Geol. Soc. Malaysia, Bulletin 9, Nov. 1977; pp. 175–186.

Some aspects of Tak Granites, northern Thailand

W. PONGSAPICH
Department of Geology, Chulalongkorn University, Bangkok.

C. MAHAWAT
Geological Survey Division, Department of Mineral Resources, Bangkok.

Abstract: The Tak Batholith is located in Tak province and nearby areas in northern Thailand. The pluton covers an area of more than 4,000 square kilometers, and is believed to be a composite intrusion. Minimum age of the emplacement is Triassic. The large pluton is elongated north-south with small stocks scattered around its southern tip.

Petrographical and geochemical investigations reveal that the rocks can be classified into four main types namely; quartz diorite, granodiorite, quartz monzonite, and granite. Quartz diorite is found predominantly in the central cores; coarse-grained granodiorite forms the northern and western margins of the batholith; whereas quartz monzonite occupies the central-north and northwestern rims; and granite is scattered as small stocks in and around the southern rim or the main pluton. Andesitic, rhyolitic, and lamprophyric dikes are common in the area studied.

The batholith shows strong enrichment of $Na_2O + K_2O$ in the A-F-M diagram.

INTRODUCTION

The study of Tak granitic rocks is part of the research project on granites in Thailand. Field work was carried out in 1972. More than 100 rock samples have been collected by blasting. All the rock samples have been studied by thin section and 23 samples have been chemically analysed.

The Tak Batholith is situated in the vicinities of Changwat Tak in northern Thailand. The exposures of granitic rocks cover an area of 4,000 sq. km. The distribution of granitic rocks is shown is Figure 1.

MINERALOGY

Granitic rocks at Tak can be classified into four main types (Fig. 2). The grain-size of these rocks, which are mostly medium-grained, tends to increase as the lithology changes from quartz diorite to granodiorite, and quartz monzonite to granite. In quartz monzonitic and granitic rocks, potash feldspar crystals are larger than other minerals and are in places red or pink.

Mineralogically the Tak Batholith is composed of five major minerals, i.e., quartz, plagioclase, potash feldspar, biotite, and hornblende. Minor minerals found are sphene, apatite, opaques, and zircon. Felsic minerals constitute approximately 80-90% of the quartz diorite and granodiorite, and 93-99% of the quartz monzonite and granite. The quartz in the Tak Batholith is generally higher than 10%, and in a few samples is as high as 50%. Potash feldspar is minor or absent in quartz diorite and increases as the rock composition changes toward granodiorite, quartz monzonite and granite. Potash feldspar in quartz diorite and granodiorite is normally interstitial and is othoclase in contrast to the larger subhedral crystals of orthoclase and micro-

