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The granitic rocks and mineralization at the Khuntan Batholith, Lampang*

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Abstract: The Khuntan batholith lies within the tin-rich granitic belt of S.E. Asia. Petrological investigations reveal that the igneous rocks at Khuntan consist predominantly of granite with subordinate amounts of quartz monzonite, biotite-muscovite granite and tourmaline granite. The manor phase is a coarse-grained porphyritic rock. Whole rock radiometric dating by Rb/Sr method suggests an age of 206 ± 4 m.y. (Upper Triassic—Lower Jurassic).

Known deposits of tin, antimony and manganese indicate a considerable mineral potential for the area. Geochemical data suggest high trace occurrences of Sn, Sb, Pb, Zn, Cu and Mn in the granitoids.

INTRODUCTION

The Khuntan batholith is one of the many granitic plutons in the tin-bearing granite range which extends from Thailand and Burma to the Malay peninsula and Indonesia. The pluton covers an area of approximately 275 square miles in northern Thailand, northwest of Lampang and southeast of Chiang Mai. It is elongated northeasterly following the regional structural trend of the area. Topographically this granitic pluton forms the core of Khuntan Range, separating two Tertiary-Quaternary basins, namely the Lampang Basin to the east and the Chiang Mai Basin to the west. The granitoid rocks at Khuntan were formerly classified as "tin-barren" granite.

The geology of Khuntan area was earlier mapped by Sanansiang (1966), and his data were compiled on the 1:250,000 geological map by Piyasin (1972). The Khuntan granite was studied by the authors at two different periods; in 1973 and 1975. Many mineral deposits in this area were also visited. The Khuntan granitoid rocks were dated by Teggin (1975) using Rb/Sr method on whole rock which yielded an age of 206 ± 4 m.y. This age is in good concordance with results obtained from analyses of single minerals by the K/Ar method. Besang et al. (1975) also suggested ages of 202 and 212 m.y. on analyses of biotite by K/Ar method.

GEOLOGICAL SETTING

The Khuntan area is underlain mostly by Paleozoic strata, Silurian-Devonian phyllite, schist, quartz schist and quartzo-feldspathic schist; Carboniferous quartz schist, slate, phyllite, tuffaceous sandstone, chert limestone, and Permian tuffaceous shale and sandstone with intercalated lenses of volcanic rocks. These country rocks, particularly the Silurian-Devonian strata which border the batholith, are very strongly folded and contorted, with major fold-axes striking northeasterly. The schistosity

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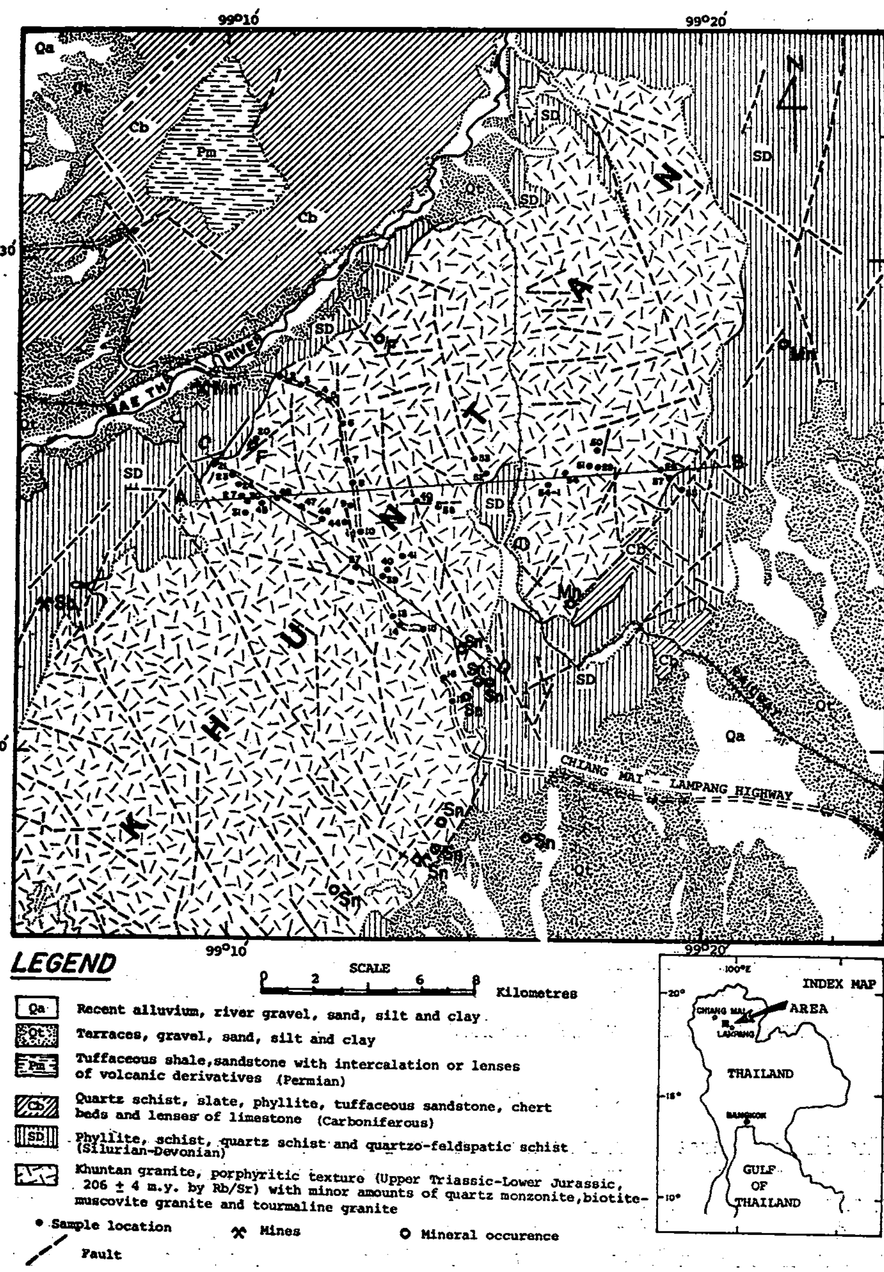


