CHAPTER VI

PETROGRAPHY

หอสมุดกลาง สถาบันวิทยบริการ จุฬาลงกรณ์มหาวิทยาลัย

6.1 Coarse-grained Porphyritic Biotite Granites (G-1)

The rock is, in general, pale gray in colour with an average total mafic mineral content (colour index, C.I.) of 13.6 %. This figure is rather high comparing to the other types. The most common mafic mineral is biotite. The rock is coarse-to medium-grained with porphyritic texture very well develop, the K-feldspar phenocrysts of various sizes showing preferred orientation (Photograph 2).

6.1.1 Textures

The rock is of a rather uniform granitic texture which is typically coarse-grained hypidiomorphic inequigranular locally grading into a medium-grained allotriomorphic variety. Foliated texture is quite common. Poikilitic textures are generally present in all specimens as characterized by small grains of zircon, apatite, biotite, and plagioclase in microcline and microcline perthite phenocrysts. Intergrowth textures including perthite-antiperthite, myrmekite, and graphic are strongly developed in most specimens. The myrmekitic texture is not developed in all of the specimens, where present appears to form by the reaction along the boundaries between plagioclase and potash feldspar. In some specimens, such as from Khao Nakha and many parts of Khao Khek

Nei, the rocks are highly fractured and they develop the motar or cataclastic texture. Alteration is not common, however, it can occur particularly in cores of plagioclase, slightly in potash feldspar and in some grains of biotite.

6.1.2 Mineralogy

Quartz. This mineral is present as anhedral, interstitial grains, and crystal aggregates of various sizes. Their average grain size is approximately 5 mm. Modal analysis reveals that its volume percent (21.3-35.2 %, or average 26.8 %) is normally less than those of the feldspar minerals. It always shows normal to slightly wavy extinction, but some grains are characterized by strongly undulatory extinction, suggestive of developed stress. At Khao Nakha, quartz is so sheared, crushed and fractured that its grain size was brought down to less than 0.1 mm. Suture lines of boundary are generally uncommon. Most of the quartz is free of inclusion but it may include other minerals such as apatite and zircon. Small anhedral myrmekitic quartz and quartz droplets are common, but quartz inclusions in other minerals are generally rare. In the sequence of crystallization, quartz appears in the latest stage.

Feldspar. The alkali feldspar includes microcline and microcline perthite. Modal analysis indicates that the volume percent of potash feldspar ranges variably from 24.42 to 36.12 % and the average is about 27.5 %, which is higher than the quartz, but lower than the plagioclase.

Microcline is present dominantly as phenocrysts but it occurs as well in the groundmass. In the groundmass, the microcline forms small individual unaltered grains varying in sizes from 1-4 mm . It commonly shows grid twin, but the perthitic texture is not common. However, the microcline in groundmass constitutes only a small amount. The microcline phenocrysts are frequently found as subhedral and tabular shape (2V 80^{o}-85^{o}). In handspecimen, it is mostly white cream to pale pink in colour sometimes broken. The phenocrysts range in length from 1 cm up to the maximum size 8 cm and its width from 0.5 cm . In thin section, it always shows poikilitic texture containing biotite and plagioclase as common inclusions. Most of the phenocrysts are microcline perthite which commonly form faint albite twins. Plagioclase in perthitic microcline occurs as very fine to fine 'en echelon' lamellae. This fine grained plagioclase may be the result of exsolution (Smith,1974).

Plagioclase. Plagioclase is the most abundant constituent of the rocks, making up from 24.86 to 38.8 modal percent of its volume, averaging 31.1 %. It mostly occurs as subhedral laths whose average sizes vary in length from 2 mm of groundmass to 5 mm of phenocryst. Besides, it may occurs as inclusions in microcline, myrmekitized and antiperthitizsed grains, many of which show strain effects as characterized by the bent and sheared grains. In some specimens (as at Kathu Fall), plagioclase occurs as euhedral crystals. Normally, the plagioclase rims are uneven and show signs of reaction with microcline and biotite. The great majority of plagioclase grains are characterized by twinning and zoning. The albite twin is of the most common twin.

Pericline-albite and Carlsbad-albite twinning is rather common in most of the specimens. In addition to complex twinning, much of the plagioclase displays either normal or oscillatory zoning, the former is rather common. The composition of the inner core of plagioclase is andesine (An_{31} to An_{37}) and the rim is oligoclase (An_{15} to An_{23}). The plagioclase composition, as determined from the homogeneous grains, is probably fall within the range of An_{26} - An_{36}.

The plagioclase has been altered into a certain degree, including alteration along the fractures or along the cleavages. The alteration products of plagioclase include kaolin, sericite, and sometimes muscovite. It is apparent that the degree of alteration in plagioclase is stronger than in alkali feldspars and particularly highly sericitized core in many sections.

Biotite. Biotite is the essential mafic mineral and forms the major part of the total mafic minerals which range from 8.2 to 20.3 volume percent. Megascopically, it forms small flake abundantly distributed throughout all specimens. Its colour ranges from brown to greenish brown. Microscopically crystal aggregates frequently occur. Irregular anhedral shape is also present but in lesser amount. The largest size observed is about 3 mm . The biotite always exhibits strong pleochroism ($\beta = \gamma$ = dark brown to deep greenish and reddish brown, and α = light brown to pale straw yellow with greenish tint). Many of the subhedral grains show ragged ends. In many specimens, flakes of biotite are distinctly bent, however this feature can probably be attributed to pressure,

caused by the crystallographic growth of the adjacent mineral grains. The important inclusions in biotite are sphene, apatite, and zircon. Biotite appears to have been one of the earlier essential minerals to crystallize. In some parts though not common, it is altered into chlorite and sometimes muscovite. Many of the chloritized biotite grains are characterized by the presence of thin strings of minute secondary sphene granules occurring in or near the chloritized biotite grains. The muscovite is not common, occurring as an alteration product from biotite.