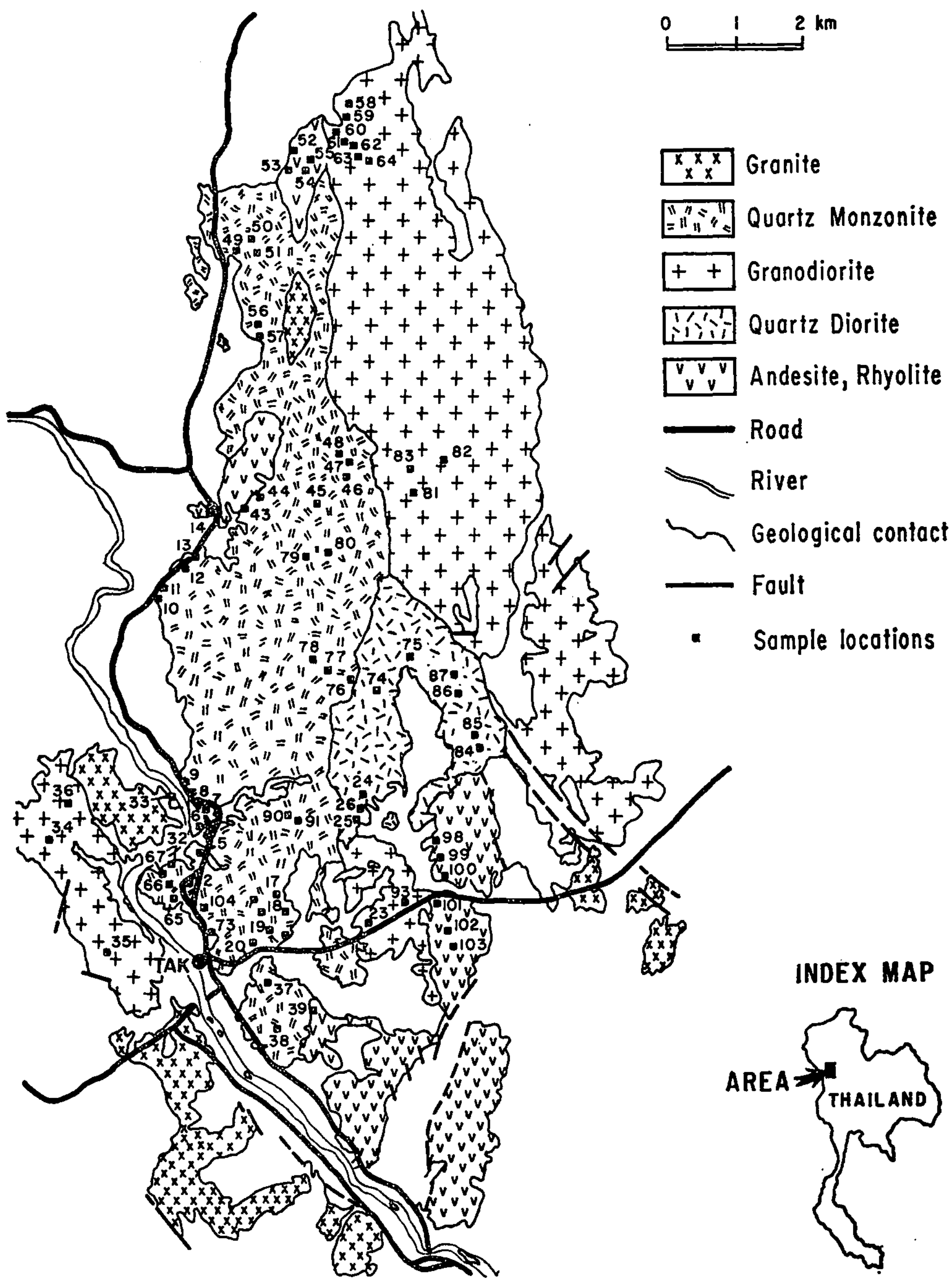

Fig. 1. Geological map showing the distribution of granitic rocks at Tak Batholith.

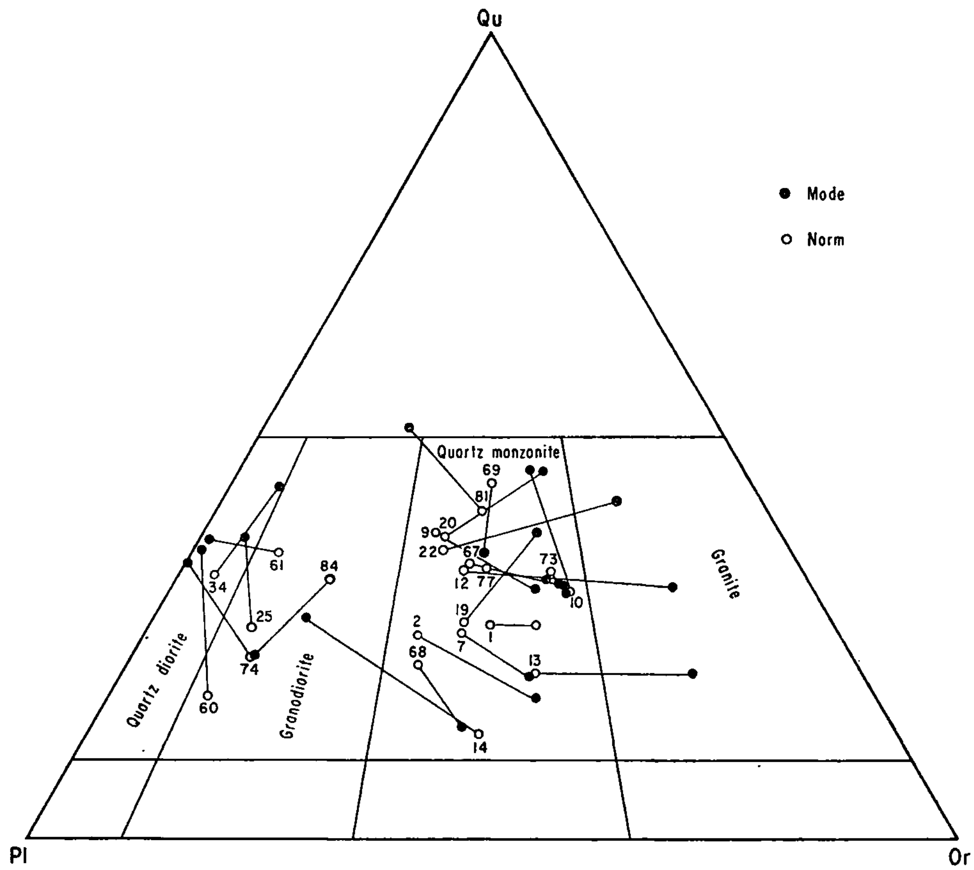

Fig. 2. Modal and normative distributions of rocks of the Tak Batholith.

cline in quartz monzonite and granite. Carlsbad twining is a very distinctive feature in these large crystals, and perthitic textures of various types are very common.

Plagioclase is the most abundant constituent in the quartz dioritic and granodioritic rocks. The amount of plagioclase decreases as the amount of potash feldspar increases in quartz monzonite and granite. The composition of plagioclase ranges from andesine (quartz diorite-granodiorite) to oligoclase and albite (quartz monzonite-granite). Normal zoning in plagioclase is rather common throughout the Tak Batholith. Oscillatory zoning and synneusis texture are uncommon. Myrmekitic texture formed along the contact between potash feldspar and plagioclase more calcic than albite. Most of the plagioclase of Tak Batholith has been subjected to post-magmatic alteration, which invariably produced sericite and epidote-clinozoisite.

Hornblende and biotite are the only major mafic minerals in Tak Batholith. Hornblende is absent or almost absent in the quartz monzonite and granite. The Hornblende and biotite are totally or partly altered to chlorite, sphene, and epidote.