Fig. 1. Geological map of Khuntan area

of country rocks on the flanks of the batholith dips eastward. Small scale shear planes in the country rocks also dip eastward but at different degrees.

The emplacement of the Khuntan granite, as suggested by the radiometric age of 206±4 m.y. (Upper Triassic), probably corresponds to the Indosinian Orogeny (Workman, 1972). The discordant and partly concordant contacts with the country rocks, indicate that the igneous body was emplaced at a late tectonic stage of this Mesozoic orogeny.

Paleogeographically this area was part of the eugeosynclinal structure in the Permian, and became the western boundary of the eugeosyncline in the Triassic, prior to folding and uplift by the Indosinian Orogeny. The dominant feature was a northeast trending anticlinal structure with southeast dipping axial planes and cored by Silurian-Devonian metasediments, and flanked by younger Carboniferous and Permian strata. The batholith was subsequently emplaced into the core of this structure.

The contact of the Khuntan granite is commonly sharply discordant. At places relics of country rocks were detected. The lack of a large aureole of recrystallization and metasomatism suggests that the pluton is mesozonal (Buddington, 1959).

Structural features. The main structural features of the area are jointing and faulting. Jointing is well developed in both the country rocks and within the granitoid.

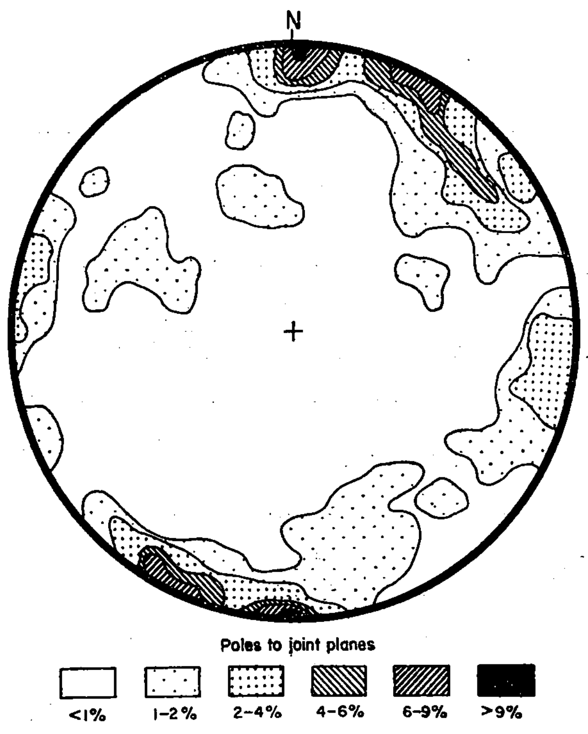


Fig. 2. Plot of joint planes, Khuntan granite

Several hundred joint planes were measured in the granitoid and their distribution in the granite is found to be concentrated in three maxima (Fig. 2), two of which lie at right angles to each other and correspond to the shear jointing system; whereas the other lies normal to the b-axis of the regional folding, thus corresponding to a tension-joint system. Presumably, during the emplacement of the igneous mass, the compressive stress was not yet completely released. The joint pattern afforded path ways for a younger phase of igneous rocks.

Faulting is extensive in this area and some of it cuts across both granite and country rocks. At least three major sets of faults can be distinguished northeasterly, northwesterly and more or less westerly. The most important fault system trends northeasterly, parallel to the Mae Tha River, which, according to Sanansiang (1966), may have been localized by the faulting. It is not yet clear whether the Mae Tha fault was developed before or after the emplacement of the granite. A thrust fault, more or less parallel to Mae Tha valley, on the western contact transects both the igneous and country rocks.

GRANITOID ROCKS

The granitoids at Khuntan consists predominantly of granite with minor amounts of quartz monzonite, biotite-muscovite granite and fine-grained tourmaline granite. Quartz and pegmatitic veins are also present, mostly following joints.

Granite. The major phase of the granitoids is a coarse-grained, porphyritic biotite granite with an abundance of phenocrysts. The size of the phenocrysts varies from 1-8 cm with the common size range of 4-6 cm. The rock includes at places some ovoid inclusions of a darker coloured igneous phase with a composition analogous to quartz monzonite.

This porphyritic granite and the two-mica granite are more or less the same phase of intrusion, although the latter is commonly equigranular and medium to coarse-grained. The from change porphyritic to equigranular texture along the Lampang-Chiang Mai highway is gradational.

Quartz monzonite on the other hand is found mainly as spots or large inclusions up to bouldery sizes in the granite. Apparently it represents a more basic phase which crystallized earlier and was enclosed in the major phase. Large quartz monzonite inclusions are found mainly on the western flank of the Khuntan batholith.

