CHAPTER IV

PETROGRAPHY

4.1 Early Intermediate-composition Lavas

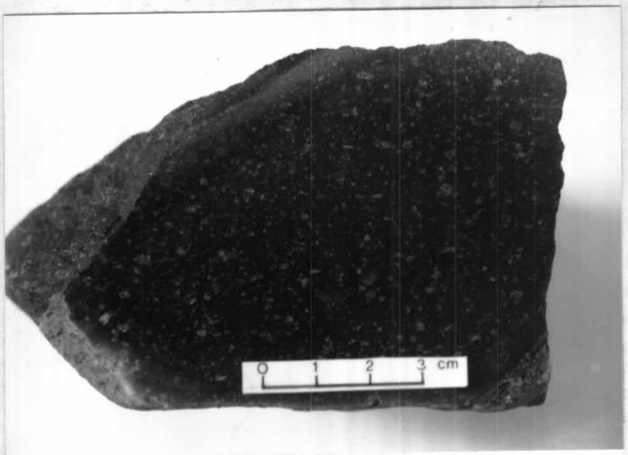
The early intermediate-composition rocks are subdivided into 3 types : basaltic andesite, andesite and dacite.

4.1.1 Basaltic Andesite

Basaltic andesite is found in many localities, particularly at the edges of the volcanic field. It occurs mostly as lava flows, flow breccias and minor amount as pyroclastic deposits that usually accumulated interlayered and formed as crudely stratified cones at or around their source vents.

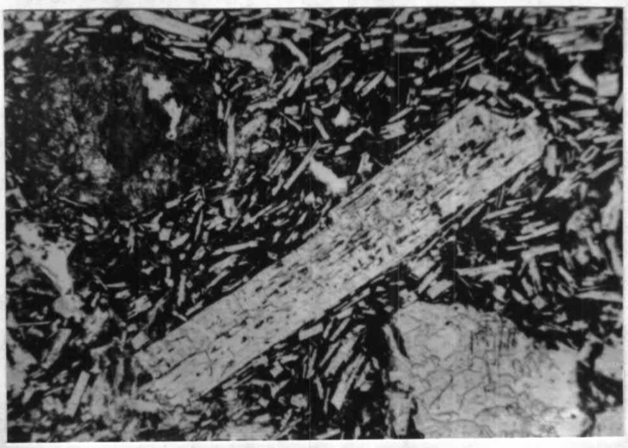
In hand specimen, basaltic andesite is gray to dark gray, porphyritic and aphanitic textures (Figure 4.1a). Phenocrysts of tabular and platy plagioclase are easily seen. The flow textures formed by alignment of plagioclase phenocrysts are also recognized. Basaltic andesite usually contains vesicles, which some of these vesicles are later filled with such secondary minerals as chalcedony, opal, calcite, chlorite and zeolites (Figure 4.2a).

Under microscope, basaltic andesite is hypocrystalline fine-grained and porphyritic texture. The groundmass consists mostly

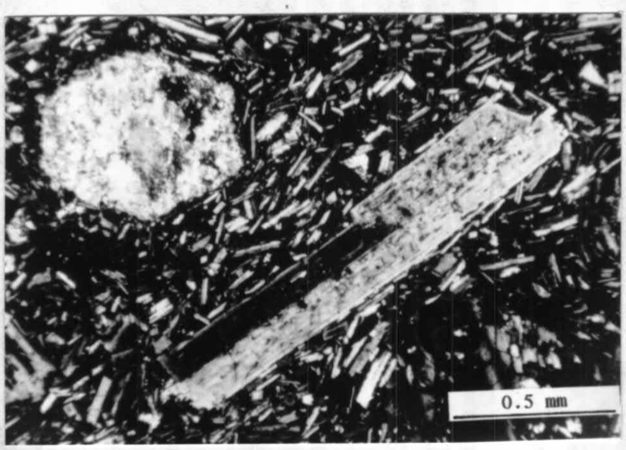


(a)

Figure 4.1a The general texture of basaltic andesite.



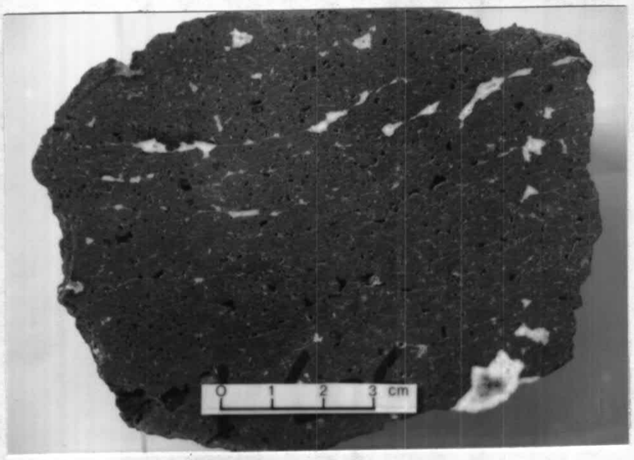
(b)



(c)

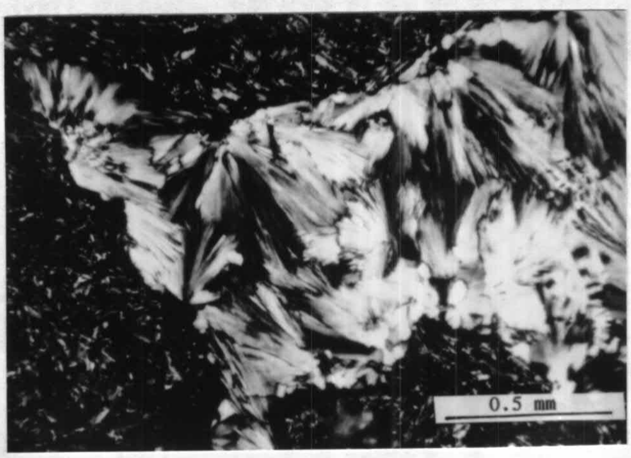
Figure 4.1b,c Photomicrographs of basaltic andesite consisting of phenocrysts of plagioclase and pseudohexagonal cross section of hornblende set in fine-grained groundmass of plagioclase microlites and dark glass.

(b= uncrossed nicols; c=crossed nicols)



(a)

Figure 4.2a Vesicular basaltic andesite and the secondary minerals filled in vesicles.



(b)

Figure 4.2b Photomicrograph of zeolite (natrolite) filling in the irregular vesicles of basaltic andesite.
(crossed nicols)

of dark interstitial glass and a number of plagioclase microlites (Figures 4.1 b and c). Minute crystals of pyroxene and magnetite are also found, but olivine is rare or absent. Flow textures are commonly indicated by alignment of plagioclase microlites. Cryptocrystalline quartz, calcite, chlorite and zeolites (natrolite, Figure 4.2b) may be found to fill in vesicles in the groundmass.

Phenocrysts of basaltic andesite are composed of plagioclase, the most dominant mineral, clinopyroxene and sometimes olivine. In Figure 4.1 b and c, there is a relict form of another phenocryst which is believed to be a former amphibole mineral. The evidence of the former amphibole phenocryst is its pseudohexagonal cross-section and is wholly replaced by calcite. The average size of phenocrysts is 0.7 mm. In some specimens, plagioclase phenocrysts can be as large as 2.0 mm.

Plagioclase phenocrysts often align parallel to plagioclase microlites in the groundmass. The composition of plagioclase phenocrysts is labradorite (An_{55-60}). Albite twins are very common. Some of plagioclase phenocrysts show oscillatory zoning.

Phenocrysts of clinopyroxene (augite) are found in a small amount and usually smaller in size when comparing to plagioclase phenocrysts. Olivine phenocrysts are rather rare or absent in this rock type.

4.1.2 Andesite

Andesite is found at the central and the southeastern parts of the volcanic field. It occurs mostly as lava flows and flow breccias with minor portion forming small vein and dykes.

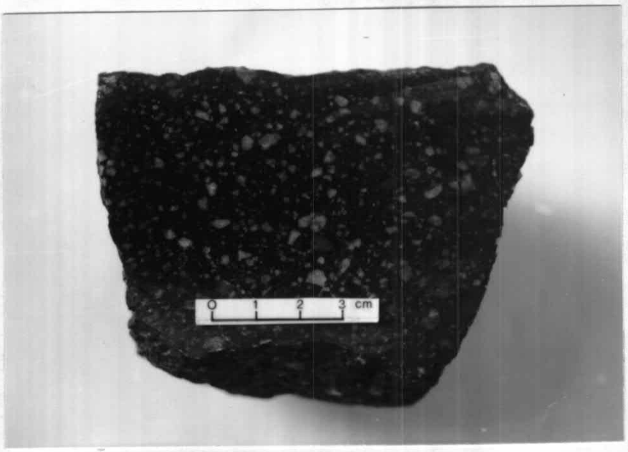
In hand specimen, andesitic rocks are green or greenish gray, porphyritic and aphanitic textures(Figure 4.3 a). Phenocrysts consist about 20 percents of plagioclase and pyroxene. In all specimens, the plagioclase phenocryst is more distinctive and more widespread than the pyroxene phenocryst.

Under microscope, the rock is hypocrystalline and porphyritic texture. Brown glass and plagioclase microlites form a major part of the groundmass with perhaps small amount of magnetite crystals (Figures 4.3 b and c). Flow lines are commonly indicated by the orientation of plagioclase microlites.

Phenocrysts are plagioclase, the most dominant mineral, augite and sometimes hornblende. The average grain size is 1.0 mm.

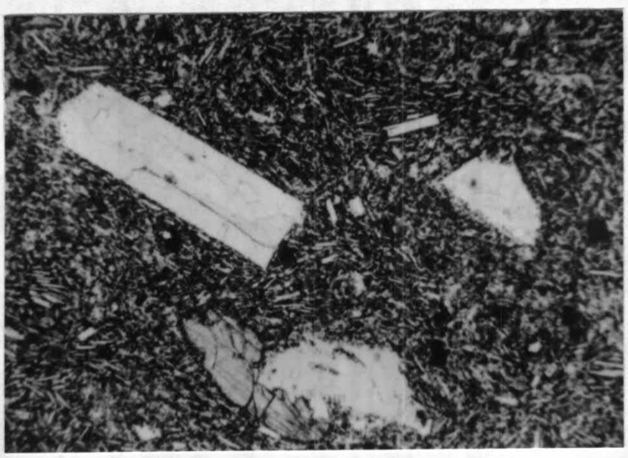
Plagioclase phenocrysts usually occur as lath-shapped, subhedral crystals. Some crystals are corroded. Plagioclase phenocrysts are often zoned, particularly of oscillatory type. Albite twins are very common. The composition of plagioclase phenocrysts lies within the range of andesine-labradorite (An_{46-53}).