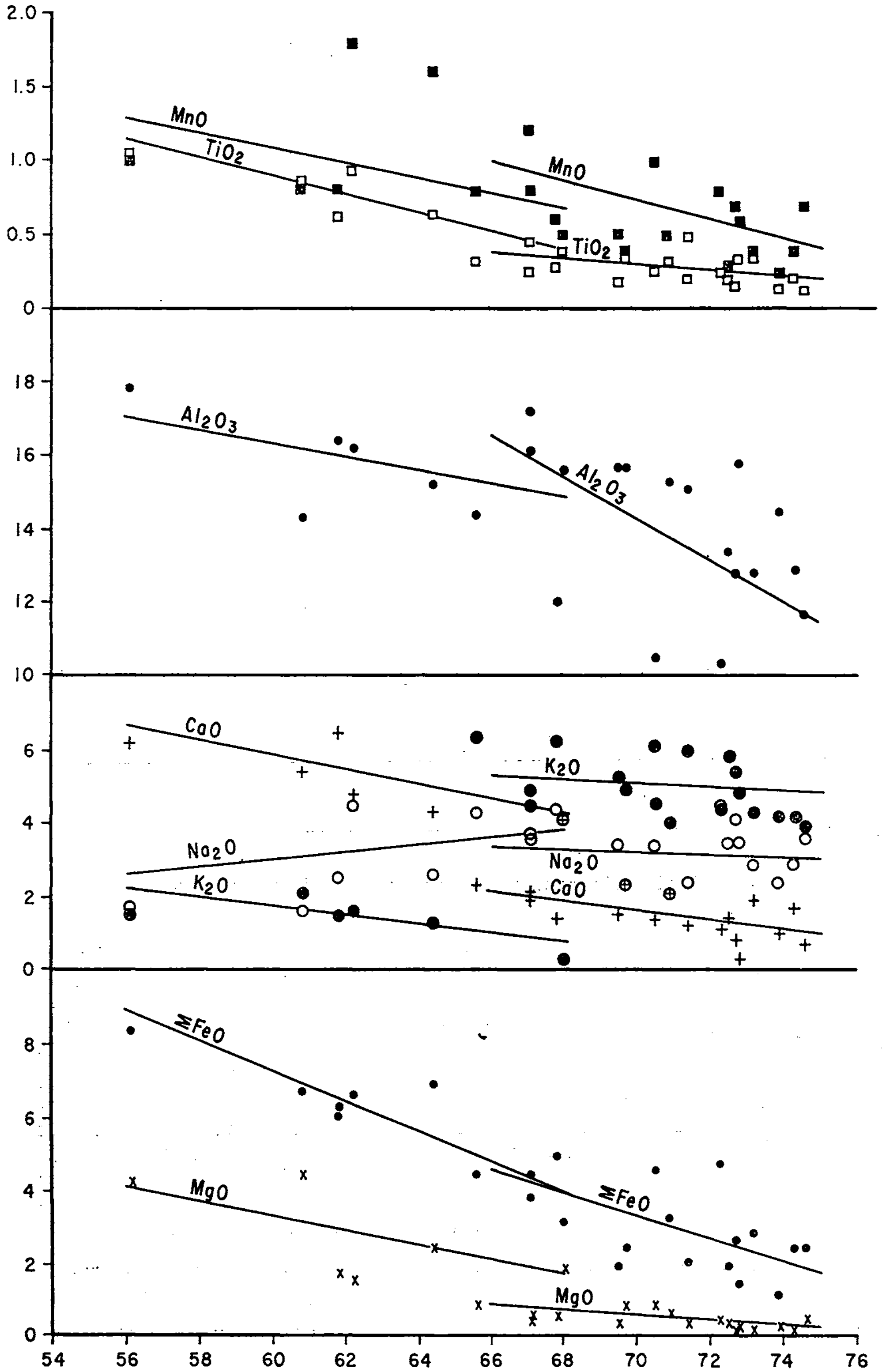

Fig. 3. Variation diagram of major oxides vs SiO_2 of the Tak Batholith.

CHEMISTRY

The variation diagrams of major oxides versus SiO_2 (Fig. 3), constructed from the bulk chemical analyses of 23 granite samples from the Tak Batholith (Table 1), obviously show two differentiation trends, one is quartz diorite-granodiorite trend and another is quartz monzonite-granite trend. In the quartz diorite-granodiorite trend, as the SiO_2 content increases, Al_2O_3, TiO_2, total FeO, MnO, MgO, CaO, and K_2O decrease but Na_2O increases. In the quartz monzonite-granite trend K_2O and Na_2O remain unchanged, whereas the other oxides decrease as SiO_2 increases.

TABLE 1(i)