Accessories

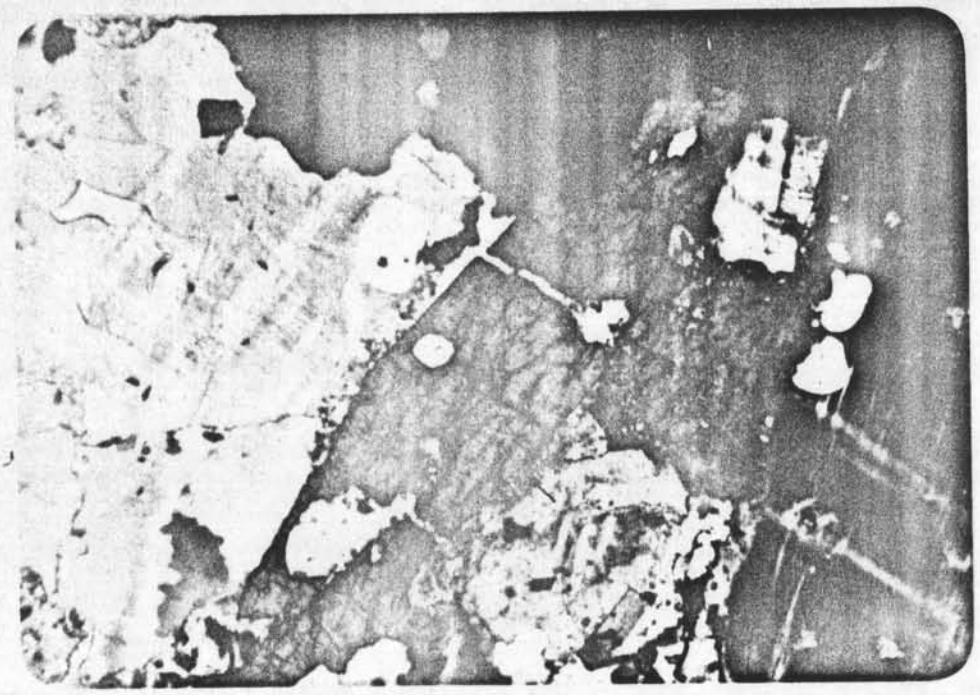
Sphene. This mineral is the most important accessorial mineral of the rock, present in all the samples studied. It ranges in size from 0.1 mm up to grains over 4.5 mm in length. It occurs typically in close association with biotite and apatite. It is frequently found as inclusion in biotite and also occurs as discrete crystals in quartz and feldspars. Usually it forms acute rhombic, wedge-shaped crystal with prominent partings (Photomicrograph 1). Most of the sphene present in the rock is primary. Secondary sphene is also found as minute granules formed by the alteration of biotite to chlorite. The primary sphene is usually common only in this G-2 granite. In most cases it crystallizes before biotite and plagioclase, therefore, it is the earliest mineral formed. It is, therefore, worthnoting that it has a long period of crystallization. Quite important, sphene is a major accessory used to distinguishing the coarser-grained granite of this type from the other coarse-grained variety.

Allanite. Although not abundant, allanite (orthite) is present in most of the samples, occurring as euhedral to corroded subhedral elongate crystal. It varies in length from 0.5 mm to 15 mm . It has brown pleochroism ($\gamma = \beta$ = brown to dark brown, α = light brown to greenish brown). In general, it is associated with biotite and sphene, sometimes it is surrounded by quartz. Allanite is found only in this type of rock.

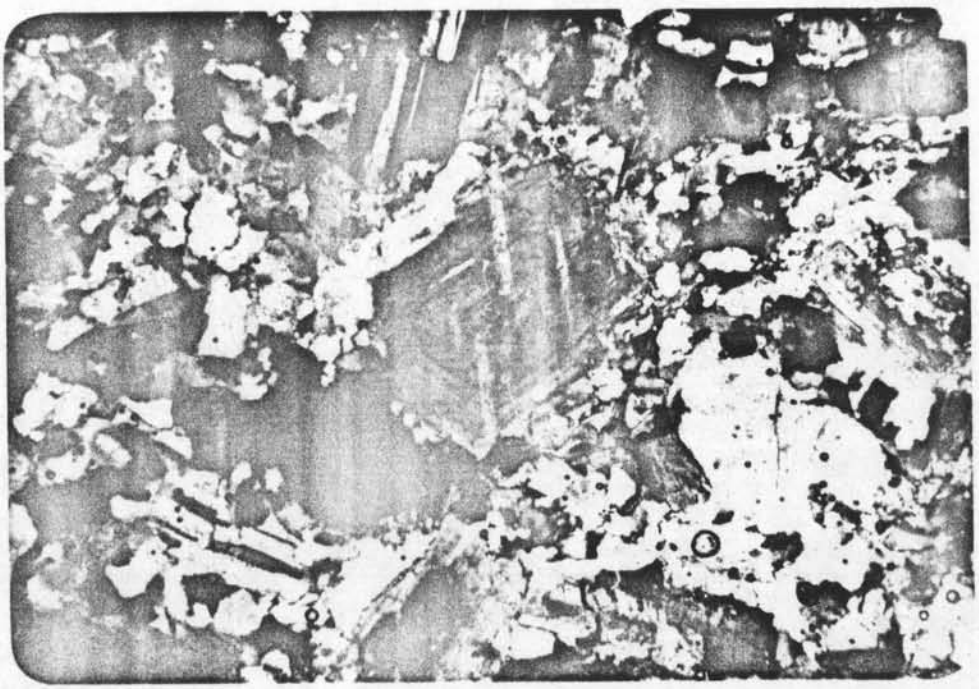
Apatite. All of the samples of this granite contain apatite varying from minute grains to stubby prisms of 0.5 mm in length. Many of them are present as acicular needles, some are euhedral six-sided forms. Apatite commonly occurs in close association with biotite, and sometimes acts as inclusion in sphene and biotite. It is also found as discrete grains in plagioclase crystals, but rarely occurs as inclusion in orthoclase and quartz. From this point of view, it commences the early period of crystallization.