Tourmaline granite is a fine-grained rock, found in veins or dikes cutting through the major phase. This fine-grained granite may represent a younger phase of intrusion which was derived from the same magmatic source as a product of fractional crystallization.

PETROGRAPHIC INVESTIGATIONS

Stained slabs of about 40 samples of Khuntan granitoids were prepared and modal analyses were obtained from most of them.

The results obtained reveal that the *porphyritic biotite granite* shows a hypidiomorphic granular texture. The phenocrysts are mostly of potash feldspar, plagioclase and quartz. The potash feldspars are commonly orthoclase and microcline, which often show microperthitic intergrowth with sodic plagioclase. Alterations to clay minerals are not uncommon. Some potash feldspar phenocrysts contain small inclusions of quartz, biotite and plagioclase.

Plagioclase consists of subhedral-euhedral crystal grains. The compositions vary from An_{15} to An_{32} (oligoclase to andesine) and the average An content is 27%. Normal zoning is often found in large phenocrysts with more calcic cores (An_{35}) and sodic rims (An_{15-17}). Plagioclase is often sericitized.

Quartz usually forms subhedral to anhedral crystals. Undulatory extinction and graphic intergrowth with potash feldspar are common.

The groundmass is usually medium-to coarse-grained and the main mineral constituents are more or less similar to the phenocrysts except there are additional minerals, e.g., opaque minerals (magnetite) and accessory minerals.

Biotite in most sections is the most abundant mafic mineral. It is generally fresh with perfect cleavage. In shear zones most biotite grains are chloritized, e.g. at the quarry along the Lampang-Chiang Mai highway. In some sections biotite is replaced by muscovite. Pleochroic haloes surrounding inclusions of zircons are common. Muscovite is probably a secondary mineral, resulting from an alteration of biotite and plagioclase due to hydrothermal solution, but it is present in several parts of the batholith, and some of these crystals may be primary.

Accessory minerals including zircon, apatite and magnetite are found in most sections. Zircon is commonly included in biotite. Interstitial tourmaline is also found.

Biotite-muscovite granite. The mineral and chemical composition of the rock is similar to the porphyritic granite but the two-mica phase is more equigranular, and medium-to coarse-grained. The An content of plagioclases in both rocks is in the same range. Thus, the rock is not a distinctly separate phase of intrusion but a differentiated product. The muscovite grains are formed as an alteration product of the biotite.

Quartz monzonite. This is the only more basic phase, and petrographic investigation shows that it is similar to the dark inclusions found in the granite, i.e. equigranular texture, low quartz content and more mafic minerals. The inclusions may vary in composition to some extent due to size. This rock type consists of less than 10% quartz ,with a high content of mafic minerals (up to 30%); hornblende is present in most cases. Sphene is noted as an accessory mineral. The An content of the plagioclase varies from 32 to 38.

Tourmaline granite or tourmaline aplite. This is a fine to very fine-grained rock. The tourmaline content increases in the coarser variety. Tourmaline granite forms dikes in the eastern part of the batholith, where it presumably represents the youngest phase of intrusion of the area. Obviously, the dikes are much younger than the joint pattern of the major phase which control them. The rock is equigranular in texture and consists predominantly of tourmaline, muscovite and potash feldspar. Minor amounts of garnet have been found. The differential index is as high as 91.86.

CHEMICAL ANALYSES

The chemical analyses (Table 1) provide the CIPW normative minerals which after plotting gave a granite composition (Fig. 3.), except sample No. 23 which is quartz monzonite. Analyses of different samples were plotted and projected along the C-D line across the batholith, which is approximately normal to the fold axis, in order to investigate any compositional change across the batholith (Fig. 4). Apparently CaO,

TABLE 1

CHEMICAL COMPOSITIONS, CIPW NORMS AND MODAL ANALYSES OF KHUNTAN GRANITIC ROCKS

Chem. Comp.	1	2	3*	5	6	7	8	9*	10
SiO_2	65.94	67.62	71.77	71.99	69.91	72.80	73.90	71.64	71.77
Al_2O_3	15.04	14.24	16.37	13.43	15.11	13.93	13.98	14.37	13.99
Fe_2O_3	0.22	0.46	0.82	0.28	0.42	0.45	0.64	0.58	0.39
FeO	3.18	3.11	0.59	1.99	2.00	1.66	2.06	1.12	2.44
MgO	1.28	1.36	0.07	0.45	0.49	0.38	0.56	0.14	0.81
CaO	1.94	2.61	0.66	1.24	1.22	0.97	1.04	0.54	1.03
Na_2O	2.36	2.20	4.33	2.85	2.97	2.76	2.85	3.21	2.76
K_2O	5.97	4.61	5.14	5.37	5.53	5.26	4.60	4.97	5.11
H_2O^+	1.12	1.08	0.15	0.76	0.32	0.43	0.57	0.09	0.63
H_2O^-	0.15	0.15	0.07	0.17	0.15	0.17	0.17	0.15	0.19
TiO_2	0.48	0.51	0.05	0.28	0.29	0.17	0.27	0.06	0.33
P_2O_5	0.37	0.44	0.09	0.40	0.33	0.42	0.30	0.37	0.38
MnO	0.05	0.05	0.10	0.02	0.04	0.03	0.003	0.01	0.03
Total	97.95	98.29	100.42	99.06	98.63	99.26	99.67	99.96	99.54
CIPW Norm									
q	21.60	28.74	30.48	31.26	27.48	33.84	34.86	34.38	32.40
or	35.58	27.24	30.58	31.69	32.80	31.14	27.24	29.47	30.02
ab	19.91	18.34	26.72	24.10	25.15	23.58	24.10	27.25	23.06
an	8.06	10.56	–	3.61	4.45	2.24	3.61	1.95	2.50
co	1.63	1.73	–	1.63	2.55	2.86	2.96	2.96	3.06
hy (en)	8.08	7.89	0.10	4.14	3.97	3.64	4.30	1.85	5.70
mt	0.23	0.70	1.16	0.43	0.70	0.70	0.93	0.93	0.46
il	0.91	0.91	–	0.46	0.60	0.30	0.46	–	0.61
ap	0.62	1.01	–	1.01	0.67	1.01	0.67	0.34	1.01
di	–	–	4.74	–	–	–	–	–	–
Total	96.62	97.12	97.78	98.33	98.37	98.61	99.13	99.13	98.82
Mode.									
q	19.40	nd	40.80	31.30	26.87	29.36	36.50	30.18	30.72
k-fsp.	35.90	nd	17.80	39.30	33.60	37.00	38.90	38.66	30.52
plag.	34.40	nd	30.60	26.00	30.80	26.16	21.35	28.34	26.68
mafic min.	10.70	nd	11.20	2.70	8.73	9.88	3.25	4.32	12.58