	Tk_1	Tk_2	Tk_7	Tk_9	Tk_{10}	Tk_{12}	Tk_{13}	Tk_{14}
CHEMICAL ANALYSES								
SiO_2	72.51	67.05	69.45	74.56	70.52	72.29	67.83	65.59
Al_2O_3	13.37	17.15	15.68	11.63	10.51	10.27	12.03	14.36
TiO_2	0.19	0.25	0.18	0.13	0.26	0.15	0.29	0.32
Fe_2O_3	1.22	2.91	1.27	1.97	4.16	4.33	4.15	3.69
FeO	0.81	1.77	0.80	0.68	0.75	0.81	1.15	1.04
MnO	0.03	0.08	0.05	0.07	0.10	0.08	0.06	0.08
MgO	0.32	0.35	0.34	0.37	0.79	0.44	0.51	0.79
CaO	1.43	1.85	1.54	0.73	1.42	1.09	1.37	2.26
Na_2O	3.48	3.57	3.43	3.57	3.35	4.45	4.38	4.34
K_2O	5.82	4.50	5.34	3.94	6.05	4.36	6.23	6.34
H_2O+	0.48	0.41	0.68	0.80	0.74	0.54	0.34	0.57
H_2O-	0.02	0.01	–	0.04	0.13	0.12	0.11	0.10
P_2O_5	0.05	0.02	0.11	0.18	0.23	0.12	0.16	0.19
Total	99.73	99.92	98.87	98.67	99.01	99.05	98.61	99.67
CIPW Norm								
Q	27.20	24.35	25.48	38.18	27.32	30.17	20.07	12.55
Or	34.42	26.63	31.58	23.30	35.81	25.80	36.86	37.47
Ab	29.40	30.18	28.98	30.18	20.23	28.45	26.78	36.68
An	3.64	9.09	6.98	2.53	–	–	–	0.95
Ac	–	–	–	–	7.15	7.85	5.87	–
C	–	3.05	1.68	0.55	–	–	–	–
Il	0.36	0.47	0.35	0.24	0.50	0.29	0.55	0.61
Mt	1.76	4.22	1.83	2.04	1.97	2.44	3.06	2.67
He	–	–	–	0.56	0.34	–	–	1.86
Wo	1.30	–	–	–	2.39	2.17	2.46	3.84
Fs	0.22	0.58	0.21	–	–	–	–	–
En	0.80	0.88	0.85	0.93	1.98	1.10	1.28	1.98
Ap	0.13	0.03	0.27	0.44	0.54	0.27	0.37	0.44
Total	99.23	99.48	98.21	98.95	98.23	98.54	98.13	99.05
MODAL ANALYSES								
Quartz	25.4	16.6	19.3	30.3	44.2	30.6	20.0	24.8
Feldspar	39.6	43.8	42.6	38.4	30.2	52.8	59.8	14.8
Plagioclase	30.6	34.5	35.0	28.8	22.3	14.5	17.3	51.6
Biotite	3.9	3.3	1.8	1.4	2.7	1.4	1.8	6.3
Muscovite	–	1.5	–	–	–	–	–	–
Hornblende	–	–	–	–	–	–	–	0.5
Others	0.5	0.3	1.3	1.1	0.6	0.7	1.1	2.0

TABLE 1(ii)

	Tk_{19}	Tk_{20}	Tk_{22}	Tk_{67}	Tk_{68}	Tk_{69}	Tk_{73}	Tk_{77}
CHEMICAL ANALYSES								
SiO_2	72.70	74.25	73.17	72.76	67.10	73.88	71.39	69.74
Al_2O_3	12.75	12.92	12.79	15.83	16.07	14.49	15.05	15.70
TiO_2	0.16	0.22	0.35	0.34	0.45	0.14	0.21	0.35
Fe_2O_3	1.65	1.77	1.76	0.63	2.52	0.67	1.19	1.71
FeO	1.09	0.85	1.11	0.79	1.57	0.49	0.93	0.88
MnO	0.07	0.04	0.04	0.06	0.12	0.02	0.05	0.04
MgO	0.08	0.08	0.13	0.16	0.52	0.20	0.32	0.75
CaO	0.76	1.65	1.86	0.28	2.12	0.97	1.19	2.31
Na_2O	4.08	4.16	4.26	3.46	3.71	2.41	2.38	2.29
K_2O	5.40	2.89	2.88	4.76	4.86	4.20	5.96	4.93
H_2O+	0.62	0.40	0.41	0.05	0.39	0.20	0.29	0.09
H_2O-	0.04	0.12	0.13	–	0.06	0.03	0.05	0.09
P_2O_5	0.10	0.03	0.07	0.01	0.05	0.23	0.28	0.29
Total	99.50	99.38	98.96	99.13	99.54	97.93	99.20	99.17
CIPW Norm								
Q	27.10	37.94	36.08	33.40	21.65	41.92	32.21	32.23
Or	31.91	24.63	25.19	28.13	28.75	24.85	35.25	29.13
Ab	34.48	24.42	24.37	29.24	31.34	20.38	20.12	19.34
An	0.50	8.03	8.81	1.39	10.20	3.48	4.25	9.81
Ac	–	–	–	–	–	–	–	–
C	–	0.70	0.19	4.47	0.95	4.69	3.10	2.99
Il	0.30	0.43	0.67	0.65	0.85	0.27	0.40	0.67
Mt	2.39	2.23	2.55	0.90	3.67	0.97	1.72	1.95
He	–	0.24	–	–	–	–	–	0.37
Wo	1.33	–	–	–	–	–	–	–
Fs	0.50	–	0.08	0.48	0.28	0.15	0.48	–
En	0.20	0.20	0.33	0.40	1.30	0.50	0.80	1.88
Ap	0.24	0.07	0.17	–	0.13	0.54	0.67	0.67
Total	98.95	98.89	98.44	99.06	99.12	97.75	99.00	99.04
MODAL ANALYSES								
Quartz	37.4	44.4	40.1	30.2	13.2	35.1	30.5	29.7
Feldspar	35.3	31.8	40.7	42.6	37.5	31.5	40.5	36.7
Plagioclase	25.8	21.0	14.5	26.2	43.7	33.0	26.0	26.1
Biotite	1.3	2.0	4.6	0.6	4.0	0.3	2.7	5.4
Muscovite	–	–	–	–	0.7	–	–	–
Hornblende	–	–	–	–	–	–	–	–
Others	0.2	0.8	0.1	0.4	0.9	0.1	0.3	2.1