Augite commonly occurs as subhedral crystals of about 0.7 mm in average size and is usually smaller than plagioclase. A



(a)

Figure 4.3a The general texture of andesite.



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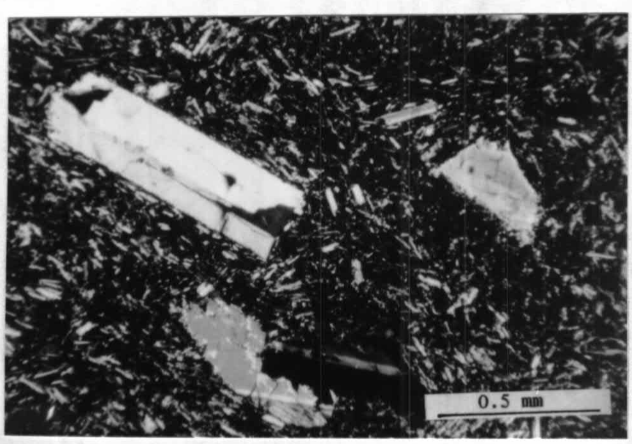


(c)

Figure 4.3b,c Photomicrographs of andesite consisting of phenocrysts of plagioclase and augite set in the groundmass of plagioclase microlites and brown glass.

(b= uncrossed nicols; c=crossed nicols)

few crystals of brown hornblende are seen. At their margins, hornblendes are usually rimmed by opaque minerals, while internally, their original parts are replaced by calcite and/or chlorite.

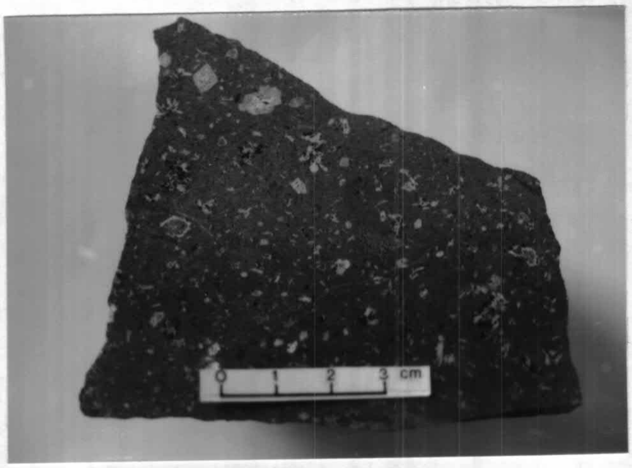
In some sections, the mineral phenocrysts and groundmass are widely altered (Figures 4.4 a, b and c). The glass groundmass is commonly replaced by pale green chlorite, whereas plagioclase both in phenocryst and in groundmass is replaced by a combination of calcite, chlorite and also sericite.

4.1.3 <u>Dacite</u>

Dacite is found at the central part of the volcanic field. It occurs as lava flows and flow breccias that accumulated and formed as domes lying along the northeast-southwest fault.

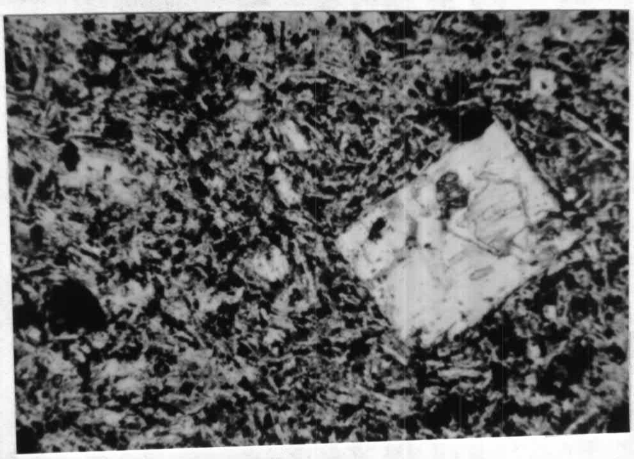
In hand specimen, dacite is gray, porphyritic and aphanitic textures (Figure 4.5 a). Phenocrysts of tabular and platy plagioclase are obvious and present up to 20 percents in the lava. Their average grain size is 1.5 mm. The decitic rocks often show discontinuous, laminated structure in the groundmass. This foliation is generally attributed to shear parting developed during laminar flow. This feature can sometimes be confused with textures developed in densely welded tuffs.

Under microscope, the rock is hypocrystalline and porphyritic textures. Phenocrysts consist mostly of plagioclase, and minor amount of quartz, biotite and magnetite set in the groundmass of devitrified glass (Figures 4.5 b and c).



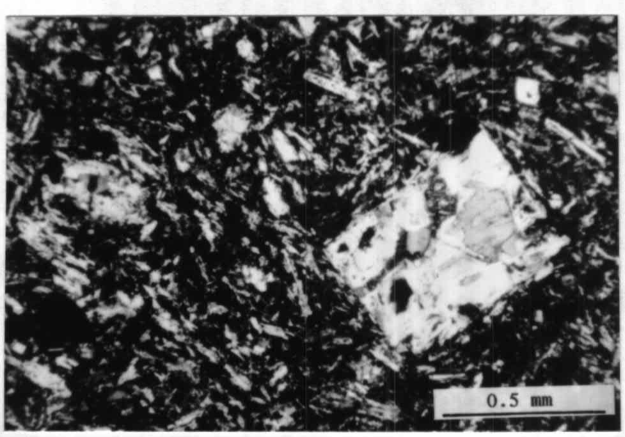
(a)

Figure 4.4a The general texture of altered andesite.

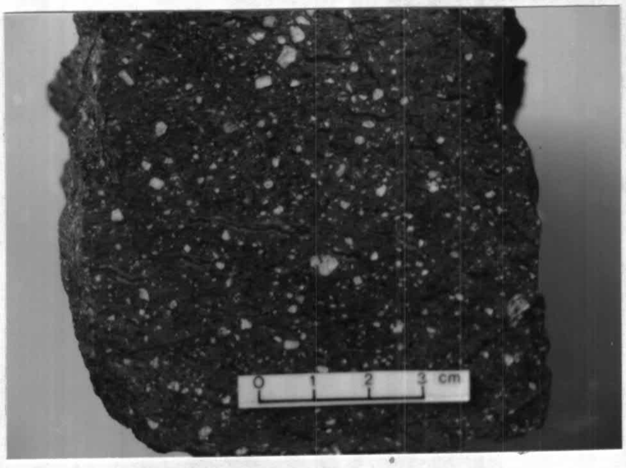


(b)

Figure 4.4b,c Photomicrographs of an altered andesite consisting of plagioclase which has been partly replaced by calcite, chlorite and sericite, set in groundmass of glass and plagioclase microlites.
(b= uncrossed nicols; c=crossed nicols)

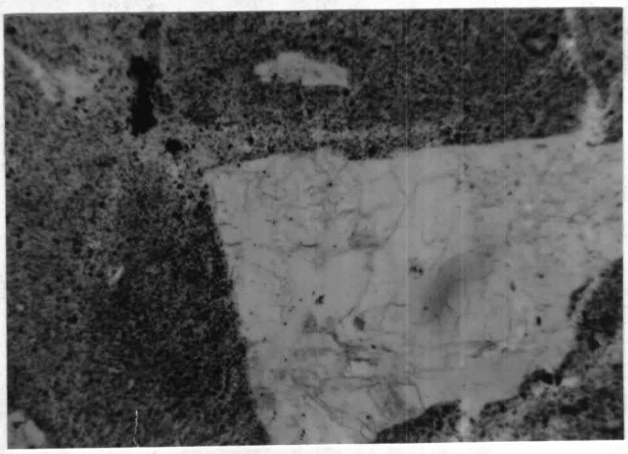


(c)



(a)

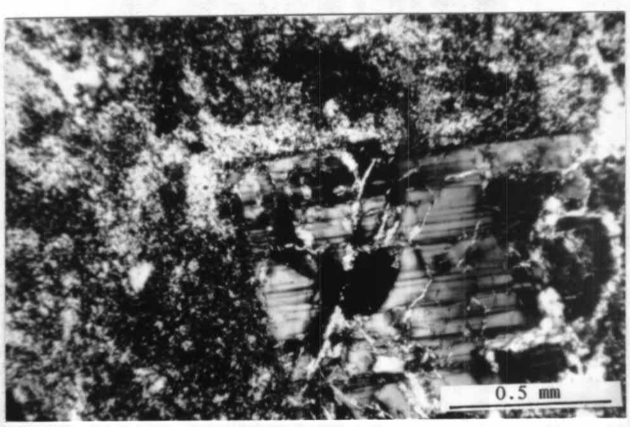
Figure 4.5a The general texture of dacite.



(b)

Figure 4.5b,c Photomicrographs of dacite consisting of plagioclase phenocrysts set in the groundmass of completely devitrified glass.

(b= uncrossed nicols; c=crossed nicols)



(c)

Plagioclase phenocrysts are the principal mineral constituents of this rock. The composition of the plagioclase is oligoclase (An_{18-21}). Plagioclase phenocrysts distribute throughout the rock as discrete subhedral grains. Albite twinning is very common. Some of the large plagioclase phenocrysts often show normal zoning. Secondary quartz and calcite commonly filled along cracks of plagioclase phenocrysts.

Phenocrysts of quartz and biotite occur in a very small amount. Quartz phenocrysts usually occur as subhedral grains which are commonly cracked and corroded. Biotite occurs as small flakes and shows strong pleochroism from pale brown to dark brown.

Opaque mineral is magnetite. It occurs as small crystals distributed throughout the rock.

4.2 Silicic Tuffs

As previously mentioned in chapter III, the term "silicic tuff", used in this study, is applied to the deposit successions of all silicic pyroclastic rocks with irrespective to their grain sizes and other accompanying compositions which exploded and deposited during this silicic eruption activity.

The deposit successions of silicic tuffs apparently distribute widely throughout the volcanic field. These deposit successions commonly form as the steepest topographic terrains on which their tops are mostly or completely overlain by the following rhyolitic lavas.

In general, the deposit successions of silicic tuff have a great variety of different depositional facies. According to their mode of transport and deposition, silicic tuffs in each deposit succession can be grouped into three genetic types: pyroclastic fall deposits, pyroclastic flow deposits and pyroclastic surge deposits. However, the initial description and consideration of the total field characteristics should be made before the genetic name can be applied.

