CHAPTER III

VOLCANIC SUCCESSION

3.1 Introduction

Volcanic succession of the Lam Narai volcanic field proposed in this study is the results of the present field observations and previous investigation, especially on the detailed study of Nikom Jungyusuk ans Panya Suriyachai (1987). The term "Lam Narai Volcanic Field", following the geographic volcanic subdivisions of Fisher and Schmincke (1984), is applied herein to all volcanic and related rocks which exposed in the well known Lam Narai district and vicinity areas. This name is more or less equivalent to the term "Lam Narai Volcanic Formation" as proposed by Nikom Jungyusuk ans Panya Suriyachai (1987).

The Lam Narai volcanic field is part of the elongate volcanic region lying along the western margin of the Khorat Plateau. In this area the Lam Narai volcanic field consists of many different lavas and their related pyroclastic rocks, ranging in composition from basalt to rhyolite. The related intrusive rocks (microgranite) which closely associated with rhyolite lavas are also included in this volcanic field. Lately, Nikom Jungyusuk ans Panya Suriyachai (1987) have reported that the eruptive activities producing all volcanic and related intrusive rocks in the volcanic field had been formed in the period of late Cenozoic time which is accordant with the presence of well preserved rhyolitic obsidian (or glass), the orientations of pyroclastic layers, the flows of basalt overlying unconsolidated sediments, paleomagnetic study and isotope age dating (Barr and Macdonald, 1981).

3.2 General Volcanic Succession of the Lam Narai Volcanic Field

From the present field observation, all lavas and their related pyroclastic rocks in the Lam Narai volcanic field form the largest erosional remnant of a once nearly continuous volcanic succession. Throughout the volcanic successions in this volcanic field, the general volcanic succession is relatively simple, beginning with intermediate-composition lavas, changed notably to more silicic pyroclastic deposits, subsequently followed by silicic lavas, and ending with widespread basaltic lavas. This volcanic succession can be mapped as shown in Figure 3.1.

Detailed descriptions of the volcanic succession are shown below.

3.3 Early Intermediate-Composition Lavas

The early intermediate-composition lavas of the Lam Narai volcanic field are proposed for collective sequences of the intermediate-composition rocks composed of basaltic andesite, andesite and dacite. Sequences of these rocks are generally overlain by the deposit successions of silicic tuffs or directly overlain by silicic lavas, where the silicic pyroclastics are absent. As here defined, the early intermediate-composition lavas are thought