Zircon. This mineral is present in nearly all specimens studied as small euhedral grains varying in sizes from tiny crystals up to 0.2 mm length. It frequently occurs as small inclusions in biotite. Quite commonly, its grains form faint pleochroitic haloes in biotite. Discrete crystals are scarcely present, very few can be found in quartz.

Iron-oxide and opaques minerals. Magnetite and ilmenite are present in a small amount in all the specimens. It occurs both primary and secondary as anhedral to euhedral grains. These minerals are commonly associated with or enclosed in larger grains of biotite, sphene and allanite.



Photomicrograph 1. Primary wedged-shape sphene fractured and filled by quartz. Microcline in contact with sphene shows reaction rim. (G-1 at Kathu Fall) (x-nicol, 25x).



Photomicrograph 2. Typical oscillatory zoned and fractured plagioclase in G-2. The core is altered into sericite and shwos inclusions of opaque minerals (at Khao Pan Thu Rat) (x-nicol, 25x).

Cassiterite. Cassiterite is not found in this rock type in the present study, however it was reported by Garson and others (1975) that cassiterite occurs as small euhedral pale brown crystals, occasionally zoned notably in the Kathu Valley of Khao Khek Nei.

6.2 Fine-to Medium-grained Biotite Granites (G-2).

In general, this group of rock is typically dark gray (Photograph 4). The colour index ranges from 13.6 to 17.5 and averages about 15.7. The granites are mostly medium-grained, although fine-grained varieties are also present. G-2 has even-grained texture, but sometimes grades into slightly porphyritic texture with the average length of K-feldspar phenocrysts about 3 cm and width of 1 cm.

6.2.1 Texture

This G-2 group is generally fine-to medium-grained hypidiomorphic granular, occasionally allotriomorphic inequigranular. Poikilitic textures also develop with apatite, biotite, and minor quartz inclusions in plagioclase and microcline. The phenocrysts where present sizing about 5 mm, are mostly potash feldspar and plagioclase. The groundmass (2-3 mm of average grain size) consists largely of quartz, alkali feldspar, plagioclase, and greenish brown biotite. Alterations tend to be more common than in G-1. They are kaolinization of alkali feldspar and sericitization of plagioclase. Minor amount of accessory minerals as fluorite and iron oxides suggests that the rock has undergone some greisenization (Sheraton & Labonne, 1978). The intergrowth textures

as perthite-antiperthite, graphic and myrmekite, are not common.

6.2.2 Mineralogy

Quartz Quartz occurs as anhedral to subhedral grains and aggregates of small crystals. The average grain size is about 1.5 mm. It always shows wavy extinction and serrated boundaries. Quartz inclusions in microcline and microcline perthite are also present. Quartz is present in smaller amount than plagioclase and alkali feldspar. Modal data show that the rock contains quartz ranging in volume from 22.1 to 28.75 percent (averaging 26.2) nearly as the same as that of G-1.

Alkali feldspar The alkali feldspar includes microcline and microcline perthite. The latter is more abundant. The modal analysis gives the volume percent of potash feldspar ranging from 23.1 to 32.3 percent or averaging 27.0 percent. These values lie in the same range as G-1. Alkali feldspar has the grain size ranging from 0.5 to 2.0 mm.

Microcline occurs as anhedral crystals in groundmass, as interstitial and sometimes as crystal aggregates. Microcline phenocrysts, though rarely present, usually contain poikilitic biotite and plagioclase. The average grain size of microcline is approximately 1 mm, commonly smaller than quartz. Mostly it forms clear grains, sometimes containing many inclusions of apatite, biotite and quartz. It can be intergrowth with quartz. Oftenly, microcline is perthitized and shows faint cross-hatched twinning. Microcline is suggested to be crystallized in the late stage.

Plagioclase Plagioclase is more abundant than those of the minerals described previously. Modal percent of plagioclase ranges from 30.1 to 38.9. Because of its abundance, it appears to dominate the major fabric of the rock with the remaining minerals form interstitially. It occurs as subhedral to euhedral with rectangular outline, and as inclusions in microcline, of which many have undergone sericitization especially in the inner core (Photomicrograph 2). Plagioclase grains are also sheared, along the fractures. Also the feature of plagioclase is characterized by many types of twins. The most important are Carlsbad-albite and pericline-albite twin. Of these two types, the former is more abandunt. However, simple albite twin also occurs but less commonly. Zoned plagioclase is by far the most common feature (Photomicrograph 2). Zoning may be obscure by alteration. Plagioclase ranges in composition from An_{53} to An_{40} in the core to An_{30} to An_{24} at the rim. Since plagioclase grains contain biotite inclusions, this suggests that they were formed after biotite.

Biotite One of the dominant mineral is the brown biotite which is the only ferromagnesian mineral scattered fairly evenly throughout this granite suite. It normally occurs as subhedral flakes and occasionally as inclusions in quartz and plagioclase. Biotite varies in length from less than 1 to 2 mm. Considerable amount of apatite and primary non-pleochroitic sphene are often seen enclosed in biotite. It is present in an appreciable amount, averagely 15.7 modal volume percentage as total mafic mineral content.