Silicic tuffs which generated from pyroclastic fall deposits are generally characterized in the field by mantle bedding; that is, they locally maintain a uniform thickness while draping all but the steepest topography. They are relatively well sorted because of aeolian fractionation during transport. Sometimes they show planar internal stratification or lamination, but never cross-stratification or bedform showing erosion or truncation of the underlying layers. Silicic tuffs generated from pyroclastic flow deposits are generally massive and poorly sorted, but sometimes show coarse-tail grading of the larger clasts. Silicic tuffs which generated from pyroclastic surge deposits are commonly recognized by well stratified, showing unidirectional sedimentary bedforms, for instance, low angle cross-stratification, dune forms, climbing dune-forms, pinch and swell structures, and chute and pool structures.

All of the three types of silicic tuffs have a wide range in grain sizes and variable amounts of constituent materials. The dominant material is pumice ash, but some are composed predominantly of pumice fragments of lapilli or block sizes. The lithic fragments of the early intermediate-composition lavas, of preceeding silicic tuffs and of rhyolitic lavas are common.

Under microscope, fine-grained silicic tuffs are depicted for study. They are typical vitric characteristics that are composed predominantly of glass fragments more than crystal fragments and/or lithic fragments. All specimens commonly contain fragments of all three types with varying proportions. These fragments are commonly embedded in fine glassy particles (ash) as shown in Figures 4.6 a, b and c; 4.7 a, b and c.

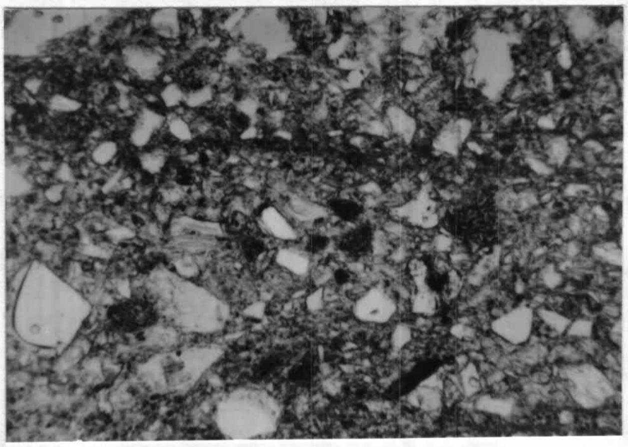
The glassy fragments commonly show shard-like forms, for instance, arrow heads, plate-like, curved form, and other slender shapes (Figures 4.8 a and b). Glass shards are diagnostic of explosive fragmentation during eruption. They represent fragments of bubble wall of glass which have been explosive disrupted and produced curved plates. The different forms indicate that the original plastic glass contains bubbles of different size, shape and wall thickness.

Some specimens of silicic tuffs which generated from pumice flow deposits (ignimbrite), the pumice fragments are flattened, welded together and occur as lens shapes aligned in a fine-grained pumice ash matrix (Figures 4.9 a, b and c). This texture represents the structure known as eutaxitic texture, while the lenses of flattened pumice are known as fiamme.

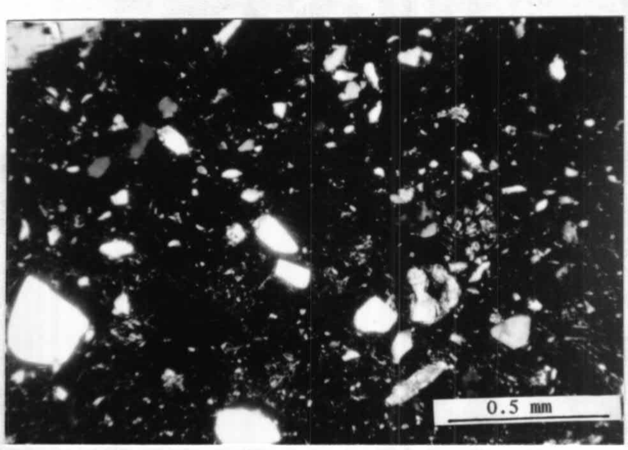
Welding is important characteristic ones that indicates the rock having a pyroclastic origin. However, welding is not uniquely indicative of a pyroclastic flow origin. Welded of fall tuffs are

(a)

Figure 4.6a Pumice ash-fall deposits showing planar internal stratification with well sorting and reverse grading.

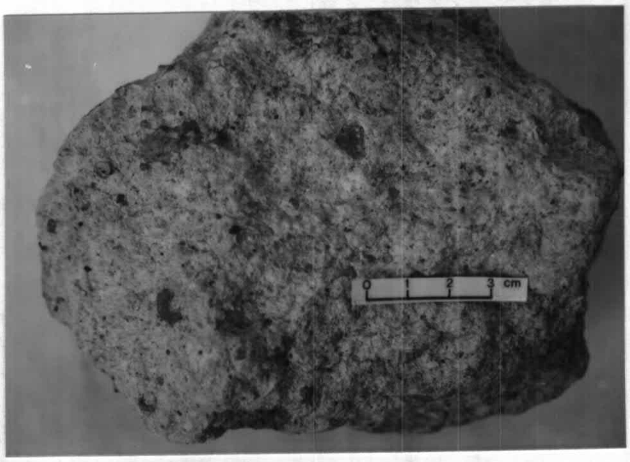


(b)



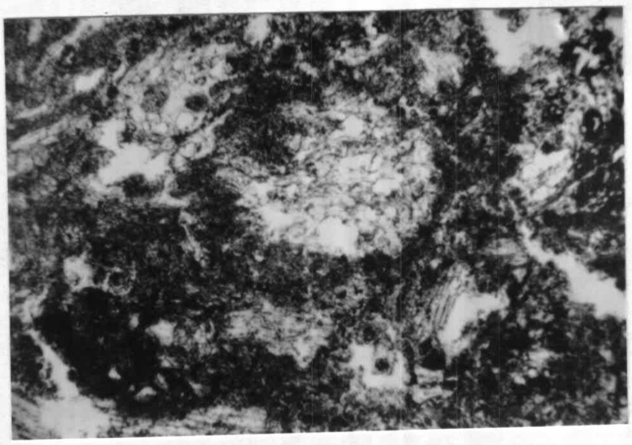
(c)

Figure 4.6b,c Photomicrographs of pumice ash-fall deposit containing fragments of glass, crystals of quartz, plagioclase, alkali feldspar and biotite, and lithic grains set in fine-grained glass particles (ash). Most of the crystal fragments are subrounded and show slightly reverse grading.
(b= uncrossed nicols; c=crossed nicols)

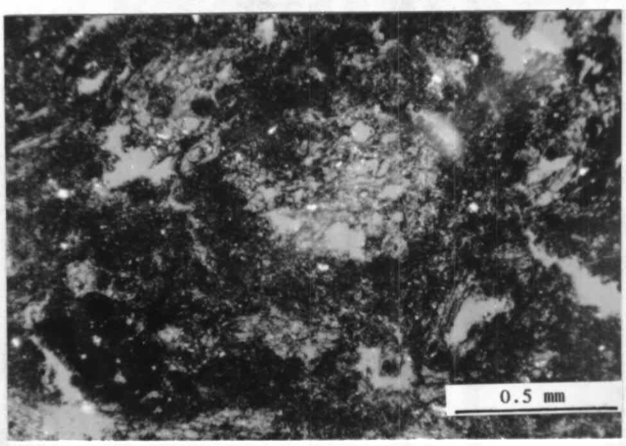


(a)

Figure 4.7a The general texture of unwelded ignimbrite.

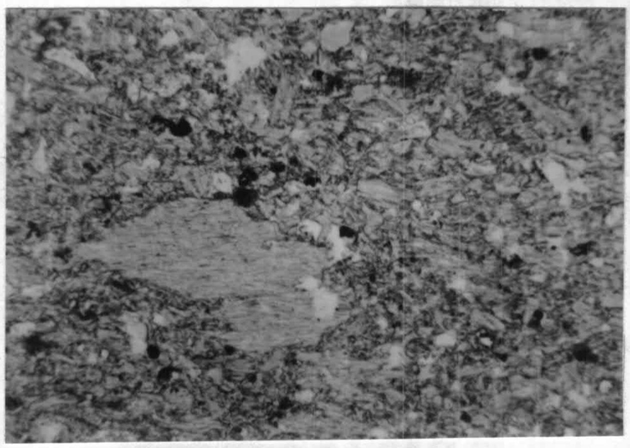


(b)



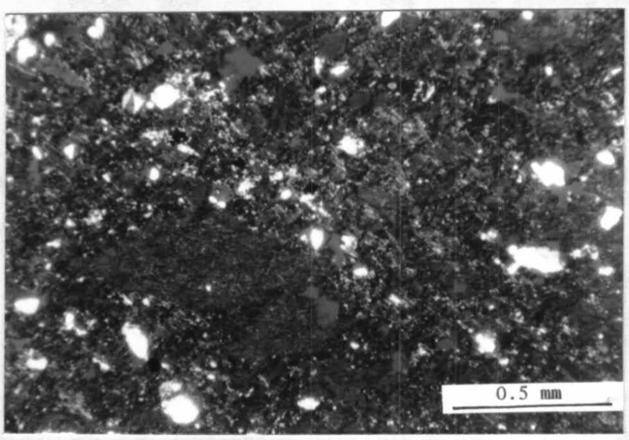
(c)

Figure 4.7b,c Photomicrographs of unwelded ignimbrites containing highly vesicular fragments set in fine-grained glassy ash.
(b= uncrossed nicols; c=crossed nicols)



(a)

Figure 4.8a, b Photomicrographs of unwelded ignimbrite showing different forms of glass-shards, banding characterized by slightly flattened pumice fragments.
(a= uncrossed nicols;b= crossed nicols)