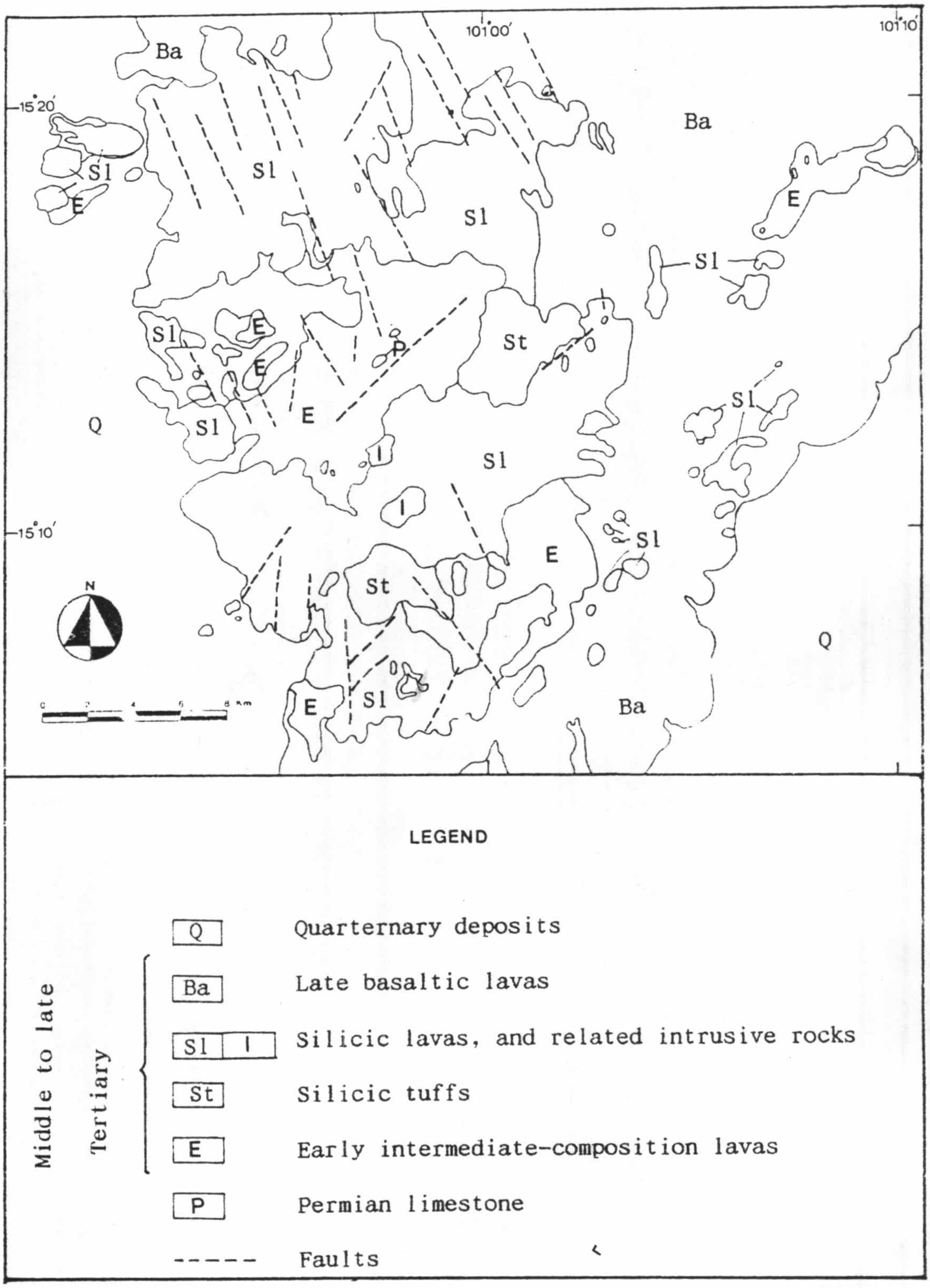

Figure 3.1 Generalized geologic map of the Lam Narai volcanic field (modified after Nikom Jungyusuk and Panya Suriyachai, 1987).

to be the products of the initial stage of volcanic activity before the pyroclastic deposits of more silicic rocks produced by the more violent volcanic explosions.

From the field observation, the early intermediate-composition lavas have been erupted from numerous local volcanoes that scattered throughout the volcanic field. Individual centers generally erupted monotonously uniform sequences of basaltic andesite, andesite or dacite (Figure 3.2), although at a few volcanoes the rocks apparently range from basaltic andesite to rhyodacite. The eruptive sequence of these early volcanic rocks is relatively intricate. However, evidences from field relations and structural significance suggest that the general petrologic progression of the early volcanic rocks seems toward more silicic types as in ascending sequence.

3.3.1 Basaltic Andesite

Basaltic andesite of the early intermediate-composition lavas is the monotonous sequences of mainly basaltic andesite lava flows, flow breccias and minor inter layered explosion breccias. It apparently represents the first major lava eruptions of the initial volcanic activity which may probably continue to the violent pyroclastic explosions of more silicic rocks. In general, sequences of basaltic andesite are sharply overlain by the successions of silicic tuffs, except where silicic pyroclastics have not been deposited, they are directly overlain by silicic lava flows. However, at least one sequence of basaltic andesite is found to be interlayered with layers of silicic tuffs (Figures 3.3 a and b).