Muscovite Though present in many specimens, muscovite constitutes in a small amount (up to 1.3 modal volume). Most of the muscovite present is considered to be secondary sericitized mineral which is the alteration product from plagioclase. Generally, it is fine sericite flakes but some large grains up to 2 mm in length can also be found.

Accessories Allanite is a common minor accessory mineral found in most rocks. It is longitudinal subhedral to euhedral which a maximum size may exceed 3 mm. Typically it is pleochroitic brown to dark brown and often zoned. Quite commonly it occurs in adjacent to sphene and apatite and has a close association with biotite.

Apatite occurs abundantly and usually forms as minute euhedral prismatic crystals. It is commonly found in close association with biotite or occasionally present as tiny inclusion in biotite. Sphene is another common accessory mineral which may be present as either a primary or a secondary phase. It is observed that sphene associates with iron oxides (magnetite) and also can be enclosed by quartz. Well-formed oval tiny zircon is rather rare. If present, it is nonpleochroitic. Both sphene and zircon are usually accomodated in biotite but descrete crystals are rather uncommon. The opague minerals include an abundance of euhedral crystals of primary magnetite or irregular forms of secondary one as well as probably primary ilmenite. In rare cases, anhedral grains of fluorite tend to form close to secondary muscovite.

6.3 Medium-to Coarse-grained Biotite muscovite Granites Slightly Porphyritic (G-3)

Megasopically, the G-3 granites are more felsic than the G-1 granites by the fact that the G-1 varies from 8.9-17.5, and the average is about 12.0. In general, the most common rock type grades from the grayish white, medium to coarse-grained, and highly leucocratic rock to the gray, slightly mafic, and porphyritic rock that contains muscovite. The rock consits of quartz, K-feldspar, plagioclase, biotite, and muscovite. The phenocryst is always potassium-rich feldspar, which is white cream, subhedral to euhedral rectangular crystal, and as large as 2 x 3 cm. The less-silicic granite is found only along the contact zone with metasedimentary rock at the eastern part of Khao Mai Tao Sip Song. Likewise G-1, the granites contain only one ferro-magnesian mineral, i.e. biotite which occurs in lower amount which causes the average C.I. to be less than that of G-1. Biotite always forms small plates ranging from 0.05 to 3 mm in diameter. Muscovite forms a large flake averagely sizes about 2 mm, but up to 5 mm in the northern part of Khao Pak Bang. Quartz and feldspar crystals, usually over 2 mm , sometimes are broken. This type of granites is rather altered and highly kaolinized, particularly at Pinyok Mine and slightly altered in the eastern parts of Khao Mai Tao Sip Song. Field observations indicate that many of the G-3 granites are similar to the G-1, however the G-3 is, in many parts, a nonporphyritic rock mostly more felsic, and contains small amount of muscovite (Appendix 1). Moreover, a marked difference is the presence of accessory tourmaline.

6.3.1 Texture

Texture of the G-3, predominantly coarse-grained, hypidiomorphic and porphyritic, appears to be somewhat similar to that of the G-1. However, in some localities, particularly at Khao Mai Tao Sip Song, the rocks may grade into almost equigranular texture of the medium-to coarse-grained type. Some samples from Khao Pak Bang and Khao Mai Tao Sip Song show pronounced granophyric texture (Photomicrograph 3). Perthitic and myrmekitic textures are still rather common. Crushed and fractured grains of rock are not as common as in G-1. Quartz, microcline and biotite are the major constituents. The presence of many minor and accessory minerals, i.e. muscovite, tourmaline, and garnet, are also used to distinguish this type of granites from the first type of granite.

6.3.2 Mineralogy

Quartz. As in G-1, quartz still appears to be anhedral to subhedral in the groundmass, interstitial grains and crustal aggregates of various sizes. Its size ranges mostly from 1.5-2.5 mm whereas the maximum size may sometimes exceeds 5 mm. It also forms aggregates of mosaic texture, sometimes elongated grains occur but in less amount. In general, it is present as clear grains, but can contain minor inclusion of biotite and tourmaline. In rare cases, it occurs as inclusion in biotite, plagioclase, and potash feldspar. Myrmekitic quartz is also present in plagioclase, especially in the rock from the fall at the eastern slope of Khao Mai Tao Sip Song. Granophyric quartz is also present in microcline phenocryst (Photomicrograph 3). In some sections quartz grains

are crushed due to stress effects. Quite commonly, quartz grains show slightly undulatory extinction, and their sutured boundaries are not strongly developed. The modal composition of quartz is about 25.4 up to 28.75 percent in volume, averagely 27.5, which is higher than that of the G-1. Quartz crystallized late.

Alkali-feldspar. Alkali feldspars are mostly, microcline and microcline-perthite both of which occur in the same amount. The volume percent varies widely from 24.1 to 40.05 percent or averages about 31.5 percent which is higher than that of the G-1 granites.

Microcline occurs as unaltered anhedral grains in the groundmass with the average grain size of 2-3 mm and as phenocryst of more than 4 cm. length. The white cream microcline phenocryst is prominent even in hand specimens. The phenocryst is mainly subhedral tabular crystals (2V as large as 80°) and shows faint alteration. Microcline of G-3 is less perthitic than that of G-1 and G-2. Microcline perthite frequently occurs more abundant as the phenocryst component. It is normally twinned and cross-hatched, albite type is most common, uncross-twinned crystal are also present. Most of the microcline-perthite megacrysts are poikilitic and contain inclusions of small globular quartz, plagioclase, biotite and sometimes muscovite. Microcline usually post-dates plagioclase and biotite, but generally forms before quartz and muscovite. It began to crystallize in the late stage.