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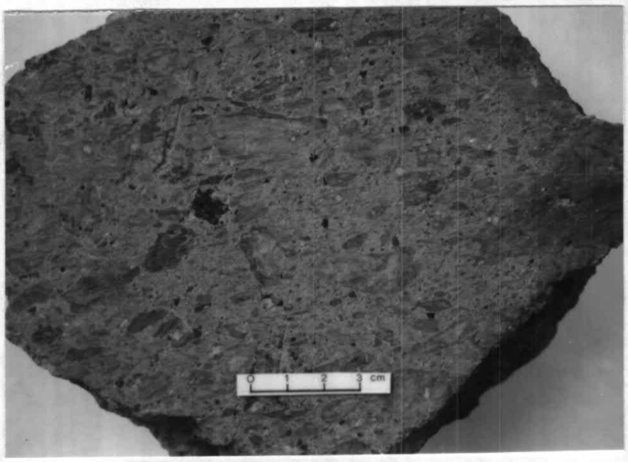
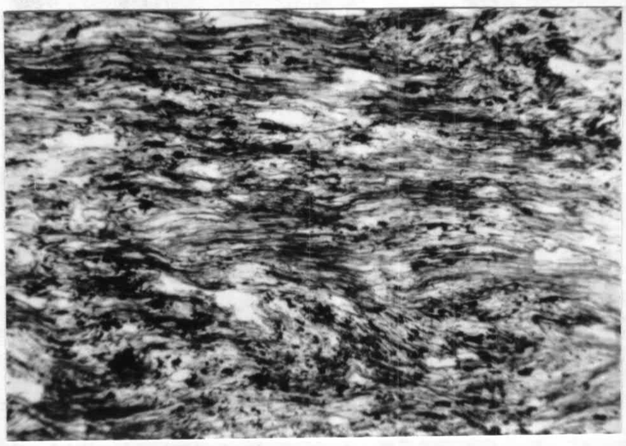


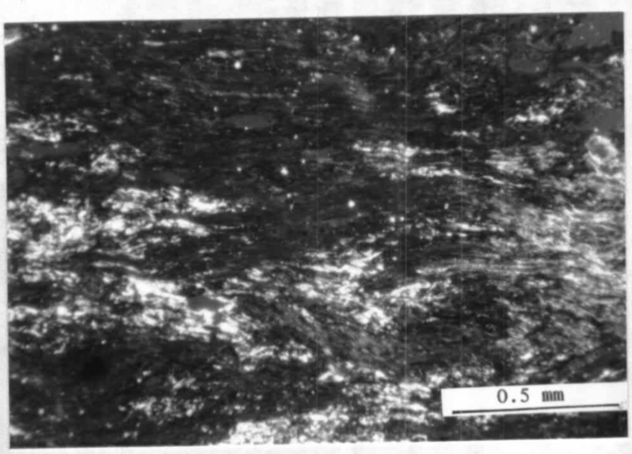
(a)

Figure 4.9a Welded ignimbrite showing eutaxtic texture which is characterized by the flattened pumice clasts(fiamme) arranged in a fine pumice ash matrix.



(b)

Figure 4.9b,c Photomicrographs of welded ignimbrite showing relative continuous lamination caused by extreme compaction and welding of pumice fragments.
(b= uncrossed nicols; c=crossed nicols)



(c)

also a common rock and, if recognized, can be important in determining vent proximity (Cas and Wright, 1987).

The crystal fragments of all silicic tuffs are common of quartz, plagioclase, alkali feldspar and biotite. All of these crystal fragments are often subhedral in shape with corroded borders (Figures 4.6 b and c). In general, rounded clasts imply post-eruptive reworking by surface processes. However, rounded edges and corners on crystals, especially of volcanic quartz, may be due to the magmatic resorption before eruption, rather than to post-eruption reworking (Cas and Wright, 1987).

In some specimens of silicic tuffs which generated from pyroclastic fall deposits, the crystal fragments sometimes show slightly grading (Figures 4.6 b and c). Whereas the crystal fragments in silicic tuffs which generated from pyroclastic flow deposits usually show crystal alignments parallel to the flow pattern.

The crystal fragments of quartz are common in all sections of silicic tuffs. They commonly occur as subhedral grains with corroded borders. Their grain sizes vary from 0.1-0.3 mm and average 0.15 m in diameter.

The crystal fragments of plagioclase are also common in silicic tuffs. They apparently constitute larger in amount than alkali feldspar. They vary in size from 0.1-1.0 mm. Plagioclases common show albite and Carlsbad-albite twins. An-content of plagioclase, where it is possible to be determined optically, appears to be around An_{20}. This indicates plagioclase composition is in the range of sodic oligoclase.

Alkali feldspar are frequently sanidine, occasionally orthoclase. Optical characteristics of sanidine is relatively low birefringence and posses extremely small optical angle. Orthoclase, though present in a small amount, is generally subhedral and often shows Carlsbad twins. Orthoclase is distinguished from sanidine by its large optical angle.

The crystal fragments of biotite are present in nearly all samples of silicic tuff, but only in a small amount. Many of biotite fragments are relatively rounded. Biotite fragments generally show strong pleochroism from pale brown to dark brown.

The lithic fragments of silicic tuffs are composed of the early intermediate-composition lavas, silicic tuffs and rhyolitic lavas. The early intermediate-composition lavas found in silicic tuffs are common of basaltic andesite. The silicic tuff fragments are similar in texture and mineral compositions to its mother rock. This indicates that the eruptions of silicic magma occur at least more than one time. The rhyolitic lava fragments in silicic tuffs are also support this evidence.

4.3 Silicic Lavas

The rocks of this group are composed mostly of glass or glassy groundmass. The classification based on modal proportion of mineral constituents (quartz and two feldspars) is therefore impractical for this volcanic group. Chemical analyses of silicic volcanic rocks show that they are well within the composition of rhyolite. However,based on their ferromagnesian mineral constituents, the silicic rocks are further subdivided into three types: augite rhyolite, hornblende-biotite rhyolite and biotite rhyolite.

When comparing these three types of rhyolites, a number of common features are recognized.

i) Groundmass is composed entirely or partly of glass (or devitrified glass). Crystallites, microlites and spherulites are commonly developed, which they usually form as specific flow layers and also interlayers to each other.

ii) Plagioclase is the dominant mineral in augite rhyolite and hornblende-biotite rhyolite, but it is not found in biotite rhyolite. Plagioclase occurs both as phenocryst and groundmass. The microcrystalline groundmass plagioclase often forms a flow texture. Plagioclase phenocrysts are oligoclase having composition (An_{12}-An_{28}). The modal volume and the composition of plagioclase apparently decrease systematically with changing of the ferromagnesian mineral from augite to hornblende-biotite. Albite and Carlsbad-albite twins and oscillatory zoning are very common.

iii) Alkali feldspar, normally sanidine, occurs as the dominant phenocrysts in biotite rhyolite but is rare or absent in others.

iv) Quartz normally occurs in biotite and hornblende-biotite rhyolite but is rare or absent in augite rhyolite. Quartz, if present, is often cracked and corroded rims.

v) Spherulites are abundant in hornblende-biotite rhyolit and biotite rhyolite is rare or absent in augite rhyolite. By X-ray analysis, the composition of spherulites is cristobalite.

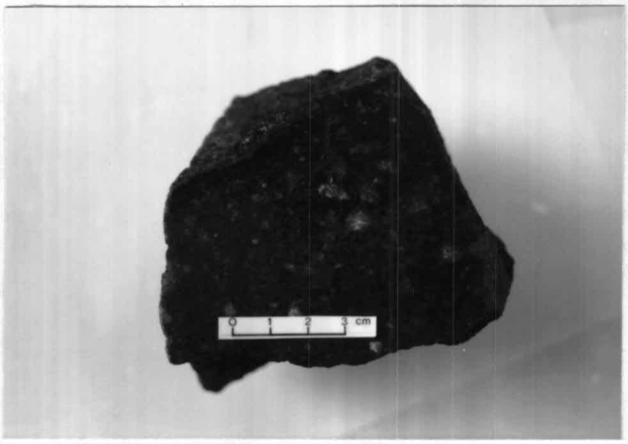
Detailed description of each rock type is given in the following paragraphs.

4.3.1 Augite Rhyolite

Augite rhyolite is found at some localities, for instance, at Khao Khat, Khao Ka and Khao Wang Plae, the northeast, the southeast and the central west of the volcanic field in respectively. The rock commonly occurs as lava flows which probably extruded through sequences of the early intermediate-composition lavas or covered on the deposit successions of silicic tuffs.

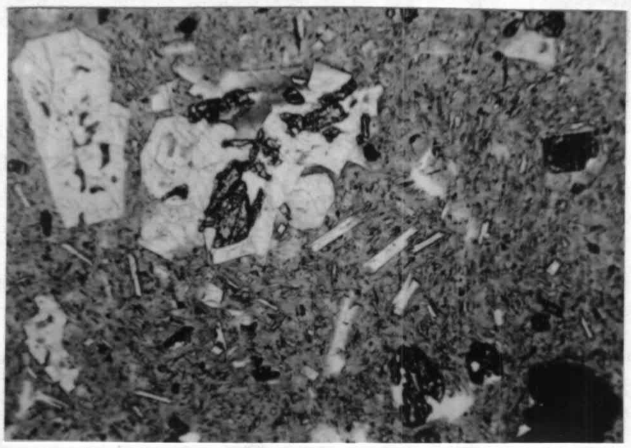
Augite rhyolite is reddish purple or greenish gray, vitrophyric and aphanitic groundmass (Figure 4.10 a). The interlayers or flow band of glass and glassy groundmass can be recognized.

Under microscope, the rock is hypocrystalline. The groundmass, the main constituent, is predominantly composed of brown glass with a small number of tiny plagioclase crystals (Figures 4.10 b and c). Its flow texture is indicated by the orientation of plagioclase microlites. The first generation of plagioclase, augite

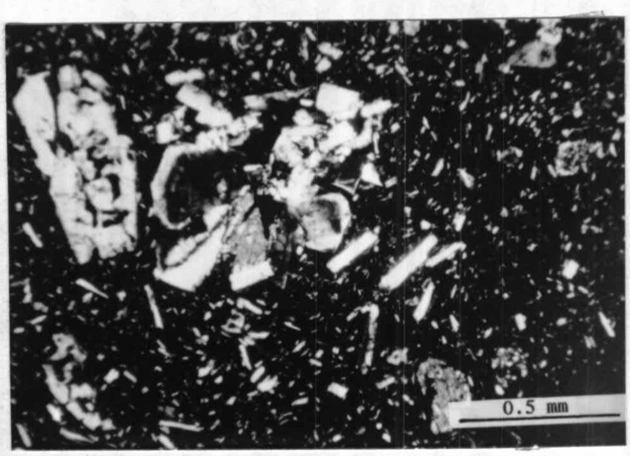


(a)

Figure 4.10a Augite rhyolite.



(b)



(c)

Figure 4.10b,c Photomicrographs of augite rhyolite consisting of plagioclase and augite phenocrysts set in brown glass matrix.

(b= uncrossed nicols; c=crossed nicols)

and iron oxides occur as phenocrysts. Quartz is occasionally present. The average size of the phenocrysts is about 0.3 mm.