Note:-*Tourmaline granite
nd—not detected

TABLE 1 Continued.

Chem. Comp.	11	12	13	14	15	16*	17	21	22**
SiO_2	69.91	72.21	72.21	73.48	72.66	71.14	71.71	67.06	67.78
Al_2O_3	14.04	14.47	14.32	14.01	13.29	13.80	13.82	12.51	17.99
Fe_2O_3	0.29	0.26	0.01	0.01	0	0.02	0.30	1.96	0.86
FeO	1.86	2.57	1.83	1.28	1.88	1.82	2.11	3.05	0.83
MgO	0.56	0.86	0.25	0.14	0.33	0.29	0.60	1.86	0.14
CaO	1.39	1.59	0.68	0.68	1.03	1.56	1.69	2.91	0.09
Na_2O	2.54	2.54	4.18	3.36	3.30	5.19	3.07	2.05	5.04
K_2O	5.84	5.54	5.08	4.86	4.75	2.66	4.92	3.79	4.36
H_2O^+	0.04	0.19	0.14	0.09	0.19	0.29	0.43	0.00	0.00
H_2O^-	0.11	0.19	0.19	0.17	0.11	0.15	0.15	1.38	0.17
TiO_2	0.24	0.15	0.12	0.08	0.19	0.18	0.19	0.62	0.15
P_2O_5	0.42	0.48	0.36	0.59	0.41	0.41	0.46	0.13	0.16
MnO	0.03	0.03	0.04	0.03	0.04	0.04	0.04	0.12	0.08
Total	98.42	98.59	99.22	98.61	98.07	97.40	99.34	97.44	97.65
CIPW Norm									
q	29.34	26.77	26.04	33.66	32.58	27.06	32.58	30.42	21.30
or	34.47	32.80	30.02	28.92	27.80	15.57	28.91	22.24	25.58
ab	21.48	21.48	35.13	28.30	27.77	43.50	21.48	17.29	42.44
an	6.12	6.95	1.67	0.84	2.50	5.28	5.84	13.90	0.56
co	1.33	1.73	1.33	2.86	1.84	0.51	2.14	–	4.79
hy (en)	4.17	6.40	3.90	2.78	3.97	3.74	5.06	7.54	1.06
mt	0.46	0.46	–	–	–	–	0.46	2.78	1.16
il	0.46	0.30	–	–	0.30	0.03	–	4.42	0.30
ap	1.01	1.01	0.67	1.01	1.01	1.01	1.01	–	–
di	–	–	–	–	–	–	–	0.46	–
Total	98.84	97.90	98.76	98.37	97.77	96.97	97.48	99.05	97.19
Mode.									
q	31.04	28.84	33.44	25.18	35.60	26.45	31.00	31.47	19.80
k-fsp	25.66	29.31	27.63	39.63	29.10	35.65	33.95	35.96	33.00
plag.	31.56	28.92	31.10	31.99	29.60	29.10	29.30	26.72	38.35
mafic min.	11.95	13.79	10.11	4.20	4.80	8.85	10.60	5.82	7.65

Note :- *Biotite-muscovite granite
**Tourmaline granite

TABLE 1 Continued.