TABLE 1(iii)

	Tk_{81}	Tk_{25}	Tk_{34}	Tk_{60}	Tk_{61}	Tk_{74}	Tk_{84}
CHEMICAL ANALYSES							
SiO_2	70.85	61.80	67.98	62.19	64.38	56.14	60.75
Al_2O_3	15.29	16.40	15.63	16.19	15.15	17.80	14.25
TiO_2	0.33	0.62	0.39	0.93	0.64	1.04	0.87
Fe_2O_3	0.82	1.01	2.03	2.21	3.83	1.06	4.22
FeO	2.45	5.08	1.26	4.60	3.44	7.32	2.94
MnO	0.05	0.08	0.05	0.18	0.16	0.10	0.08
MgO	0.63	1.67	1.76	1.46	2.42	4.16	4.40
CaO	2.11	6.53	4.14	4.76	4.26	6.17	5.36
Na_2O	2.08	1.51	0.31	4.49	2.63	1.70	1.59
K_2O	3.99	2.50	4.05	1.60	1.27	1.49	2.10
H_2O+	0.57	0.83	1.39	1.18	0.87	1.30	1.13
H_2O-	0.09	0.19	0.02	–	0.01	0.07	0.09
P_2O_5	0.31	0.26	0.04	0.01	0.06	0.23	0.31
Total	99.57	98.48	99.05	99.80	99.12	98.58	98.09
CIPW Norm							
Q	37.31	22.60	31.85	16.10	30.55	16.66	25.94
Or	23.57	8.95	1.83	9.45	7.51	8.84	12.40
Ab	17.55	21.12	34.22	37.94	22.22	14.36	13.41
An	8.65	29.02	20.29	19.27	20.82	29.30	24.77
Ac	–	–	–	–	–	–	–
C	4.38	–	1.18	–	1.81	2.63	0.28
Il	0.62	1.19	0.74	1.76	1.22	1.98	1.66
Mt	1.18	1.46	2.95	3.20	5.54	1.53	6.12
He	–	–	–	–	–	–	–
Wo	–	0.79	–	1.82	–	–	–
Fs	3.37	7.60	0.08	5.41	2.40	11.02	0.61
En	1.57	4.18	4.40	3.65	6.05	10.40	11.00
Ap	0.74	0.60	0.10	–	0.13	0.54	0.74
Total	98.95	97.51	97.64	98.60	98.25	97.26	96.93
MODAL ANALYSES							
Quartz	49.1	31.7	38.1	28.2	32.7	27.8	18.3
Feldspar	14.7	3.9	4.3	0.2	0.5	–	10.6
Plagioclase	31.6	49.3	44.5	49.8	54.5	53.5	51.9
Biotite	5.1	10.8	4.3	6.3	4.5	11.9	8.9
Muscovite	–	–	–	–	–	–	–
Hornblende	–	4.2	7.0	13.4	7.6	6.2	10.2
Others	0.5	0.1	1.8	2.1	0.2	0.6	0.1

The quartz diorite-granodiorite series has a alkali-lime index that falls in the calcic igneous suite but rocks of quartz monzonite-granite do not show any distinctive alkali-lime index (Fig. 4). Plots of weight percent of cations against Nockolds differentiation index confirm these two trends (Fig. 5). However, these trends seem to form into one simple trend in the AFM diagram (Fig. 6), from the center towards the F-A side and plunges down to the A corner.

Normative percentages of the felsic minerals in the granites and quartz monzonites make up approximately 90% of the total. The plagioclase in these rocks is highly

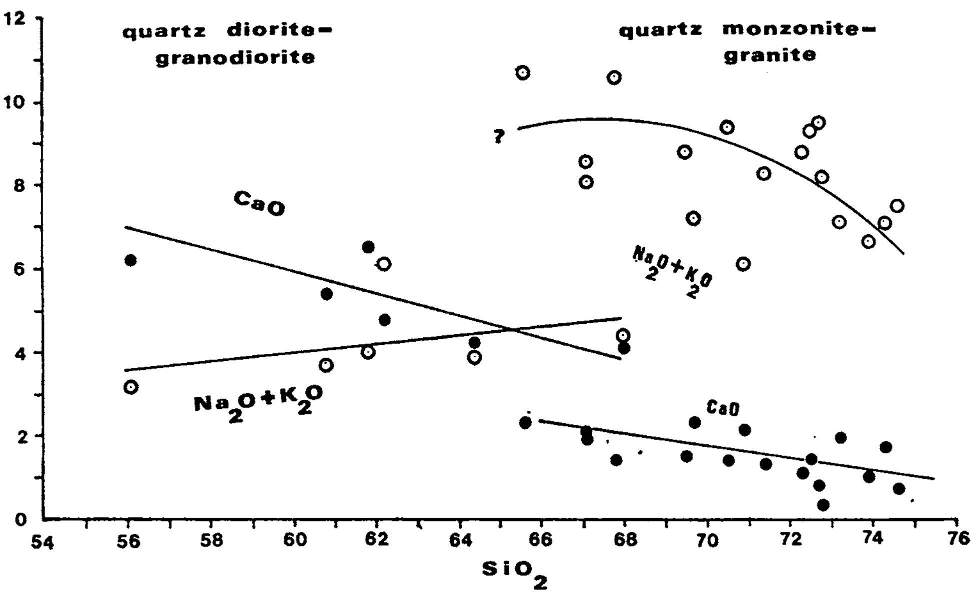

Fig. 4. Alkali—lime index of the Tak Batholith.