Plagioclase phenocrysts are the principal crystals of this rock. Its composition ranges from An_{24} to An_{28} which is higher than hornblende-biotite rhyolite. Albite and Carlsbad-albite twins and oscillatory zoning are common. Plagioclase phenocrysts distribute throughout the rock, generally, as lath-like, subhedral crystals which usually orientate parallel to the orientation of plagioclase-microlite groundmass. Plagioclase phenocrysts sometimes form as glomeroporphyritic texture. The large grains of plagioclase often enclose blebs of brown glass, sometimes contain the inclusions of augite, while they are corroded at their margins.

Augite is only ferromagnesian mineral assemblage found in this rock. It occurs as small euhedral and subhedral crystals in a very small amount but noticeable in nearly all-thin sections. Quartz is rare in this rock type.

4.3.2 Hornblende-Biotite Rhyolite

This rock type is found in many parts of the volcanic field, for instance, Khao Rawang at the central east, and Khao Takon and Khao Tham at the northwest. It commonly occurs as lava domes and flows which usually rest on the deposit successions of silicic tuffs.

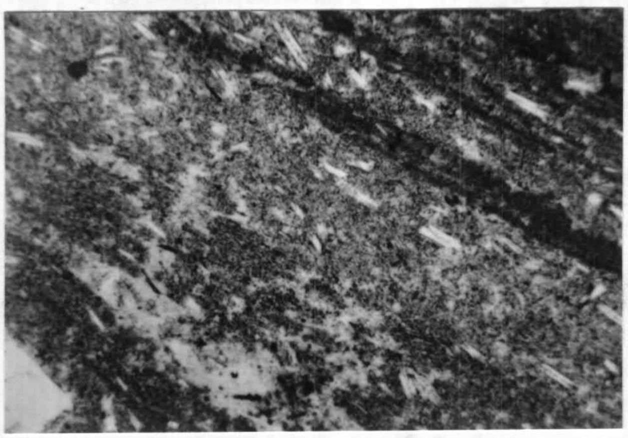
Except for obsidian and some varieties of glassy, the rock is generally light color, porphyritic with aphanitic groundmass. It is often banded and shows flow structure which usually appears as color-interbands of varying of crystallinity (glass and stony character), spherulites and vesicularity (Figure 4.11 a).

Under microscope, the rock is hypocrystalline. The groundmass is either entirely glass or a mixture of glass and crystallites plus minor microlites and also spherulites which conspicuously form internal laminations and flow structures (Figures 4.11 b and c). A variety of hornblende-biotite rhyolite containing a glassy groundmass is also common (Figure 4.12 a). It seems to be a transition from hornblende-biotite vitrophyre to obsidian pitchstone (Figures 4.12 b and c). Moreover, an entirely glassy groundmass occurs in stony rhyolite (Figures 4.13 a,b and c). The growth of spherulites superimposed on the flow-structure is common, (Figures 4.14 a and b), suggestion that the spherulites are formed after the flowage of lavas have been ceased. Perlitic cracks often occur both inobsidian and pumice, but is absent in stony rhyolites (Figures 4.12 b and c). The inclusions of mafic materials which picked up from the underlying surface during the lava flows are often found in them (Figures 4.15 b and c).

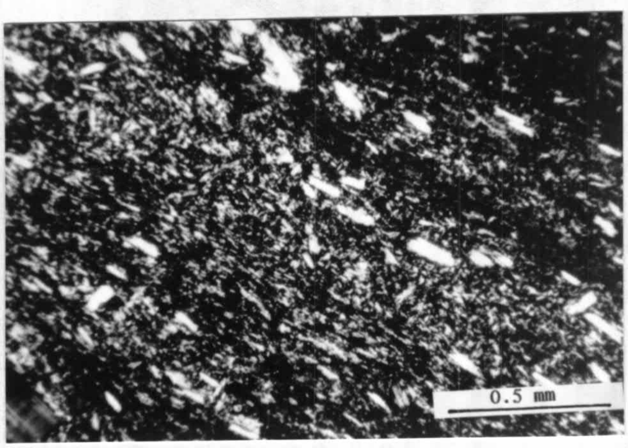
The crystal content of hornblende-biotite rhyolite is less than 10 percents. Phenocrysts consist of plagioclase, quartz, sanidine, biotite and hornblende in descending order of abundance. Plagioclase is commonly present as phenocrysts in all sections. In some specimens, it occurs both as phenocrysts and groundmass. The groundmass plagioclase is present as very small laths and normally forms flow lines. The composition of plagioclase phenocrysts is typically oligoclase, ranging from An_{12} to An_{14}. Albite and Carlsbad-albite twins and oscillatory zoning are common.

(a)

Figure 4.11a Hornblende-biotite -stony rhyolite showing flow layers.



(b)

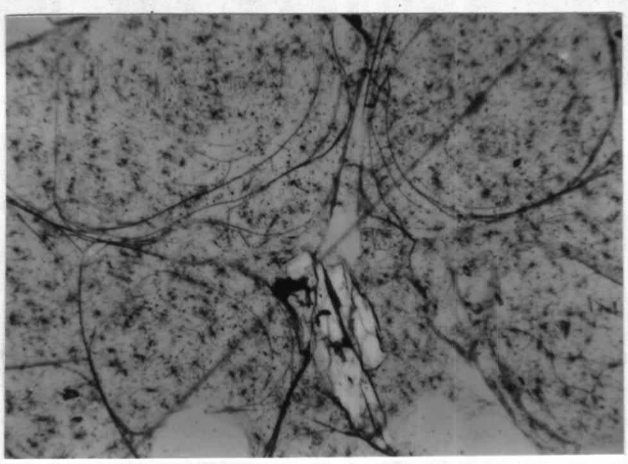


(c)

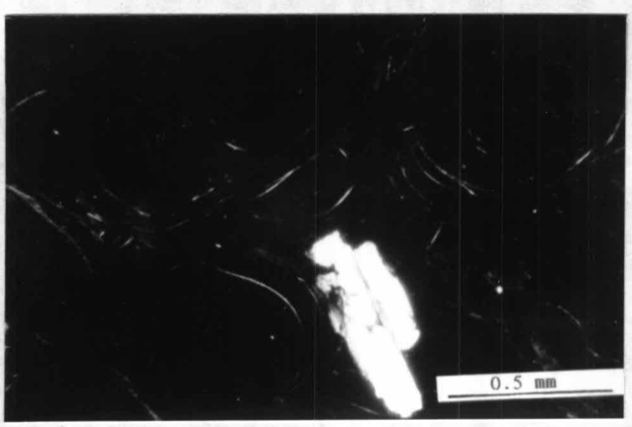
Figure 4.11b,c Photomicrographs of stony rhyolite showing interlayer of glass, crystallites and microlites show a flow-line pattern.
(b= uncrossed nicols; c=crossed nicols)

(a)

Figure 4.12a Hornblende-biotite rhyolite containing glassy groundmass.



(b)

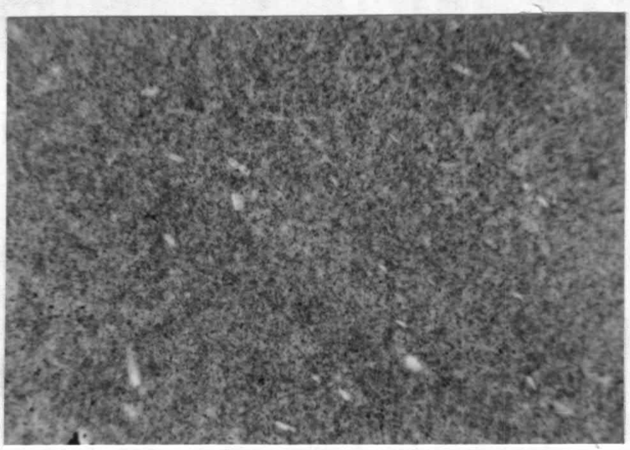


(c)

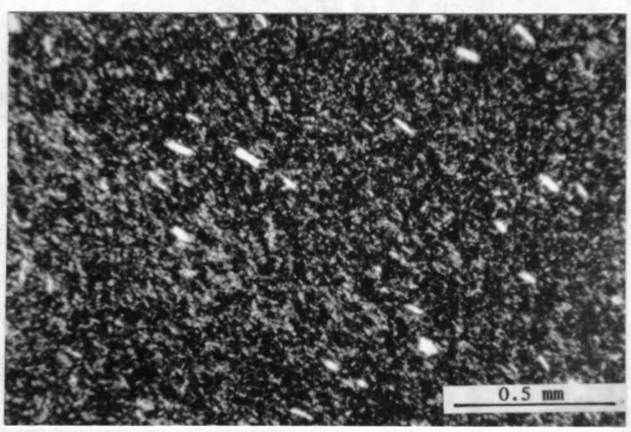
Figure 4.12b,c Photomicrographs of rhyolitic obsidian with perlitic cracks containing rare plagioclase phenocrysts.
(b= uncrossed nicols; c=crossed nicols)

(a)

Figure 4.13a Stony rhyolite.

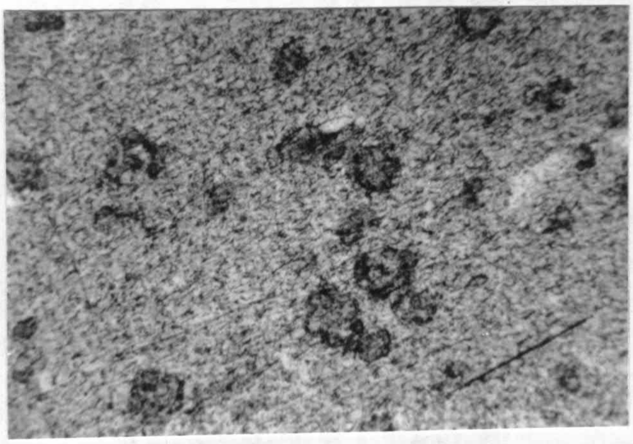


(b)

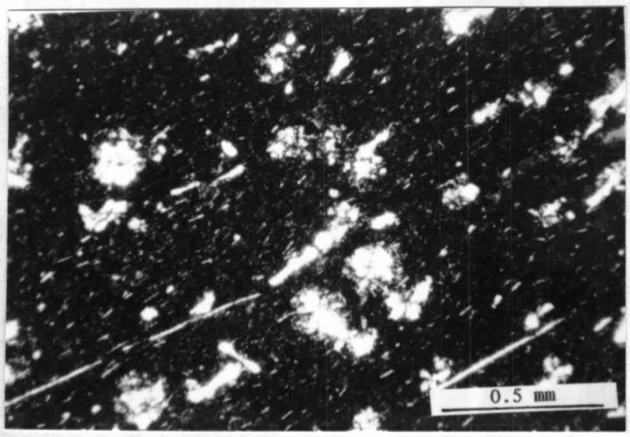


(c)