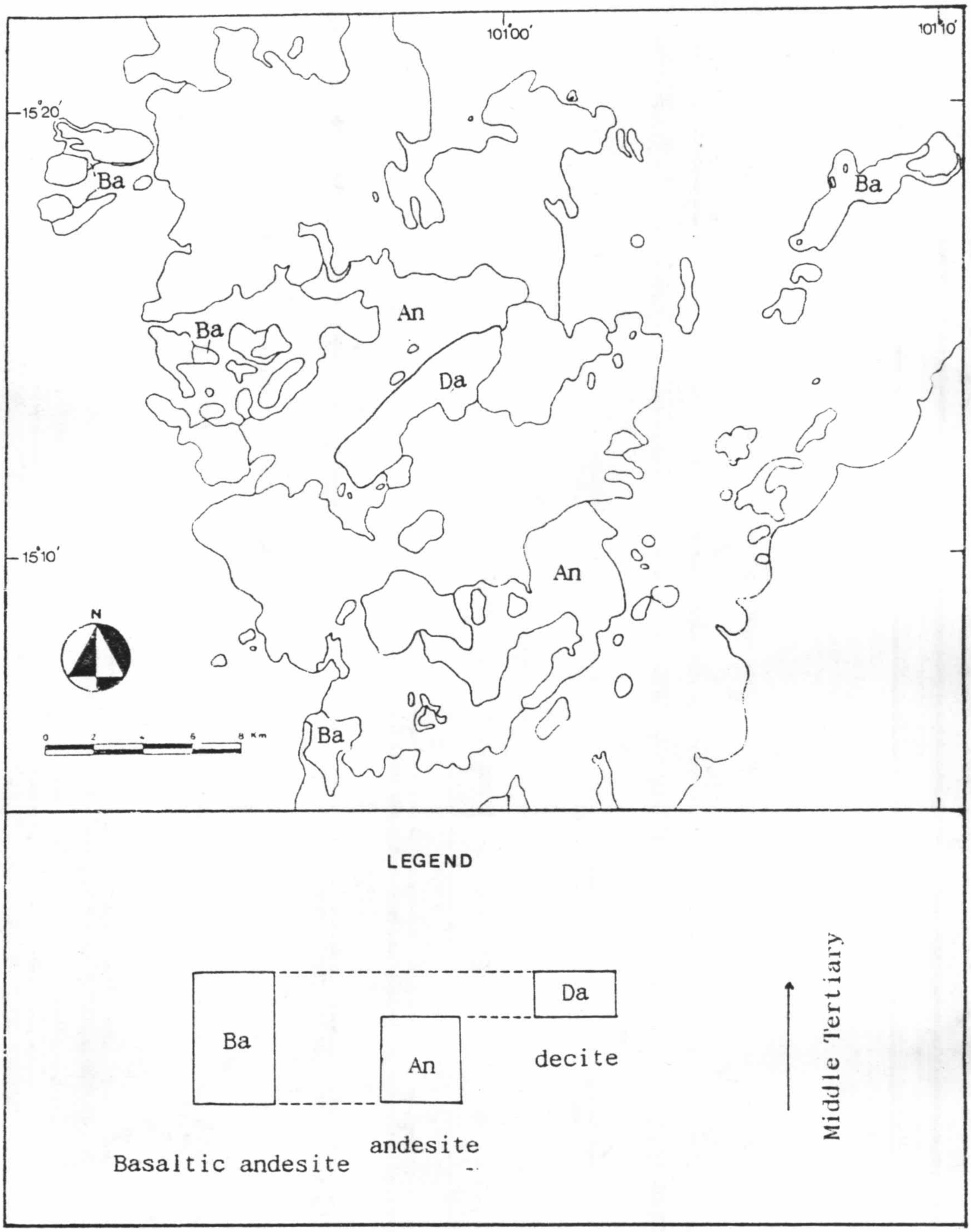

Figure 3.2 Distribution of the early intermediate-composition lavas, dividing into basaltic andesite, andesite and dacite, based on mapping by Nikom Jungyusuk and Panya Suriyachai (1987).