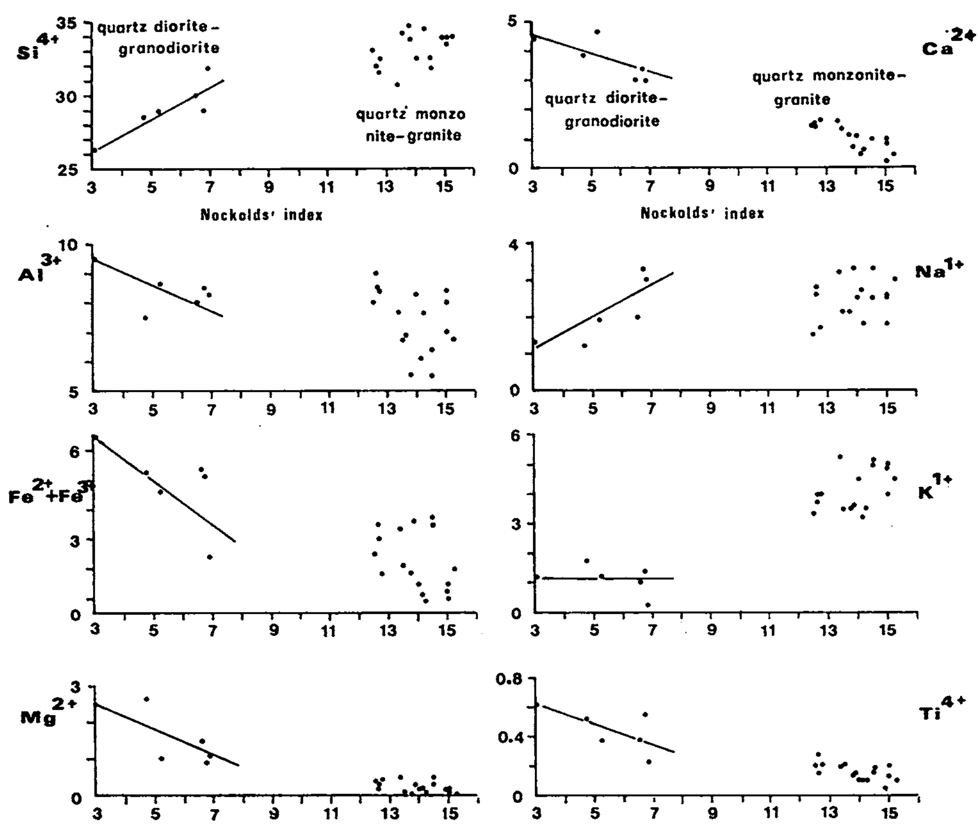

Fig. 5. Weight percent of major cations vs Nockold's index.