Chem. Comp.	23*	24	27	31	37	39	40	41	44
SiO_2	54.21	68.10	66.05	68.09	66.51	65.92	65.26	66.91	71.90
Al_2O_3	15.70	16.12	15.00	18.24	18.03	15.72	14.91	14.49	14.26
Fe_2O_3	2.11	1.44	0.99	0.11	0.73	1.82	1.85	1.51	0.43
FeO	4.79	1.83	2.42	1.70	1.87	2.10	2.10	1.89	1.40
MgO	4.61	0.40	2.45	0.70	0.46	0.89	1.36	1.08	1.85
CaO	6.96	2.44	2.29	2.33	1.67	2.08	2.36	2.59	1.72
Na_2O	2.02	2.96	2.67	2.45	3.08	2.77	3.40	2.89	2.59
K_2O	4.76	4.55	5.54	4.14	4.68	4.96	4.72	5.29	4.34
H_2O^+	1.28	0.00	0.00	0.00	0.10	0.04	0.03	0.33	0.33
H_2O^-	0.09	0.54	0.72	0.21	0.43	0.55	0.54	0.14	0.14
TiO_2	1.41	0.30	0.49	0.39	0.35	0.42	0.45	0.35	0.29
P_2O_5	0.16	0.10	0.12	0.09	0.07	0.07	0.10	0.08	0.23
MnO	0.11	0.07	0.10	0.07	0.09	0.12	0.08	0.10	0.07
Total	98.21	98.85	98.84	98.52	98.07	97.46	97.19	97.69	99.55
CIPW Norm.									
q	6.18	26.94	19.44	30.72	25.14	24.00	19.74	22.62	33.30
or	28.36	26.69	32.80	24.46	27.80	29.47	27.80	31.14	25.02
ab	17.29	25.15	22.53	20.96	26.20	23.58	28.82	24.10	22.00
an	5.56	12.23	11.40	11.68	8.34	10.29	11.40	11.12	8.62
co	–	1.84	0.41	5.41	4.79	1.94	–	–	2.24
hy (en)	5.28	2.58	9.00	4.31	3.44	4.18	4.62	3.75	6.32
mt	3.02	2.09	1.39	–	1.16	–	2.78	2.09	0.70
il	2.74	0.61	0.91	0.76	0.61	0.76	0.91	0.61	0.47
ap	–	–	–	–	–	–	–	–	–
di	23.29	–	–	–	–	–	–	–	–
Total	91.72	98.12	97.88	98.30	97.48	94.22	96.07	96.79	98.68
Mode.									
q	nd	31.17	37.00	26.40	31.30	25.58	31.35	33.19	32.50
k-fsp	nd	29.97	26.70	37.40	37.35	40.52	37.58	30.30	29.80
plag.	nd	25.62	25.70	24.80	22.05	25.22	23.30	23.23	27.30
mafic min.	nd	8.92	10.70	11.10	7.55	8.41	7.55	13.06	9.80

Note :- *Quartz monzonite
nd—not detected

TABLE 1 Continued.

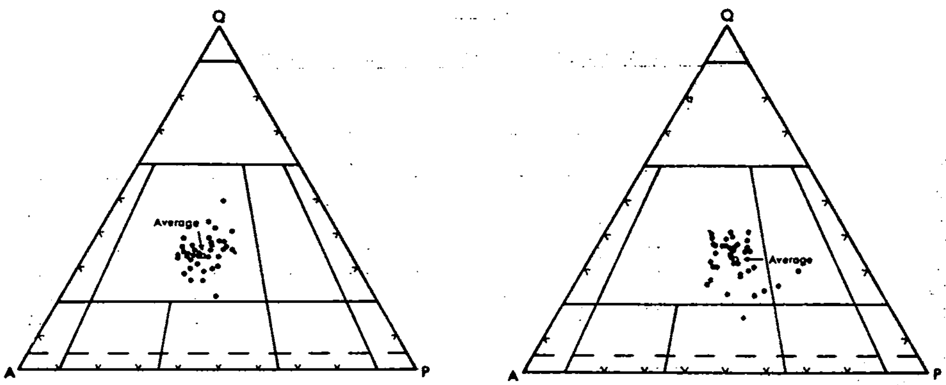
Chem. Comp.	45*	46	47	48*	49	50*	51*	52	53
SiO_2	70.86	71.18	72.02	72.27	70.91	72.04	71.37	70.06	70.71
Al_2O_3	15.42	14.08	14.17	15.07	15.15	14.71	15.74	16.04	15.86
Fe_2O_3	0.43	0.64	0.50	0.35	0.16	0.39	0.36	0.56	0.20
FeO	0.71	2.00	1.71	1.13	1.66	1.45	1.21	1.50	1.66
MgO	2.06	1.63	1.45	0.82	1.76	1.34	1.29	1.64	1.60
CaO	1.33	1.98	1.29	1.12	1.82	2.12	1.57	1.90	2.55
Na_2O	3.45	2.92	2.60	3.14	2.73	2.62	2.71	2.64	2.40
K_2O	4.45	3.95	4.36	4.88	4.40	3.90	4.33	4.52	4.88
H_2O^+	0.78	0.70	0.74	0.34	0.49	0.55	0.44	0.58	0.34
H_2O^-	0.27	0.13	0.23	0.23	0.20	0.13	0.23	0.26	0.25
TiO_2	0.09	0.40	0.34	0.10	0.33	0.20	0.21	0.27	0.25
P_2O_5	0.36	0.27	0.24	0.31	0.21	0.33	0.36	0.23	0.28
MnO	0.04	0.06	0.05	0.04	0.05	0.03	0.04	0.04	0.05
Total	99.95	99.94	99.70	99.90	99.87	99.81	99.86	100.24	101.03
CIPW Norm.									
q	27.36	31.26	36.54	30.78	30.48	34.20	26.22	29.88	28.92
or	26.13	23.35	25.58	28.91	26.13	22.80	25.58	26.69	28.91
ab	29.34	24.63	22.01	26.72	23.06	22.01	23.06	22.53	20.44
an	6.67	9.73	6.39	5.56	9.17	10.56	7.78	9.45	12.79
co	2.45	1.43	2.86	2.55	2.45	2.35	3.67	3.26	1.84
hy (en)	6.12	6.74	5.84	3.82	6.78	5.38	4.78	5.08	6.51
mt	0.23	0.93	0.70	0.32	0.23	0.46	0.46	0.93	0.23
il	0.32	0.76	0.61	0.15	0.61	0.46	0.46	0.30	0.46
ap	–	–	–	–	–	–	–	–	–
di	–	–	–	–	–	–	–	–	–
Total	98.62	98.83	100.53	98.81	98.91	98.22	92.01	98.12	100.10
Mode.									
q	33.20	37.50	33.32	28.20	30.38	31.60	33.30	22.00	29.70
k-fsp	28.60	23.50	38.68	32.60	35.06	40.50	29.75	36.70	26.30
plag.	27.10	28.90	22.16	32.40	24.28	21.60	26.30	25.40	22.50
mafic min.	10.50	9.90	5.84	5.80	10.65	15.40	11.50	12.80	7.20

Note :- *Biotite-muscovite granite

TABLE 1 Continued.