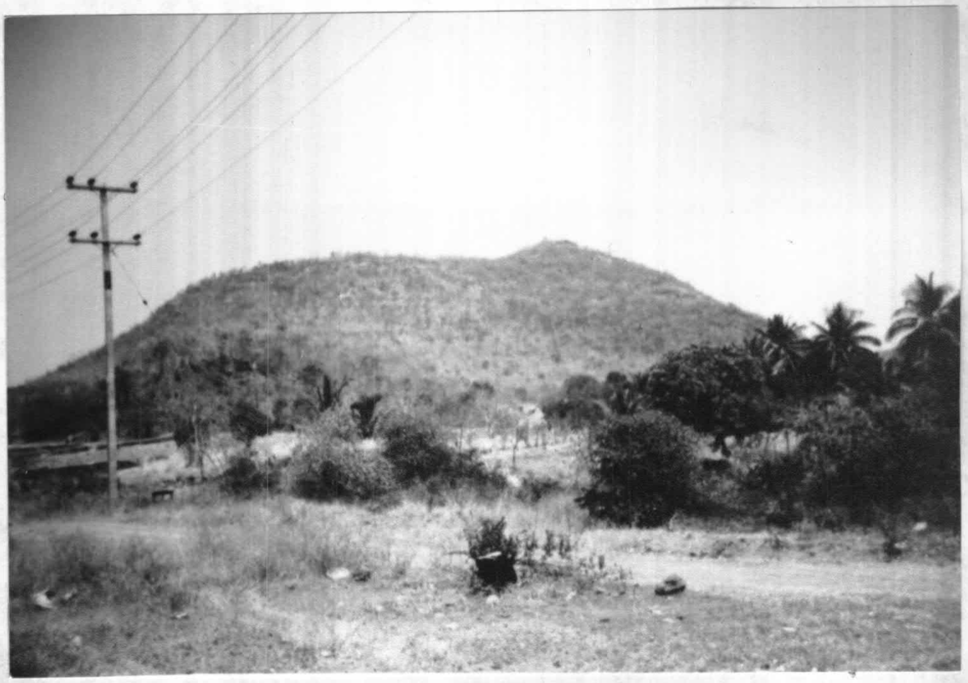

Figure 3.3a A crudely stratified cone of basaltic andesite, at the north of Ban Hin Phloong, consisting mostly of basaltic andesite lavas and minor interlayered rhyolitic ash-fall deposits.

Figure 3.3b Stratified layers of rhyolitic ash-fall deposits sandwiched between the underlying and overlying basaltic andesite lavas.

This evidence clearly indicates that the eruptions of the early intermediate-composition rocks and of more silicic rocks have been erupted in close geological event.

From the field observation, the accumulations of basaltic andesite are commonly exposed along margins of the volcanic field. In most places, basaltic andesite is generally erupted from a central (or point source) vent forming a high cone or a few small cones surrounding at that principal vent. However, at the northeast of the volcanic field, a small group of basaltic andesite cones aligns relatively in the northwest-southeast direction (Figure 3.4). This alignment probably represents an outline of a small restricted fissure vent system which confine to the extrusions of basaltic andesite along this direction.

At each vent area, the general accumulative facies of basaltic andesite volcano are relatively continuous and usually form as the unrefined stratified cone, for instance, at Khao Tham (Figures 3.5 a, b and c) and Khao Takon (Figures 3.6 a and b). In general, the unrefined stratified cone of basaltic andesite at the vent area consists mostly of explosion breccias that are commonly interlayered with accompanying basaltic andesite lava flows and flow breccias. The explosion breccias are composed mainly of highly vesiculated lapilli, blocks and bombs, and agglutinated lava spatters, while ash particles are rather rare or absent. The depositional facies of these pyroclastics are generally characterized by poorly sorted and poorly bedded (Figure 3.5 b), if beds are developed, however, in general, they are laterally discontinuous (Figure 3.5 c). The deposits are sometimes slightly

Figure 3.4 The northeast-southwest range of the early basaltic andesite.