Figure 4.13b,c Microphotographs of a stony rhyolite containing devitrified glass.
(b= uncrossed nicols; c=crossed nicols)

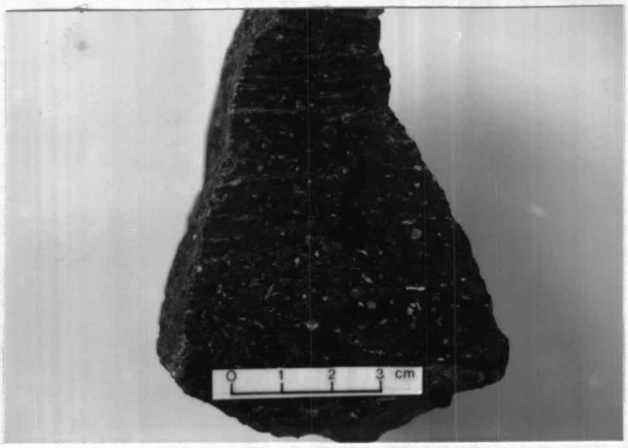


(a)



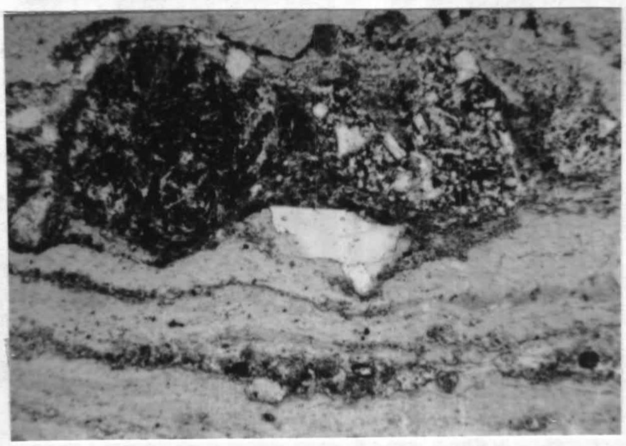
(b)

Figure 4.14a,b Microphotographs showing the development and growth of spherulites are usually superimposed on the flow-structure and indicating that their crystallization took place after the flowage of the lava have nearly ceased.
(a= uncrossed nicols; b=crossed nicols)

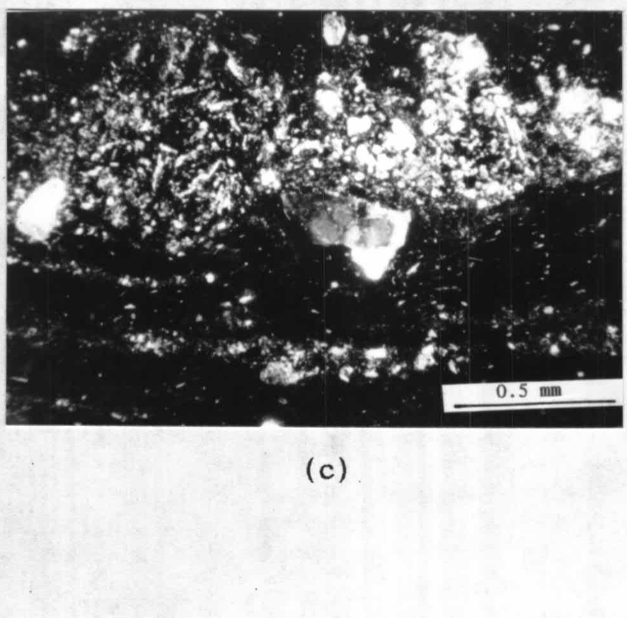


(a)

Figure 4.15a Hornblende-biotite rhyolite with basaltic inclusions.



(b)



(c)

Figure 4.16b,c Photomicrographs of basaltic inclusions occurring in rhyolitic vitrophyre.
(b= uncrossed nicols; c=crossed nicols)

Quartz phenocrysts usually occur as subhedral crystals. Most of them are cracked and corroded by the flow of glass groundmass. Therefore, they often occur as more or less rounded grains (Figures 4.16 a and b).

Sanidine phenocrysts constitute a small amount in content in hornblende-biotite rhyolite. It normally occurs as lath-like, simple twins and nearly parallel extinction.

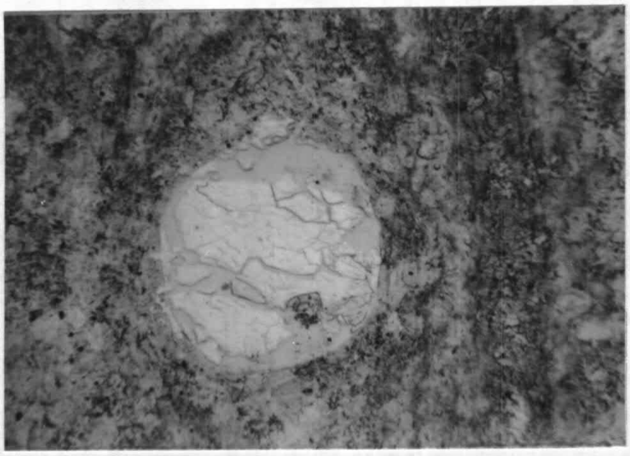
Biotite commonly occurs as small flakes. It is typically pleochroic from pale brown to dark brown. Hornblende is rather rare. If present, it commonly shows strong pleochroism from pale green to dark brown.

4.3.3 Biotite Rhyolite

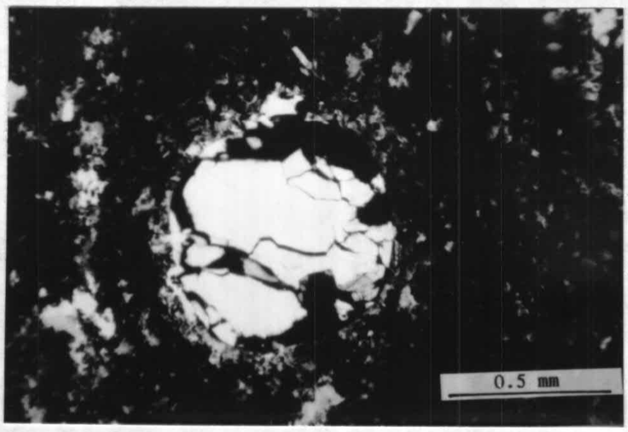
This rock type is found at isolate lava domes and flows which lying along the east of the volcanic field. It is probably the youngest extrusions of silicic lavas.

The rock is pinkish white to white in color. In general, it has porphyritic and aphanitic texture. The interlayers of glass and stony characters are common (Figure 4.17 a). Phenocrysts of euhedral sanidine are easily recognized (Figure 4.18 a). Locally, the rock may contain inclusions of more basic materials.

Under microscope, the rock is hypocrystalline. Groundmass, either completely or partly glass, contains crystallites,

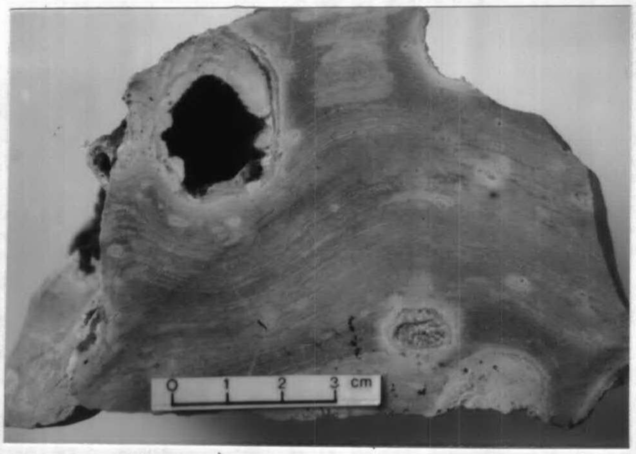


(a)



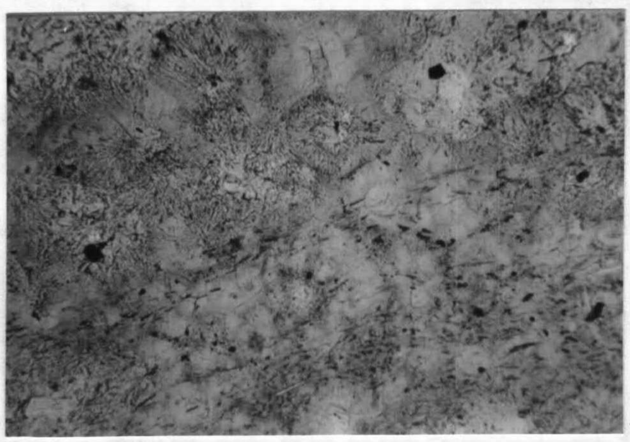
(b)

Figure 4.16a,b Photomicrographs of hornblende-biotite rhyolite showing a cracked and corroded intratelluric phenocryst of quartz rounded by the flow of glass matrix.
(a= uncrossed nicols; b=crossed nicols)



(a)

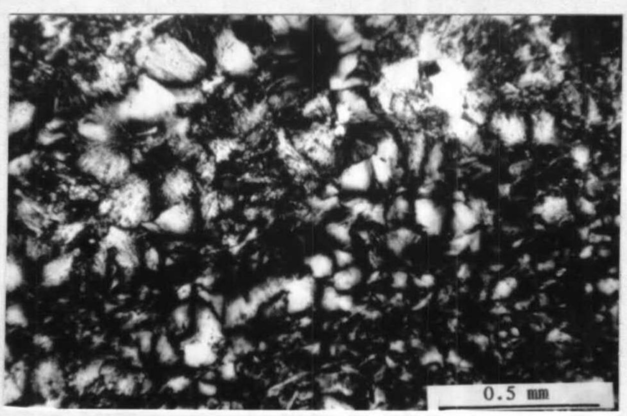
Figure 4.17a Biotite rhyolite showing flow-structure characterized by fine laminations of different crystallinity.



(b)

Figure 4.17b,c Photomicrographs of interlayers of aciculites and spherulites suggest that spherulites formed after the lava stopped.