Plagioclase. Plagioclase occurs in smaller amount than quartz, its average volume percent is about 28.6. This modal percentage is

definitely lower than that of the G-1. Its grains are primarily small subhedral tabular in most sections, some show corroded rims. The average grain size of plagioclase in the groundmass varies from 2 to 5 mm in the coarser-grained variety and is 1.5 mm in medium-grained variety. Phenocrysts of plagioclase are quite rare. Most of the plagioclase are slightly altered by the process of sericitization and kaolinization. Simple albite twinning is rather common, pericline twin is relatively subordinate, Carlsbad-albite twin are rarely seen in most sections. Zoning in plagioclase is not common, but when occurs, it ranges from weak to moderate, normal zoning. Such zoning is observed by slight change (not more than 6°) in the miximum extinction position in twin lamella of oligoclase from core An_{27} to margin An_{21}. Moderate zoned crystals have An_{28} in the cores and An_{10} at the rim. However zoning may be obscured due to sericitization. Myrmekite is rather common between grains of plagioclase and microcline. In most cases, plagioclase seemed to be crystallized after biotite. It always contains biotite inclusions. Plagioclase in may specimens has been engulfed by quartz and sometimes tourmaline . Plagioclase formed in the intermediate stage of crystallization after biotite.

Biotite Biotite is the sole ferromagnesian mineral in the rocks. It ranges modally from 8.9 to 17.5 volume percent as the total mafic minerals in those specimens in which a mode has been determined. It occurs as scattered clusters and as individual grains distributed throughout the specimens. The biotite is usually subhedral in shape and ranging in sizes from 0.5 to 3 mm (average 1.5 mm). It is charac-

terized by light to dark brown pleochroitic (mostly $\alpha = \gamma$ = dark brown to brown, β = straw yellow), and the optical angle (2V) of approximately 15°. Bleached biotite is present in some sections (nearly colourless to light brown). Some are partly altered to chlorite, forming chloritized biotite with some secondary sphene and iron-oxide opaques. Several grains show slight bending, ragged ends, and corroded rims. Zircon and apatite are common inclusions in the biotite. Muscovite may, sometimes, replace biotite or perhaps interleaf with it. Biotite is considered to be the first mineral to have had crystallized from the melt and continued for a long duration of crystallization.

Muscovite. Though muscovite is present in small amount (averaging 1 volume percent of the rock), it can be found as primary as well as secondary in all rocks examined. It is one of the characteristic indicator which distinguishes this granitic type from the other coarse-grained varieties. Textural relationships are such that it is a possible primary mineral in only a few cases. In some specimens, however, it is very difficult to distinguish whether it is of primary or secondary origin. It always occurs as subhedral prismatic crystals both as discrete grains or as small patches. The grain size ranges variably from a tiny crystal less than 1 mm up to the maximum size about 7.5 mm (at Khao Pak Bang). Quite commonly, its size varies from 2 to 4 mm with corroded rims. The primary muscovite always occurs in association with biotite, either interlayering or penetrating. The secondary one is usually found as alteration product in the fracture zones in microcline. It may alter from biotite with some iron-oxide opaques left behind and from fractured.

Photomicrograph 3. Granophyric quartz in slightly sericitized microcline perthite phenocryst (G-3 at Khao Pak Bang) (x-nicol, 25x).

Photomicrograph 4. Crystal aggregates of biotite with inclusions of long slender-shaped apatite and zircon with pleochroitic haloes. Perthite indicated by albite lamella (G-3 at Khao Tritrang) (x-nicol, 25x).

It is generally close to chloritized biotite grains. Muscovite is suggested to form in late stage of crystallization by hydrothermal alteration. Otherwise, according to the fact that it is present as flakes that appear to recrystallize aggregates. These imply that the muscovite may be a subsolidus phase (Hine, et al., 1978; Kuntz & Brock, 1977; Whitney & Walker, 1976).

Accessories.

Tourmaline. Tourmaline (up to 4.95 %), though not found in all specimens, is a characteristic accessory mineral of this granite. It occurs as prismatic elongate subhedral to irregular grains particularly showing distinctive parting. Its pleochroitic colour is bluish green to light green (ω = bluish green to yellowish green, ε = light yellowish green to nearly colorless). The average size is about 0.5 mm. Generally, it is engulfed by quartz, and always cut across plagioclase. This mineral is frequently associated with muscovite, chlorite, and iron-oxide opaques. The development of iron-rich tourmaline is commonly accompanied by the bleaching and alteration of the biotite.

Garnet. Garnet occurs in very small amount, and is not generally found dissiminated throughout the rock. It is usually present near the contact zone between this type of granites and the G-1 type. Specimen from Khao Mai Tao Sip Song where garnet is rather abundant has an average grain size about 0.2 mm with irregular anhedral to subhedral shapes. It is intimately associated with biotite, however, discrete crystals are also common occurring in the alkali feldspar minerals.

Other accessories Oval zircon is commonly found in biotite, surrounded by well-developed pleochroitic haloes (Photomicrograph 4). Apatite occurs as a euhedral elongate shape included in a variety of minerals, particularly biotite. These two minerals occur quite abundant in G-3. Opaque minerals are rectangular to rounded magnetite and elongate ilmenite grains. Secondary sphene and chlorite are also found in small amount.