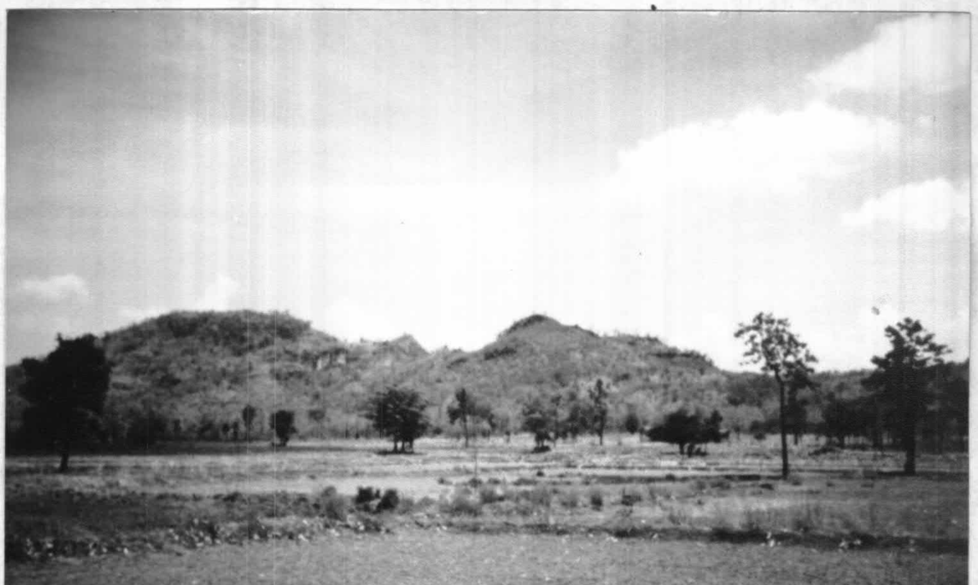

Figure 3.5a An unrefined stratified cone of basaltic andesite show erosional remnants of scoria fall deposits. Basaltic andesite cropped out at the eastern part of Khao Tham, while succession of silicic tuffs and overlying rhyolite lava covered its western flank.

Figure 3.5b Close-up, scoria-fall deposits consist mostly of lapilli and blocks of basaltic andesite. The deposit is poorly sorted and poorly bedded.

Figure 3.5c The deposits of basaltic andesite pyroclasts sometimes developed beds, but, in general, they are laterally discontinuous; Khao Tham.

Figure 3.6a The succession of scoria-fall deposits and interlayered lava flows of basaltic andesite overlain by a rhyolite lava flow,Khao Takon.