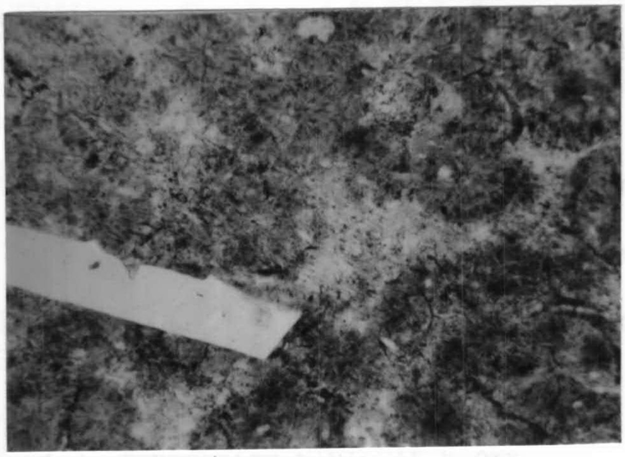
(b= uncrossed nicols; c=crossed nicols)



(c)

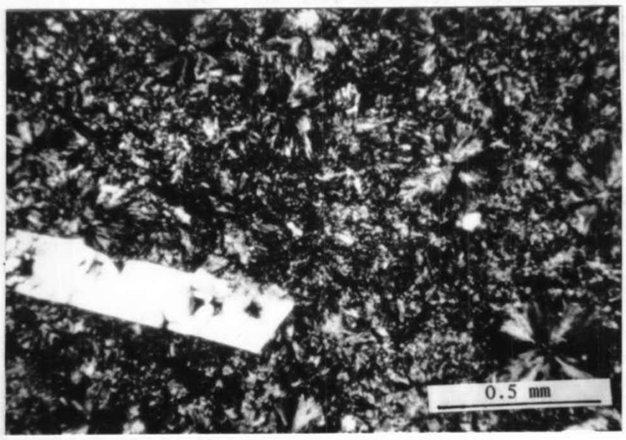
(a)

Figure 4.18a Biotite rhyolite with phenocrysts of sanidine.



(b)

Figure 4.18b,c Photomicrographs of biotite rhyolite containing sanidine phenocrysts set in spherulitic groundmass.
(b= uncrossed nicols; c=crossed nicols)



(c)

microlites and spherulites which normally show a flow-line pattern (Figures 4.17 b and c). The rock has an average phenocrysts content of about 5 percents. Phenocrysts consist of sanidine, quartz and biotite.

Sanidine is the principal crystal of biotite rhyolite. It commonly occurs as tabular, euhedral crystals (Figures 4.18 b and c). Simple twins and nearly parallel extinction are common.

Quartz in biotite rhyolite occurs in a small amount. It normally shows cracked grains and corroded rims. Micrographic texture of quartz and alkali feldspar intergrowth sometimes is present.

Biotite is the only ferromagnesian mineral in this rock type. It occurs as small flakes in a very small amount. It normally shows strong pleochroism from pale brown to dark brown.

4.4 Associated Plutonic Rocks

Two varieties of the associated plutonic rocks have been encountered at Khao Wang Plae, the central west of the volcanic field. They are biotite microgranite and hornblende microdiorite. Detailed description of each variety is given in the following paragraphs.

4.4.1 Biotite Microgranite

Megascopically, biotite microgranite is pink in color and fine-grained equigranular (Figure 4.19 a) and may locally be slightly porphyritic texture.

Microscopically, the rock is holocrystalline and hypidiomorphic granular of quartz, alkali feldspar, plagioclase and biotite. The micrographic and granophyric textures of quartz and alkali feldspar intergrowths are conspicuous. Most units are of micrographic type but some have a radiate arrangement (granophyric texture) at their margins (Figures 4.19 b and c). The microgranite with micrographic quartz-alkali feldspar intergrowth is known as a granophyre. This texture is evident that the micro-intensive rocks are likely to crystallize directly from the melt of rhyolite (Hatch et al., 1984).

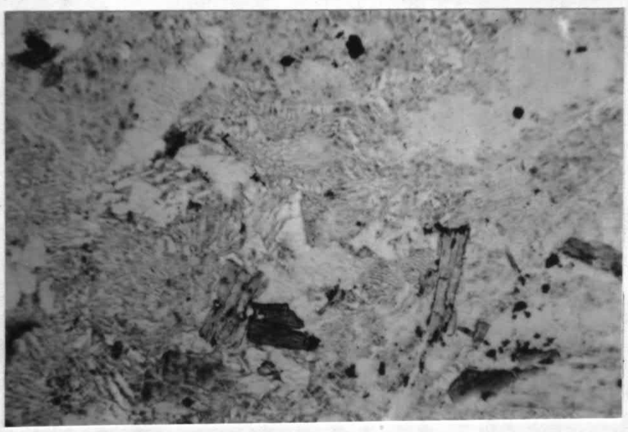
The mineral constituents of microgranite are composed almost totally of quartz, alkali feldspar and plagioclase : more than half of the feldspar is alkali feldspar. Other minerals, for instance, biotite, chlorite and opaques constitute less than 5 modal percents.

Quartz generally forms as interstitial anhedral grains, and crystal aggregates of various size. Micrographic quartz and granophyric quartz intergrowth within alkali feldspar are also common. The average grain size of quartz is approximately 0.2 mm. Its content varies in amount from 20 to 25 percents by volume and is normally less than those of feldspars.

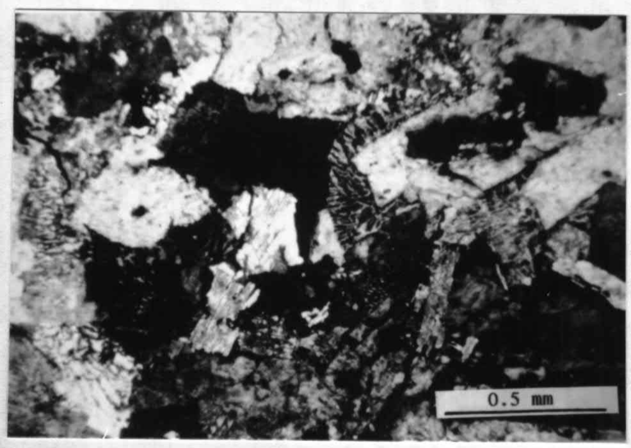
Alkali feldspar, mostly occurs as microcline, is the most abundant constituent of the biotite microgranite, and making up to 50-55 modal percents of its total volume. Alkali feldspar is

(a)

Figure 4.19a Biotite micro-granite.



(b)



(c)

Figure 4.19b,c Photomicrographs of biotite microgranite showing the intergrowth of quartz and alkali feldspar; most are of micrographic type but some have a radiate arrangement (granophyric texture) at their margins.

(b= uncrossed nicols; c=crossed nicols)

present predominantly as anhedral to subhedral crystal varying in size from 0.1-0.4 mm. It commonly shows micro-pertite and contains the micrographic and granophyric quartz intergrowth.

Plagioclase generally forms as subhedral to euhedral tabular crystal, ranging in size from 0.3-1 mm. Its content is about 15-20 percents of the total volume. Plagioclase crystals are commonly characterized by albite and Carlsbad-albite twins and weak normal zoning. The composition of these crystals falls within the range of oligoclase (An_{21-23}). In general, plagioclase has been subjected to moderate alteration by processes of sericitization and saussuritization at its core, while at its margin is usually rimmed by a radiate arrangement of quartz and alkali feldspar intergrowth known as myrmekitic texture.

Biotite is only the essential mafic mineral found in biotite microgranite. It ranges in size from 0.01-0.2 mm, but the average is about 0.1 mm. It contains only 1-3 percents of the total mineral constituents. Biotite generally occurs as small individual flakes among other minerals and also as inclusions within plagioclase and alkali feldspar. This texture indicates that biotite is likely to be the first mineral to have been crystallized from the melt. Post-magmatic replacement by chlorite, either totally or partially is also present. Other accessory minerals are zircon and iron oxides.

4.4.2 Hornblende Microdiorite

Megascopically, hornblende microgranite is light green in color and fine-grained equigranular (Figure 4.20 a) and may locally show slightly porphyritic texture.

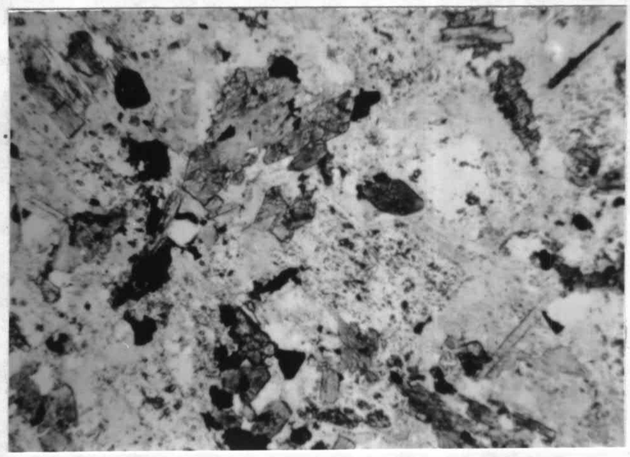
Microscopically, the rock is holocrystalline and hypidiomorphic granular (Figures 4.20 b and c). The average grain size is approximately 0.3 mm. The rock is composed mostly of two essential minerals : plagioclase and hornblende. Other subordinate minerals include quartz, alkali feldspar, pyroxene and opaques. Sphene and apatite are common accessory minerals, while chlorite, epidote and sericite are secondary ones.

Plagioclase is the most abundant constituent of the whole rock, and making up nearly two-third (about 60-70 modal percents) of its total volume. Plagioclase generally occurs as subhedral to anhedral tabular crystals, ranging in size from 0.2-1.5 mm. Plagioclase crystals commonly show albite and Carlsbad-albite twins and normal zoning. The composition of plagioclase ranges between oligoclase and andesine (An_{28-32}). The large crystals of plagioclase commonly contain the inclusions of hornblende, pyroxene and opaques, while at their margins are often rimmed by radiate myrmekite of alkali feldspar. The post magmatic alteration by sericitization and saussaritization within the crystals of plagioclase are also common.

Hornblende is the essential mafic mineral found in this rock, which its content ranges from 15 to 20 volume percents. It

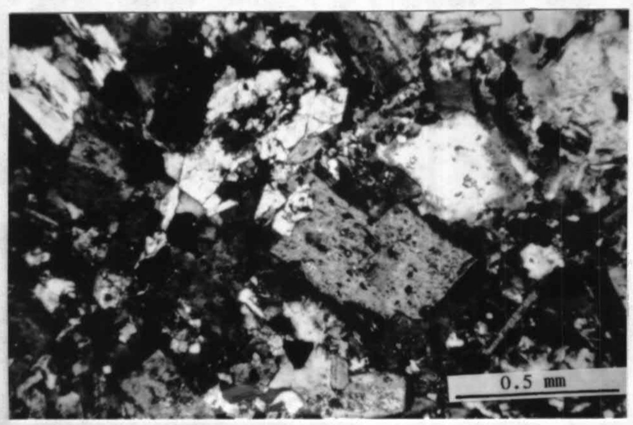
(a)

Figure 4.20a Hornblende micro-diorite.