Chem. Comp.	54	55	56	57	58	59*	60	61
SiO_2	70.37	72.60	70.77	69.80	69.94	70.64	68.76	67.63
Al_2O_3	16.05	15.23	16.08	17.08	17.33	17.88	16.03	16.26
Fe_2O_3	0.59	0.31	0.17	0.37	0.52	0.23	0.08	0.56
FeO	1.30	1.16	1.62	1.87	2.12	1.64	2.45	2.40
MgO	1.02	1.26	1.21	1.02	1.56	1.03	1.98	2.36
CaO	1.60	2.16	1.84	1.53	1.87	0.94	1.90	1.22
Na_2O	2.66	2.47	2.59	2.66	2.28	2.69	2.61	2.63
K_2O	4.46	3.67	4.82	4.47	4.00	4.01	4.38	4.90
H_2O^+	0.19	0.38	0.24	0.24	0.70	0.32	0.54	0.81
H_2O^-	0.26	0.27	0.11	0.08	0.14	0.12	0.10	0.08
TiO_2	0.21	0.19	0.23	0.30	0.39	0.17	0.63	0.46
P_2O_5	0.25	0.22	0.14	0.19	0.26	0.19	0.26	0.27
MnO	0.05	0.03	0.04	0.05	0.05	0.02	0.06	0.07
Total	99.01	99.95	99.86	99.66	101.16	99.96	99.75	99.69
CIPW Norm								
q	32.28	35.84	30.42	31.02	33.90	34.86	28.14	22.98
or	26.13	21.68	28.36	26.69	23.35	23.91	26.13	33.92
ab	22.53	20.96	22.01	22.53	19.39	22.53	22.01	22.01
an	8.06	10.84	9.17	7.51	9.17	4.73	9.45	6.12
co	3.88	3.16	3.26	5.00	5.92	7.34	3.47	3.57
hy (en)	4.05	4.78	5.51	5.24	6.80	5.24	8.30	8.94
mt	0.93	0.46	0.46	0.46	0.70	0.23	0.23	0.93
il	0.46	0.30	0.30	0.61	0.61	0.30	1.22	0.91
ap	–	–	–	–	–	–	–	–
di	–	–	–	–	–	–	–	–
Total	98.32	99.02	99.49	99.06	99.84	99.14	98.95	99.38
Mode.								
q	28.50	33.60	32.70	40.48	32.40	32.00	nd	nd
k-fsp.	38.20	35.43	29.60	28.60	35.60	35.50	nd	nd
plag.	20.30	23.53	27.10	24.38	24.40	26.26	nd	nd
mafic min.	10.30	7.88	10.30	7.08	7.40	6.83	nd	nd

Note :- *Biotite-muscovite granite
nd—not detected.



Distribution of modal quartz, alkali feldspars and plagioclase. Khuntan granite

(a)

Distribution of normative quartz, alkali feldspars and plagioclase. Khuntan granite

(b)

Fig. 3. Ternary diagrams of Khuntan granite (a) Mode (b) CIPW Norm

MgO and TiO_2 increase slightly towards the northwest, while K_2O increases slightly to the southeast. Other oxides, for instance, FeO and Na_2O, do not show any significant changes. SiO_2, on the other hand, shows a slight increase towards the central part of the batholith, suggesting the existence of a differentiation trend in a vertical direction.

The plots of CaO, femic oxides, K_2O and Na_2O against SiO_2 (Fig. 5) reveal that CaO and femic oxides increase as the SiO_2 decreases or that the changes of the CaO and femic oxide are directly related to the differentiation of the rock. Na_2O and K_2O show no discernible patterns and are possibly independent of the differentiation of the magma. Presumably the slight increase of K_2O towards southeast is the effect of hydrothermal solutions acting on the eastern flank of the batholith.

Table 2 shows that the content of most of the trace elements is higher than average, particularly Sn, Cu, Pb, Zn, Sb and Mn. A few other elements, not included in the table, are also reported to be significantly high, e.g., F. Manganese, included in major oxides, is also higher than average. Another interesting element is W which was analysed in most samples. The result was nil, except for one sample in which the W content is as high as 317 ppm. Judging from these elements it is possible to conclude that the granitoids at Khuntan are mineralized.

MINERAL DEPOSITS

As indicated in the geological map, there are a few operating mines and mineral occurrences in the Khuntan area. The mines are mostly in the contact zone of the igneous and the country rocks, and include tin-stibnite mines and a manganese mine. Most of the tin mines and tin occurrences are situated on the eastern flank of the batholith, corresponding to the presence of the youngest phase of the igneous rocks. There are at least twelve known tin occurrences, and some of them are under exploration.