6.4 Fine-to Medium-grained Biotite-muscovite Granites, Locally Porphyritic (G-4)

Megascopically, this group of granites is leucocratic, light gray, equigranular to slightly porphyritic granite (Photograph 5). Some exhibit foliation direction as at Khao Nakhale where the rock is rather porphyritic with the potash feldspar phenocryst up to 3 cm length. But in general, it is non-porphyritic fine-to medium-grained (0.5-1.5 mm) and composed mainly of quartz, potash feldspar, plagioclase, muscovite, and biotite. The common accessory minerals are mainly tourmaline and fluorite, the less common are garnet, pyrite and arsenopyrite. The colour index varies considerably from 2.1 in leucocratic granite to 13.6 in biotite-rich granite. In many places (i.e. the eastern slope of Khao Sapam and along the vallies of Khao To Sae and Khao Rang), the granites grade from biotite-muscovite granite (C.I. = 9) to muscovite-bearing granite (C.I. = 2.1). Or ortherwise, they may grade from two mica granite with biotite predominate (C.I. maximum 13.6) to that of the muscovite-rich one, i.e. at Khao Kaw and Khao Nai Grang. The granites at Khao

Nakhale are medium-grained and have porphyritic textures. The granites exposed along the beach grade from Khao Nakha Lae to the NE into finer-grained, equigranular variety, and intrude the coarser-grained G-1 granites at Khao Khek Nei.

6.4.1 Texture

Rocks of the G-4 granite are prominantly fine-to medium-grained equigranular. Some of the rocks, however, may be slightly porphyritic. The major constituents are mainly quartz, alkali feldspar, plagioclase, biotite and muscovite. Modal data reveal that the alkali feldspar is present in larger amount than the plagioclase. Most phenocrysts, where present, are microcline-perthite. The texture of the G-4 can be distinguished from those of the G-1 and the G-2 by widespread deuteric alteration of the feldspar minerals and chloritization of biotite, lack of distinctive zoning and complex twinning in plagioclase; abundance of fluorite, low content of accessory minerals (0.6-4.9 %); and the common occurrence of greisen (Photomicroghaph 5). The G-4 granites are also generally of a more leucocratic character. Greisenized varieties of the G-4 are characterized by the development of muscovite at the expense of feldspar and by the presence of some particular accessories as fluorite, tourmaline, cassiterite, garnet, and arsenopyrite. The effect of post-crystallization deformation of the rocks includes crushed grains along boundaries of several minerals, strained quartz grains with undulose extinction and fracturing, bent feldspar and biotite, particularly at Khao Rang, Khao To Sae, and the Wang Chi Ouan Fall. Myrmekite is not

a common texture in these rocks. Graphic and granophyric quartz and quartz droplets, in K-feldspar, however, develop strongly in several sections. Perthitic texture is present moderately in microcline.

6.4.2 Mineralogy

Quartz. Modal percentage of quartz ranges from 25.4 up to 37.1 (averange 29.2). The grain size ranges from 0.5-1.5 mm. The maximum size is about 3 mm. Quartz is mostly present as anhedral grains and occasionally as subhedral grains of minute crystal aggregates. It may be formed as inclusion, particularly, in microcline perthite, or as veinlets and as myrmekite. Quartz phenocrysts are also present, but uncommon. Quartz exhibits more or less wavy, undulose extinction and suture boundaries in numerous sections, e.g., at Khao To Sae. This would be an evidence of some strain introducing to the rock during the deformation stage. Small polygonal quartz grains are present in subordiuate amount. They are easily seen from their differences in the extinction angles. Such feature is probably due to postcrystallization deformation of the granites as suggested by Kuntz and Brock (1977). Quartz quite commonly replaces microcline and plagioclase and is sometimes intergrowth with it. Quartz grains are most commonly clear, however, they can be found to contain variably inclusions of zircon, biotite, and feldspar minerals. Some are found to penetrate in fractures and cracks of the earlier crystallized minerals, e.g., in plagioclase. Quartz began to crystallize not until a very late stage of the crystallization history.

Alkali feldspar. Alkali feldspar occurs mostly as microcline and microcline-perthite of which the former is more common. It is present both as anhedral microcline in the groundmass and subhedral microcline-perthite phenocryst. Modal data reveal that alkali feldspar ranges in volume from 29.6 up to 43.26 percent.

The microcline in the groundmass is an anhedral forms, varying in size from 0.5 to 1.5 mm, where in the phenocryst it is subhedral to anhedral microcline-perthite and ranges in size from 3 to 5.5 mm. Microcline often forms cross-hatched twinning and very large optical angle ($2V \approx 85^{\circ}$). The twin-absent microcline is somewhat rare. Its phenocrysts commonly contain various inclusions, e.g., biotite, plagioclase. The alteration is slightly faint or absent. Somtimes, Microcline perthite is occasionally engulfed by quartz and plagioclase. Microcline has a long duration of crystallization and mostly occured in late stage path.

Plagioclase. Plagioclase is frequently subhedral and ranging in general size from less than 0.5 to 1.5 mm. They rarely exceed 3 mm. Modal plagioclase averages about 23.0 percent in the rocks, which is the lowest amount compared to that of the other types of granites. Anhedral laths are often found as inclusion in microcline perthite. Distorted and broken grains of plagioclase, sometimes truncated by quartz veinlets, are common at Khao To Sae. Normal zoning of plagioclase is rather weak, it varies from An_{14-23} in the core to An_{7-16} at the rim. Composition of the homogeneous plagioclase varies from sodic oligoclase

(An_{12} in biotite-muscovite granite) to albite (An_6 in the leucocratic muscovite granite). Albite twin in plagioclase is rather common in compared with pericline twin. Also Carlsbad-albite twin is relatively rare. Alteration develops rather strong in many places, particularly sericitization at Khao Rang and Khao To Sae. Sometimes at the plagioclase-microcline border myrmekite forms. Mostly plagioclase is cross-cut by the later minerals as quartz, tourmaline, and microcline perthite. It began to crystallize after biotite and has a rather long range of crystallization.

