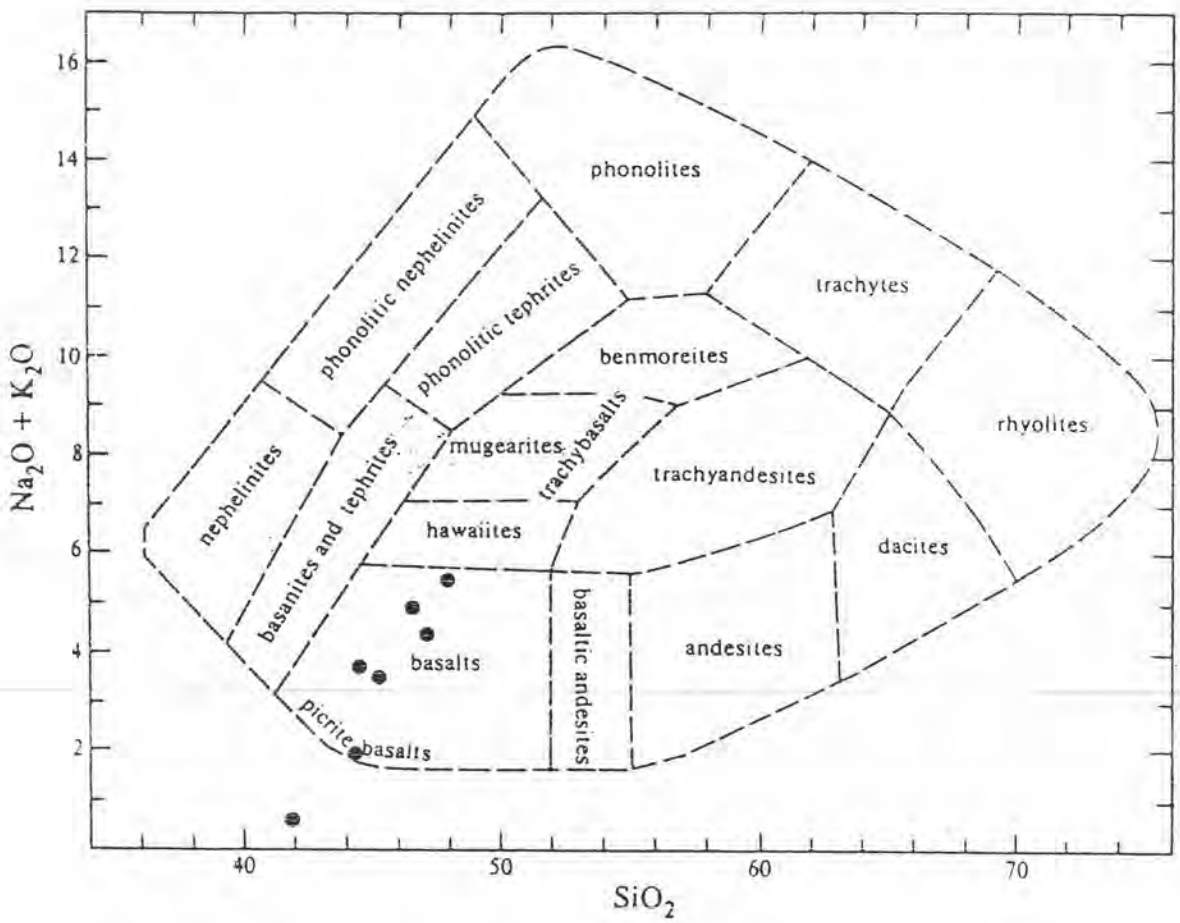


Figure 4.8 Plots of $Na_2O + K_2O$ against SiO_2 for metabasites of the Mae Chedi. Nomenclature and boundaries of volcanic rocks are from Cox et al. (1979).

SiO_2 on the diagram for nomenclature and classification of volcanic rocks (after Cox et al., 1979) in Figure 4.8 reveal that all of the originally volcanic rocks which had been metamorphosed in the Mae Chedi fall in the basaltic field, except for sample B 7 which may possibly be an ultrabasic variety.

Based on the petrochemical data of the rocks, it is obvious that the rocks were originally basaltic in composition. Thus, the author favors to term these rocks as "metabasites".