Tin deposits are found in lodes, in pegmatitic veins or disseminated in the granitoids, and as secondary deposits in the alluvial plains. The average tin concentration in the alluvial plain of the high potential area, e.g. the Huai Mae Kiang deposit, is 0.4 catty/cu. yard.

TABLE 2

TRACE ELEMENTS OF KHUNTAN GRANITOIDS

	21	22	24	27	29	31	37	39	40
Cu	0.09	0.06	0.16	0.10	0.10	0.06	0.13	0.13	0.09
Zn	0.02	0.03	0.08	0.04	0.03	0.03	0.03	0.05	0.04
Ba	0.03	nil	nil	0.03	0.07	0.03	0.02	0.03	0.07
Ni	0.01	0.01	0.00	0.00	0.01	0.01	0.02	0.01	0.01
Co	0.09	0.07	0.09	0.12	0.07	0.05	0.10	0.06	0.13
Mo	0.02	0.20	0.08	nil	nil	nil	nil	0.12	nil
Sb	0.27	0.13	0.08	0.11	0.07	0.06	0.08	0.07	0.16
Sr									
Sn	0.10	0.03	0.08	0.05	0.20	0.08	0.13	0.15	0.08
Pb (ppm.)	200	100	100	100	100	200	300	100	100
B (ppm.)	85	128	133	15	21	116	54	84	22
Be (ppm.)	37	8	15	37	37	37	75	15	8
W (ppm.)	nil	nil	nil	nil	nil	nil	nil	nil	nil
Ce (ppm.)	51	37	nil	30	30	30	nil	51	nil
$(R.E.)_2O_3$ (total)	1.31	1.25	0.55	0.57	1.11	0.28	0.76	1.50	0.99

	41	44	45	46	47	48	49	50	51
Cu	0.08	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02
Zn	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01
Ba	0.03	0.01	0.04	0.06	0.01	0.03	0.04	0.05	0.09
Ni	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.01
Co	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
Mo	0.02								
Sb	0.16	0.03	0.01	0.04	0.01	0.01	0.02	0.01	0.05
Sr		0.02	0.01	0.03	0.02	0.02	0.02	0.03	0.03
Sn	0.08	0.01	0.10	0.01	0.04	0.02	0.01	0.01	0.09
Pb (ppm.)	400	125	375	625	125	250	375	500	875
B (ppm.)	nil	105	10	44	5	66	61	77	69
Be (ppm.)	37	48	123	123	72	49	122	121	72
W (ppm.)	nil	317	nil	nil	nil	nil	nil	nil	nil
Ce (ppm.)	44	nil	nil	nil	nil	nil	nil	nil	nil
$(R.E.)_2O_3$ (total)	1.40	0.40	0.08	0.20	1.76	0.28	nil	0.24	0.02

	52	53	54	55	56	57	58	59	60	61
Cu	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.02	0.02
Zn	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02
Ba	0.13	0.09	0.09	0.13	0.08	0.09	0.09	0.09	0.09	0.08
Ni	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Co	0.02	0.02	0.01	0.01	0.02	0.03	0.03	0.03	0.02	0.02
Mo										
Sb	0.03	0.06	0.07	0.03	0.03	0.03	0.04	0.04	0.05	0.03
Sr	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.05	0.03
Sn	0.01	0.05	0.01	0.06	0.02	0.01	0.03	0.03	0.08	0.004
Pb (ppm.)	1345	875	875	1345	750	875	875	875	875	750
B (ppm.)	43	92	97	18	144	56	17	66	75	63
Be (ppm.)	123	124	49	121	120	49	50	50	48	49
W (ppm.)	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
Ce (ppm.)	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
$(R.E.)_2O_3$ (total)	0.08	0.52	0.02	0.91	0.07	1.11	0.13	0.79	0.83	0.43