Biotite. The normal ferromagnesian mineral found in the rock is biotite, ranging from nil to 6.2 percent after the modal determination. It is characterized by reddish brown pleochroism ($\alpha = \beta$ = deep reddish to reddish brown, γ = straw yellow to light brown). The most common grain size varies from 0.5 to 1 mm. It usually occurs as subhedral crystals and aggregates but short laths are also found. Shredded, bent, and corroded-rim biotites are present in some specimens. Many of the biotites are partly or entirely altered to chlorite and associated with iron-oxides, secondary sphene, and muscovite. Some of them are bleached biotite. Chlorite and chloritized biotite appear to be most prominent at Khao Rang and Khao To Sae. Biotite always contains a rich amount of oval zircon with pleochroitic haloes and some euhedral apatite as well as small amount of ilmenite as inclusions. In turn, it may be an inclusion in plagioclase and in microcline-perthite phenocryst. Biotite occurs in the early stage of crystallization but chlorite occurs as late or post magmatic alteration.

Muscovite. Muscovite is the very characteristic of this rock. Primary muscovite is present as well as secondary one. Muscovite usually occurs as small flakes, and in rare cases aggregates of radiated forms (at Khao Rang). Large and small crystal-laths occur in nearly the same amount. The modal volume of muscovite ranges from 0.6 to 8.1 percent. The common grain size is approximately 1 mm. Distorted and ragged crystals are found in some sections. Commonly, it is associated with biotite and chloritized biotite (chlorite), sometimes it is interleaved with biotite. Many show cross-cutting with sharp rim along the biotite grains and occasionally muscovite is penetrated by quartz grains and quartz veinlets. Secondary muscovite is the main alteration product of the feldspar and perhaps the biotite. It is also observed that fluorite, a very late mineral, truncates muscovite. Consequently, muscovite began to crystallize in a very late stage of crystal fractionation and partially was in the solidus phase.

Tourmaline. Tourmaline is a common accessory mineral found in this granite. The highest amount of tourmaline in the rock is 6.2 percent. It is present as subhedral long prismatic ranging in sizes from 0.5 to 1 mm some as anhedral crystals. Its grains exhibit prominent parting and brown pleochroism (yellowish brown to brown). It is associated with biotite and muscovite. It is generally found sparsely dissiminated throughout the section. Tourmaline occurred in a very late stage of fractionation.

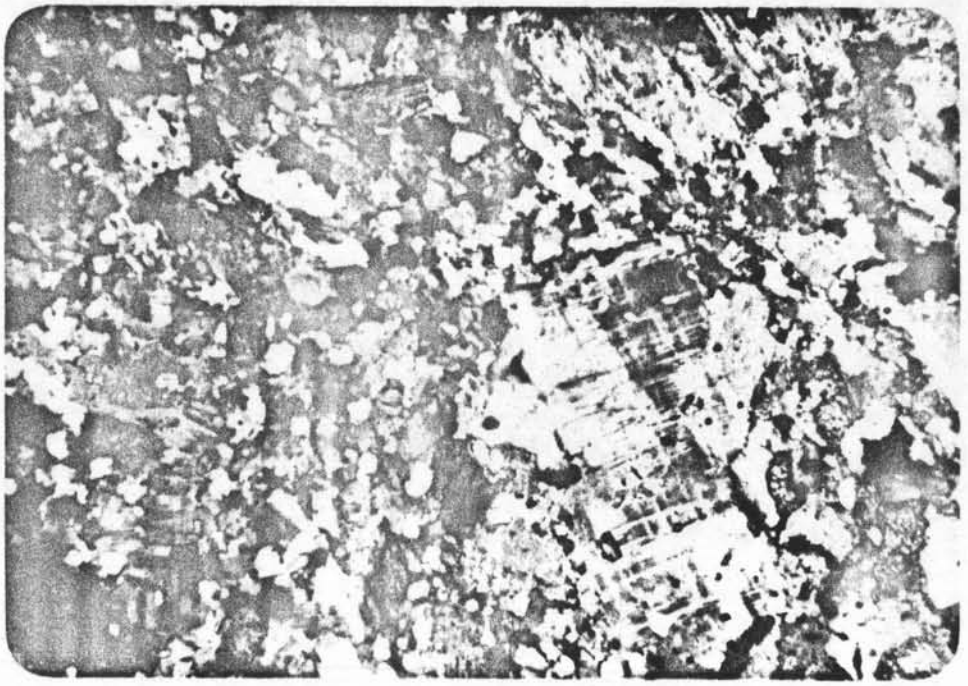
Other accessories. Zircon is characterized by the well-developed dark brown to black pleochroitic haloes in biotite. It occurs as small euhedral crystals and spindel-shape grains. It is more abundant where the rock type contains biotite and is rather rare if the rock is somwhat leucocratic and is enriched in chlorite (i.e., at Khao Rang and Khao To Sae). Zircons may be included in quartz and alkaline feldspar.

Apatite forms minute euhedral elongate crystals. It occurs commonly within biotite, or is in close association with chloritized biotite. Some are discrete crystals in quartz, it is less abundant than zircon. Both zircon and apatite are the first accessory minerals to crystallize from granitic melt.