(b)

Figure 4.20b,c Photomicrographs of hornblende microdiolite showing two essential minerals: plagioclase and hornblende. (b= uncrossed nicols; c=crossed nicols)



(c)

commonly occurs as subhedral crystals and their average size is about 0.1 mm. The crystals of hornblende normally show weak pleochroism from greenish brown to yellowish brown. Partially replacement of hornblende by chlorite is very common.

Augite is another mafic mineral found in this rock, but its modal content makes up only 1-2 percent. It commonly occurs as subhedral to euhedral crystals and their average size is about 0.1 mm. Some crystals of augite are rimmed or internal replaced by yellowish brown hornblende. Small crystals of augite are also found to be included by plagioclase. These evidences indicate that augite is the first of mafic minerals that has been crystallized from the melt.

Quartz occurs as minor amount in this rock. It makes up about 5 modal percents. In general, quartz is present as very small interstitial crystal, indicating that it is in the last stage of crystallization.

Alkali feldspar is orthoclase and occurs in rather small amount in this rock. It has crystallized in rather late stage as discrete tabular crystals and interstitial anhedral grains.

Opaque and sphene are common accessory minerals, while chlorite, epidote and sericite are secondary minerals. They are constituted to be less than 5 modal percents.

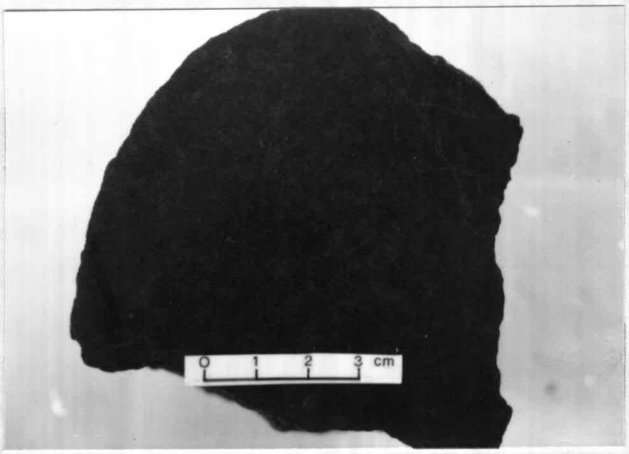
4.5 Late Basalt

Late basalt occurs mostly as effusive lava flow that is widespread and flat-lying along the margin of the volcanic field and accumulates and forms as crudely stratified cones at the north of the volcanic field. It also occurs as dykes that commonly extruded along the northwest-southeast fault and cut through sequences of the older volcanic rock.

In general, the rocks of the late basalt are dark gray or greenish gray, dense, fine-grained and porphyritic texture (Figure 4.21 a). The rocks sometimes contain spheroidal vesicles which often filled with such silica minerals as opal, agate and chalcedony. The fine-grained groundmass often shows the flow texture. Phenocrysts of lath-shaped, euhedral plagioclase are easily seen. Olivine and clinopyroxene phenocrysts are also recognized.

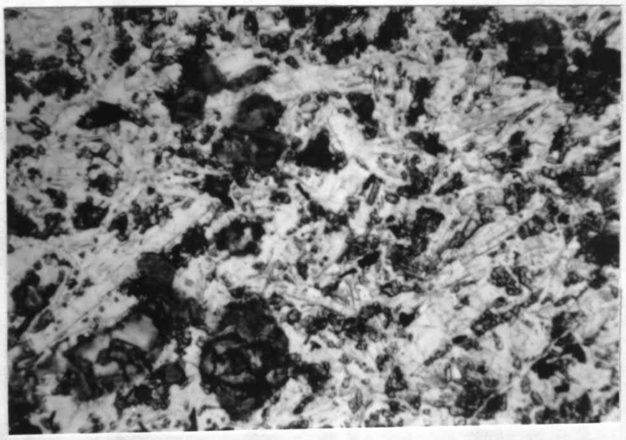
Under microscope, late basaltic rocks are holocrystalline, fine-grained and porphyritic textures. The essential minerals normally consist of olivine and plagioclase which occur as phenocrysts embedded in the groundmass of orientated laths of plagioclase, minute clinopyroxene, olivine and magnetite (Figures 4.21 b and c).

In some specimens, the major mineral constituents of basaltic rocks are composed of clinopyroxene, plagioclase and olivine in descending order of abundance. These crystals always occur as phenocrysts but set in the groundmass of only plagioclase crystals. Subophitic texture of clinopyroxene phenocrysts enclose

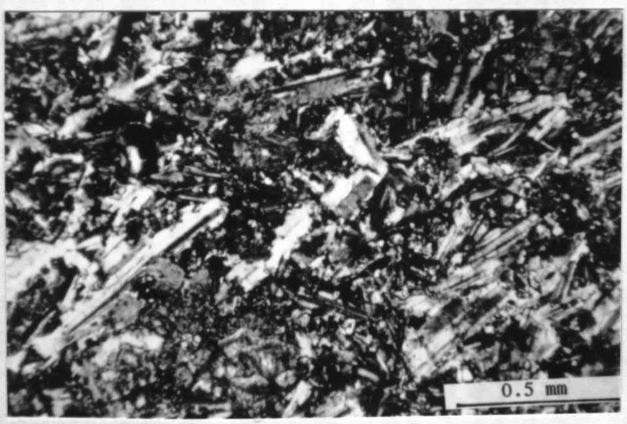


(a)

Figure 4.21a Late olivine basalt.



(b)



(c)

Figure 4.21b,c Microphotographs of late olivine basalt showing olivine phenocrysts in groundmass of orientated laths of plagioclase, olivine, pyroxene and magnetite. Olivine has almost completely been altered to greenish brown chlorophaeite.

(b= uncrossed nicols; c=crossed nicols)

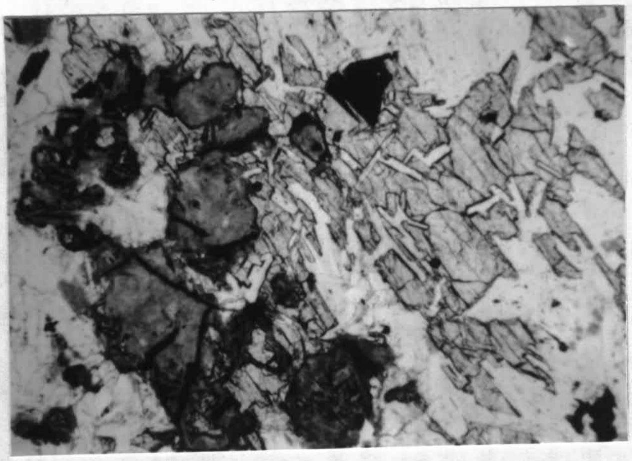
wholly and/or partly small laths of plagioclase is commonly present (Figures 4.22a and b).

Olivine is common in all specimens of late basalt that occurs both as phenocrysts and groundmass or only as phenocrysts in some specimens of basaltic lava flows. Usually, olivine occurs in euhedral crystals that having more or less corroded borders. The alteration to dark green or brownish green chlorophaeite are shown by olivine crystals in nearly all samples.

Plagioclase commonly occurs both as phenocrysts and groundmass. The composition of plagioclase phenocrysts is typically labrodorite (An_{55-62}), but the An-content increases to bytownite (An_{65-72}) in specimens of basaltic dykes (Figures 4.23 a, b and c). The plagioclase crystals are usually lath-shaped and well twinned. Albite twinning is in rather narrow lamellae and is frequently combined with Carlsbad twins. The phenocrysts of plagioclase often show oscillatory zoning.

Clinopyroxene of late basalt is augite. It typically occurs as only phenocrysts or as only minute crystals in the groundmass in any section. The clinopyroxene phenocrysts often enclose wholly and/or partly small laths of plagioclase, showing subophitic texture.

Magnetite is always present in all sections of late basalt. In sections of basaltic dyke, magnetite is present in considerable abundance, so that although it is traditionally referred to as "accessory minerals" it really ranks as essential component (Figures 4.24 a, b and c).



(a)

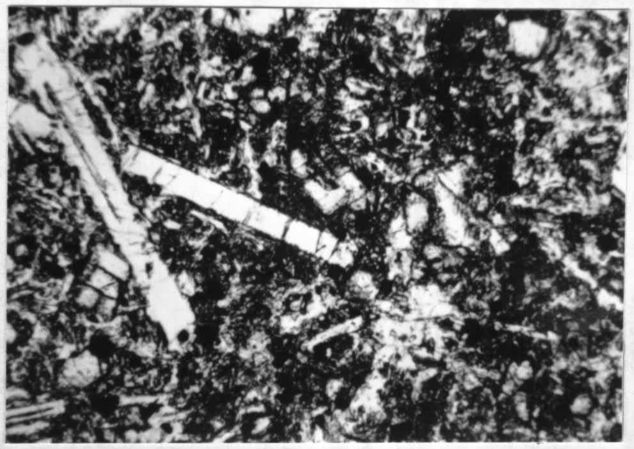
(b)

Figure 4.22a,b Photomicrographs of late olivine basalt showing subophitic texture and consisting of clinopyroxene (augite) and olivine phenocrysts in groundmass of only plagioclase.

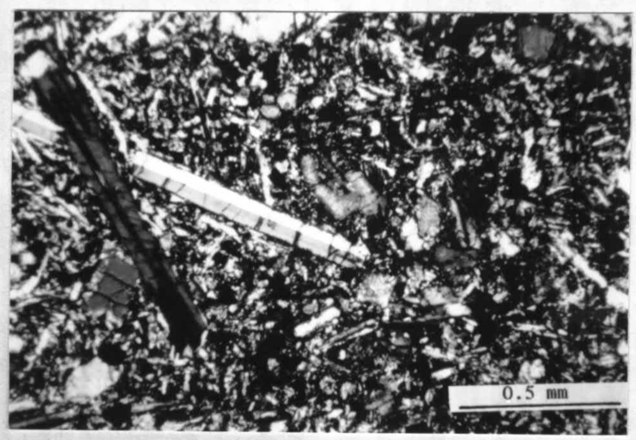
(a= uncrossed nicols; b=crossed nicols)

(a)

Figure 4.23a Basaltic dyke.



(b)



(c)

Figure 4.23b,c Photomicrographs of basaltic dyke showing plagioclase and olivine phenocrysts in groundmass of plagioclase, olivine, pyroxene and magnetite. Plagioclase phenocrysts are bytownite.

(b= uncrossed nicols; c=crossed nicols)