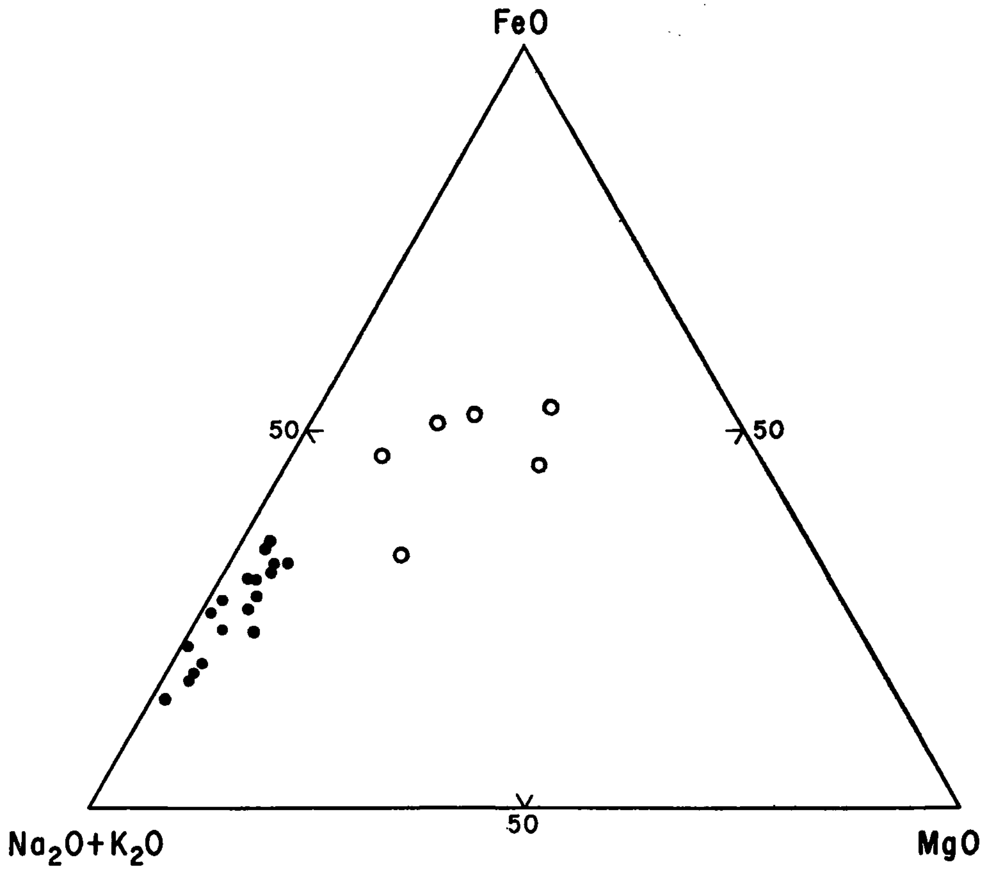

Fig. 6. Ternary plots of selected oxides (in mol. percent), Tak Granite
○ Samples from Quartz diorite—Granodiorite
● Samples from Quartz monzonite—Granite.

albitic. These granitic and quartz monzonitic rocks have only 3 major components; quartz, albite, and orthoclase (perthite), with a combined normative percentage of 78-93 %.

The quartz monzonitic rocks were dated as late Triassic by Teggin (1975) and Besang (1975), but this may be only the minimun age. The quartz diorite and granodiorite have not been dated. Field evidence indicates that the quartz diorite was intruded in the area earlier than the quartz monzonite. The normative Q-Ab-Or diagram compares with the experimental work done by Tuttle and Bowen (1958) suggests the quartz monzonitic rock was emplaced at P_{H_2O} not greater than 1Kb. (Fig. 7). If it is presumed that the quartz diorite was emplaced at the same depth and P_{H_2O} of 1 Kb. as the quartz monzonite was, the liquidus temperature of the quartz diorite is approximately 985°C when extrapolated from the experimental work by Piwinskii (1968) and Piwinskii and Wyllie (1968). Natural magmas emplaced at depth in a plutonic environment are unlikely to be saturated with H_2O. Decreasing water content at constant total pressure will raise both solidus and liquidus temperatures (Hill and Boettcher,

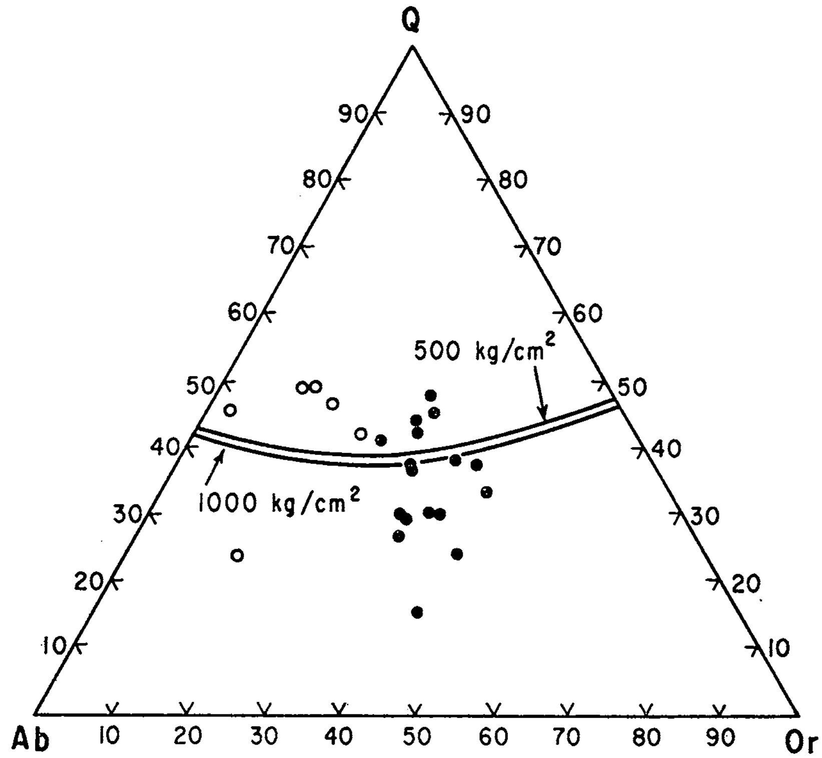

Fig. 7. Ternary plots of normative minerals: Tak Granite, compare with Liquidus Surfaces System at various water Pressures (after Tuttle and Bowen (1958)).
○ Quartz diorite—Granodiorite
● Quartz monzonite—Granite.

1970; Eggler, 1970). The temperature for a quartz diorite thus appears to be minimum. However, this liquids temperature is so high, even under the favorable conditions of high water pressure, that it is improbable that appreciable quartz diorite magma was generated by fusion in the crust (Lambert and Wyllie, 1970; Wyllie, 1971). Presumably, they were generated by partial melting of the upper mantle materials (Green and Ringwood, 1966, 1967, 1968; McBirney, 1969; Lambert and Wyllie, 1970; Kushiro, 1972; Kushiro et al, 1972; Kushiro and Yoder, 1972). The liquidus temperature of quartz monzonite at 1 kb. water pressure is estimated as 850 °C (Piwinskii and Wyllie, 1970). It is unlikely that quartz monzonitic magma was differentiated quartz dioritic magma as pointed out by their different variation trends. Quartz monzonitic magma may have been generated by crustal anatexis (Tuttle and Bowen, 1958). The volume of the exposed quartz diorite in the area is so small that large volumes of the quartz dioritic magma may have been trapped at the great depth and might have provided sufficient heat for the partial melting of lower crustal material. One other possibility for the genesis of the quartz monzonitic magma is the contamination of the fractionated quartz dioritic magma by deep crustal material.