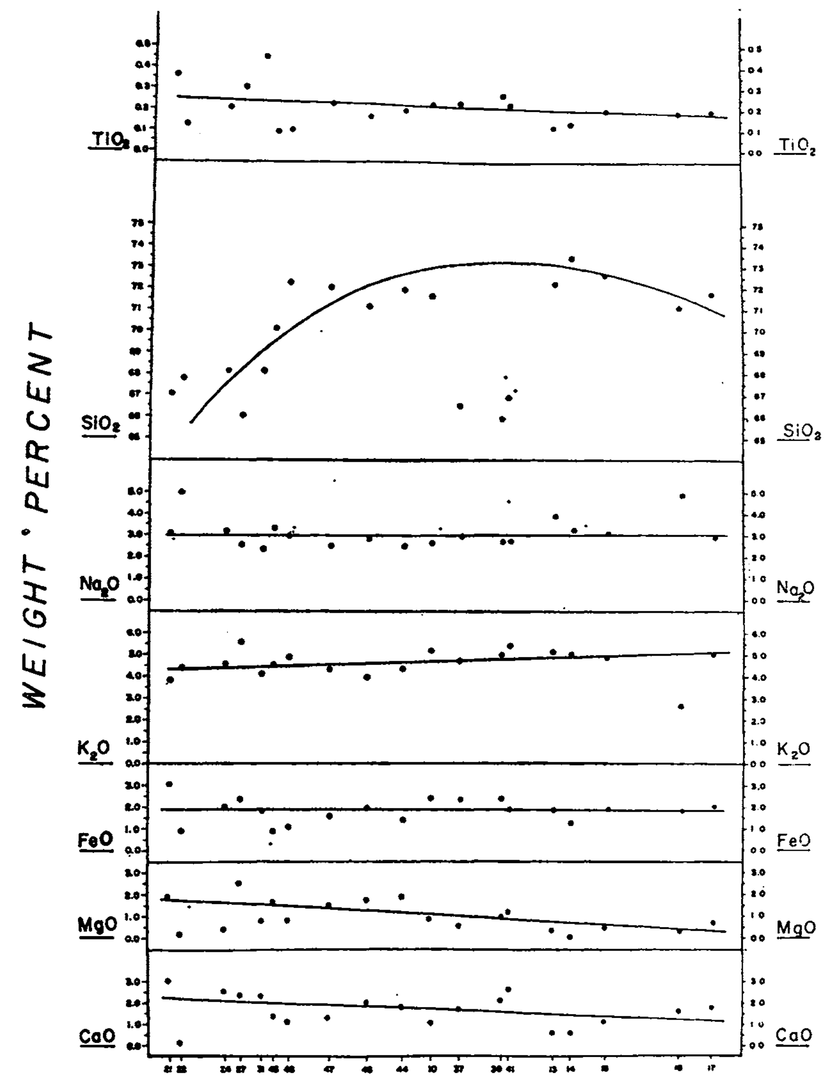


Fig. 4. Plots of some major oxides (weight %) of Khuntan granites across the batholith in NW-SE direction.

The most important stibnite deposits are found in the western part of the batholith at Mae Wa Mines. They are in the vicinity of the Silurian-Devonian rocks. The ore veins follow northerly trending faults, and their mineralogy can be divided into upper and lower zones. The upper zone is oxidized and consists mainly of stibiconite and other oxide minerals, while the lower zone consists mainly of stibnite and quartz; mi-

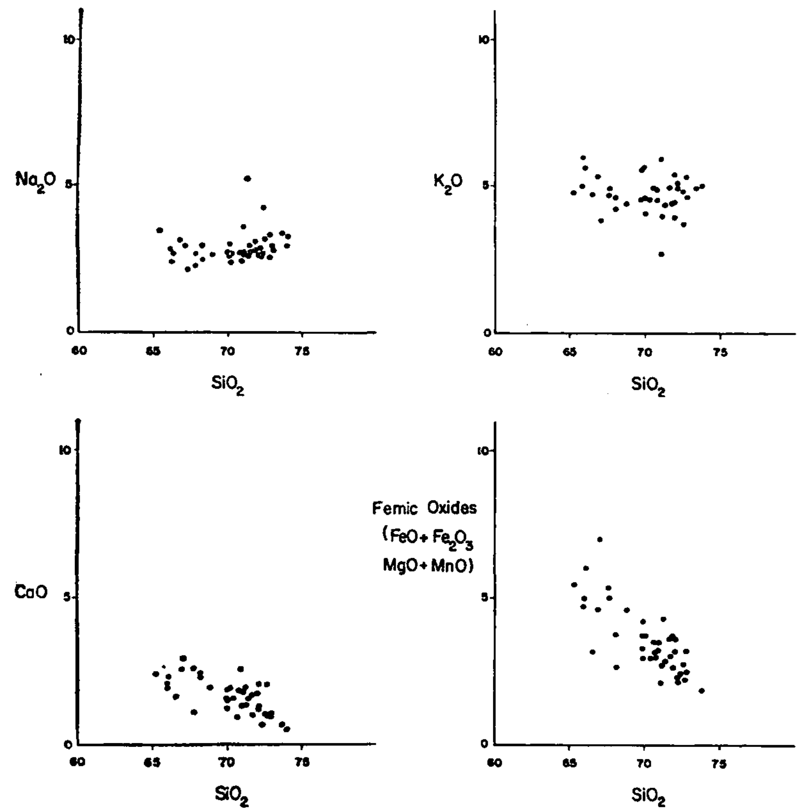


Fig. 5. Plots of selected oxides (weight %) against SiO_2 (weight %) of Khuntan granite

nor amounts of pyrite and other sulphide minerals are also found. The width of the ore veins varies from 10–20 cm to 2 m. These veins can be traced discontinously up to a few hundred metres in length. This area is under development at present.

Three magnanese deposits have found in this area, the largest deposit being the one situated in the western part of the batholith, the ore consisting mostly of pyrolusite. This deposit has now been abandoned owing to the low content of the ore. The other two deposits are on the eastern contact and they have not been developed.

CONCLUSION

The main events which took place at the Khuntan area are summarized as follows:

1. In the Triassic, the Khuntan area was the boundary of the eugeosyncline which extended to the east. During the Indosinian Orogeny (Triassic-Jurassic) strong folding and uplifting formed major structural features striking northeasterly.

2. Emplacement of Khuntan granites probably took place at a late tectonic stage (206 ± 4 m.y. ago) of the Indosinian Orogeny after widespread strong folding. Fractio-

nal differentiation produced phases of granitic rocks, first with a basic composition chiefly of quartz monzonite, then porphyritic biotite granite, biotite-muscovite granite and tourmaline granite. Quartz and pegmatitic veins are also present as the final products. The differentiation trend seems more obvious in a vertical direction.

3. Mineralization of tin, antimony, magnanese, etc., subsequently occurred, associated with quartz and pegmatitic veins, presumably at the same period or later than the latest igneous phase (tourmaline granite).

4. Erosion took place at Khuntan and ore minerals particularly tin, were accumulated in the valleys or plains.

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