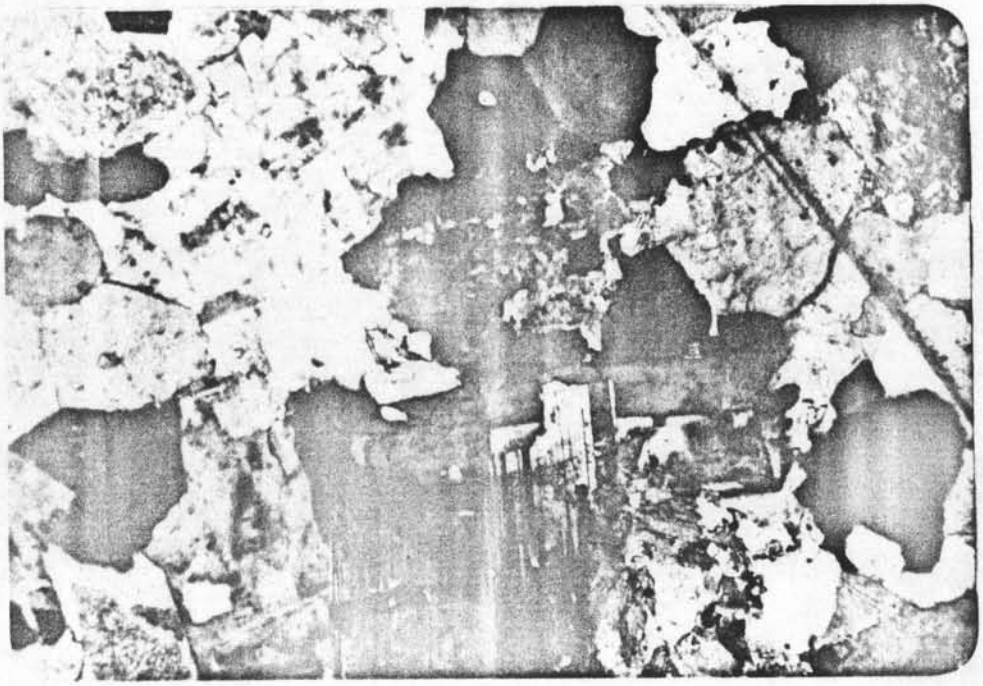
Fluorite exhibits irregular outline, and is generally close to muscovite, quartz, chlorite, and garnet. Its average grain size is about 0.5 mm, whereas the maximum size is as large as 3 mm. It sometimes filled the fractures and many replace. partially or cut across plagioclase and muscovite. Occasionally it can engulf quartz. It began to occur in the late crystallization and is found rather abundantly, particularly at Khao Rang, Khao To Sae and Khao Sapam.

Garnet occurs in small amount as small euhedral and subhedral form (0.5 mm), associated with chlorite and fluorite.

Subhedral rectangular crystals of cassiterite at the Wang Chi Ouan Fall and Khao Nai Crang are colourless to slightly pleochroitic with zoning of variable colours. It was also reported by



Photomicrograph 5. Typical characteristics of G-4, e.e. sericitization of plagioclase, chloritization of biotite, Cataclastic texture (Khao To Sae) (x-nicol, 25x).



Photomicrograph 6. Microcline partly surrounded by subhedral quartz and altered plagioclase. Plagioclase replaced by later minerals, i.e. tourmaline, muscovite (G-5) at

Garson et al., in the medium-grained greisenized mica granites at Khao Panthu Rat. It is in close association with quartz. No grains of cassiterite are found as inclusion in biotite.

Possibly primary opaque iron-oxides occurs as rounded magnetite and tabular crystals of ilmenite. These minerals occur mostly as inclusion in biotite. The secondary ones are associated with chlorite. They are rather rare in the highly silicic rocks.

Hornblende, primary sphene, and allanite are conspicuously absent. Secondary sphene occurs in small amount usually associated with chlorite. Other accessories include wolframite, scheelite, monazite and anatase (Garson, et al., 1975).

6.5 Fine-grained Biotite-muscovite-tourmaline Granites (G-5)

In hand specimen, this group of granites is typically light grey-coloured, rather leucocratic, equigranular size and nonporphyritic. The texture is rather uniform, mostly fine-grained (1 mm). The rockmass comprises quartz, feldspar, mica, and tourmaline. The C.I. ranges from 4.65 to 7.3. The high value of C.I. is probably due to the abundance of tourmaline (up to 4.1 volume percent).

The rocks of the G-5 granite are usually fine-grained allotriomorphic granular and occasionally hypidiomorphic granular. Generally, textures of these rocks are similar to those of the G-4 granites. Quartz (29.1-37.9 %) occurs as composite anhedral to subhedral grains (Photomicrograph 6) many of which show wavy extinction but suture boundaries are less

developed. Alkali feldspar (22.5-36.5 %) as large as quartz includes microcline and microcline-perthite. It usually occurs as anhedral grains mostly associated with quartz, many of the grains are somewhat altered and sometimes show strain effect. Some enclose apatite and more rarely zircon. Micrographic intergrowth with quartz is also common. Plagioclase (21.4-29.1 %) occurs as subhedral laths of albite-oligoclase (An_{10}-An_{24}). Zoning is rather faint, some show sericitized core An-content of core is nearly 26, whereas that of the rims is about 9-12. Myrmekite occurs in some samples, but is not common. Biotite (0.73 %) with yellowish brown to dark brown pleochroitic color is the sole ferromagnesian. It occurs as euhedral to subhedral and frequently tabular crystals, sparsely distributed in a small amount. Some are shreded and bent. Its grains are frequently penetrated by altered plagioclase. In many sections, particularly at Ko Maprao, biotite is commonly altered to chlorite. It always contains variably inclusions of zircon and apatite, of which the former shows darker pleochroitic haloes. Muscovite (2.6-7.9 %) usually forms large irregular lath or long slender forms, some are distorted. It is present in all specimens examined. It is mostly secondary as an alteration product of feldspar minerals. The mica crystals vary in sizes from < 1 to 3 mm. The most common accessory mineral is tourmaline (6 %) found in most sections. Its average modal volume is about 3 %. It is light green to olive green (or greenish brown) pleochroitic in subhedral prismatic crystals. Irregular forms of tourmaline are also common (Photomicrograph 6). Partings are usually present. It was formed at the expense of feldspar as well. The primary tourmaline also contains some inclusions of quartz and garnet. Other accessories include zircon, apatite, topaz, secondary sphene, garnet, and some opaques.