Presumption of magmatic origin of these granitic rocks is deduced from a few field evidences.

1. Contacts of individual plutons with one another are sharp.
2. Finer grained rock is present in the marginal parts of the quartz monzonite.
3. Mafic inclusions of different shapes and sizes are ubiquitous in the western part of the batholith.
4. Replacement of the quartz diorite by later quartz monzonite - granite is locally found.
5. The meatamorphic grade of the wallrocks is chiefly albite-epidote hornfels facies.

MINERALIZATION

Mineralization related or possibly related to the Tak Batholith comprises minerals containing Cu, Sb, Pb, Ba, F together with some gangue minerals—pyrite, arsenopyrite and quartz. Only Sb has considerable economic significance. The distribution can be summarized as follows:

Antimony ores	— lodes at Doi Phae Long, Ban Mae Sa Lab; Ban Pang Ah; along the crest of Doi Sum Pa Kha Loung.
Lead ores	— lodes at Ban Dain Mai Sung, Doi Ta Ji.
Copper ores	— dessiminated ores in andesitic rocks at Khao Kheow; Ban Wang Chao.
Barite	— deposits at Doi San Pa Kha.
Fluorite	— deposits at Ban Mae Chaing Rai Bon; Doi Ta Ji.

The distribution reveals that most of mineral deposits belong to the very late stage of mineralization. Cu, Sb, Pb are found as sulphide minerals and are generally concentrated in the sedimentary rocks at the contact zone. Obviously, mineralization occurred during a late stage of granite magmatism. Lodes generally cut through the granitic rocks. Only sulphide minerals are found as gangue in the granite of the latest phase. Pegmatites throughout the Tak Batholith are poor in ore minerals.

ACKNOWLEDGEMENT

The authors are very grateful to Dr. J.A. Roddick of the Geological Survey of Canada for a very thorough review and invaluable comments.

REFERENCES

BESANG, C. et al., 1975. Radiometric age determinations of granites in Northern Thailand. *Proc. of the seminar on isotopic dating UNDP*, Bangkok, 94–117.

EGGLER, D.H., 1970. Water saturated and understurated melting relations in two natural andesites. *Geol. Soc. America Abstracts with programs, 2*, 544.

GREEN, T.H., and RINGWOOD, A.E., 1966. Origin of the calc-alkaline igneous rock suite. *Earth Planet. Sci. Letters, 1*, 307–316.

GREEN, T.H. and RINGWOOD, A.E., 1967. Crystallization of basalt and andesite under high pressure hydrous conditions. *Earth Planet. Sci. Letters, 3*, 481–489.

GREEN, T.H. and RINGWOOD, A.E., 1968. Genesis of calc-alkaline igneous rock suite. *Contr. Mineral and Petrol., 18*, 105–162.

HILL, R.E.T. and BOETTCHER, A.L., 1970. Water in the earth's mantle : melting curves of basalt-water and basalt-water-carbon dioxide : *Science, 167*, 980–981.

KUSHIRO, I., 1972. Effect of water on the compositions of magma formed at high pressures *J. Petrology, 13*, 311–334.

KUSHIRO, I., SHIMIZU, N., NAKAMURA, Y. and AKIMOTO, S., 1972. Compositions of coexisting liquid and solid phases formed upon melting of natural garnet and spinel lherzolites of high pressures: a preliminary report. *Earth Planet. Sci. Letters, 14,* 19–25.

KUSHIRO, I. and YODER, H.S., 1972. Origin of calc-alkalie peraluminous andesites and dacites. *Carnegie Inst. Wash. Year Book 71,* 411–413.

LAMBERT, I.B. and WYLLIE, P.J., 1970. Melting in the deep crust and upper mantle and the nature of the low velocity layer. *Phys. Earth Planet. Interiors, 3,* 316–322.

MCBIRNEY, A.R., 1969. Compositional variations in Cenozoic calc-alkaline suites of Central America. *Oregon Dep. Geol. Mineral Ind. Bull., 65,* 185–189.

PIWINSKII, A.J., 1968. Experimental studies of igneous rock series, Central Sierra Nevada Batholith, California. *J. Geol., 76,* 548–570.

PIWINSKII, A.J. and WYLLIE, P.J., 1968. Experimental Studies of igneous rock series : a zoned pluton in the Wallowa Batholith, Oregon : *J. Geol., 76,* 205–234.

PIWINSKII, A.J. and WYLLIE, P.J., 1970. Experimental studies of igneous rock series : felsic body suite from the Needle Point Pluton, Wollowa Batholith, Oregon. *J. Geol., 78,* 52–76.

TEGGIN, D.E., 1975, Rubidium-strontium whole rock ages of granite from Northern Thailand. *Proc. of the seminar on isotopic dating UNDP,* Bangkok, p 94.

TUTTLE, O.F., and BOWEN, N.L., 1958. Origin of granite in the light of experimental studies in the system $NaAlSi_3O_8 - KAlSi_3O_8 - SiO_2 - H_2O$. *Geol. Soc. America Mem. 74,* 153 p.

WYLLIE, P.J., 1971. *The dynamic earth.* John Wiley and Sons, Inc., New York, 416 p.