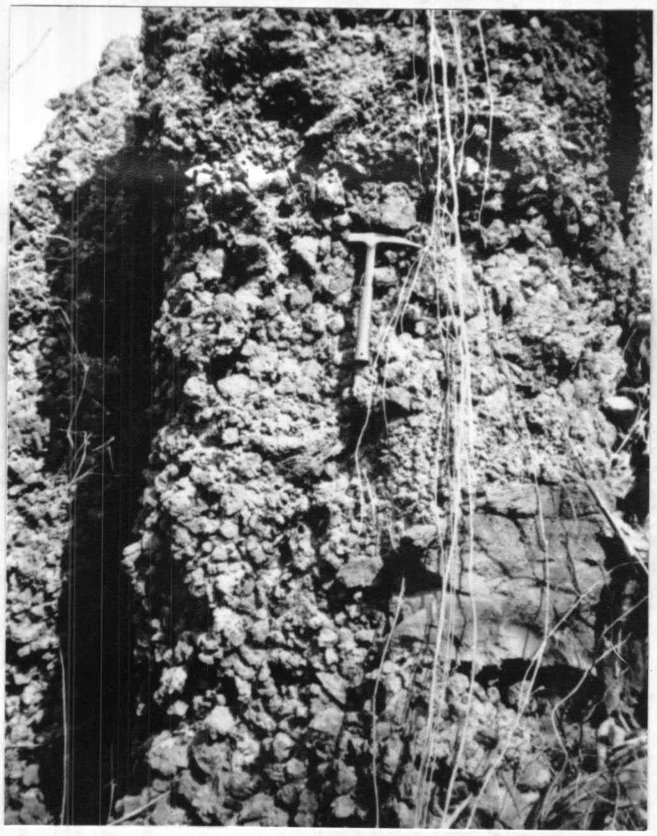

Figure 3.6b Scoria-fall deposits consist mostly of lapilli and blocks, ash is rather rare or absent. The deposits show slightly normal grading.

normal graded (Figure 3.6 b). Accompanying basaltic andesite lava flows and flow breccias that closely interlayered with basaltic andesite pyroclastics are typically highly vesiculated, particularly at the basal and the upper parts of the flow while rather less vesiculated at the central portion of that flow. The top layer of the basaltic andesite cone is usually the layer of highly vesiculated lapilli, blocks and bombs, before its top is sharply overlain by the overlying layers of silicic tuffs or silicic lavas.

In general, the depositions of basaltic andesite pyroclastics have limited aerial extent. Therefore, a highly stratified cone or a small group of a few basaltic andesite cones can more or less represent their source vent areas.

On the other hand, at vent areas, many basaltic andesite cones or volcanoes are composed predominantly of basaltic andesite lava flow and interlayered flow breccias. In general, the accumulative facies of these volcanoes are also formed as unrefined stratified cones (Figure 3.7 a). Individual lava flows of basaltic andesite cones are relatively thin, about 0.5-1 m thick. One flow layer can be recognized by irregular vesiculated block lavas lying at the top and the bottom of flow, while rather less vesiculated lava is included at the basal portion of that flow (Figure 3.7 b).

As aforementioned, many sequences of basaltic andesite cones or volcanoes are composed mainly of coherent lava flows and flow breccias. Throughout the field observation, many of the features of these basaltic andesite lava flows can be subdivided into two main types : pahoehoe and aa lavas. These two terminologies

Figure 3.7a A unrefined stratified cone of basaltic andesite consists mostly of lava flows, and interlayered flow breccia. It is overlain by the deposit succession of rhyolitic tuffs , Khao Sab Bon.

Figure 3.7b Basaltic andesite lava flows interlayered with flow breccia, Khao Sap Bon.

are the Hawaiian names given to two main types of subaerial basaltic lava flows that have been distinguished from studies in Hawaii (Cas and Wright,1987).

In the volcanic field, pahoehoe lavas are common on smooth, gentle slope, and tend to form rather thin flow (often less than 1 m thick). Internally pahoehoe lavas are characterized by large numbers of smooth, and regular spheroidal vesicles.

In contrast, aa lavas are generally fragmented, and thicker than pahoehoe flows (about 2-3 m, may be upto 20 m thick). Internally, aa is characterized by irregular elongate vesicles that are drawn out in response to internal flow, and a stratification consisting of a massive lava body sandwiched between layers of fragmented lava that may be welded together (Figure 3.8).

Although pahoehoe and aa lavas are the predominant types of subaerial basaltic andesite lava flows occurring in the volcanic field. However, the formation pillows or pillow lavas, the most distinctive feature of basaltic lava erupted under water, are also present in some places. For instance, at the lower part of Khao Lon's successive section; basaltic andesite lava flows have formed as pillow lavas and then were overlain by many thin layers of simple lava flows, and the other one at a small hill which was cut into pillow form of highly weathered basaltic andesite (Figures 3.9 a and b).

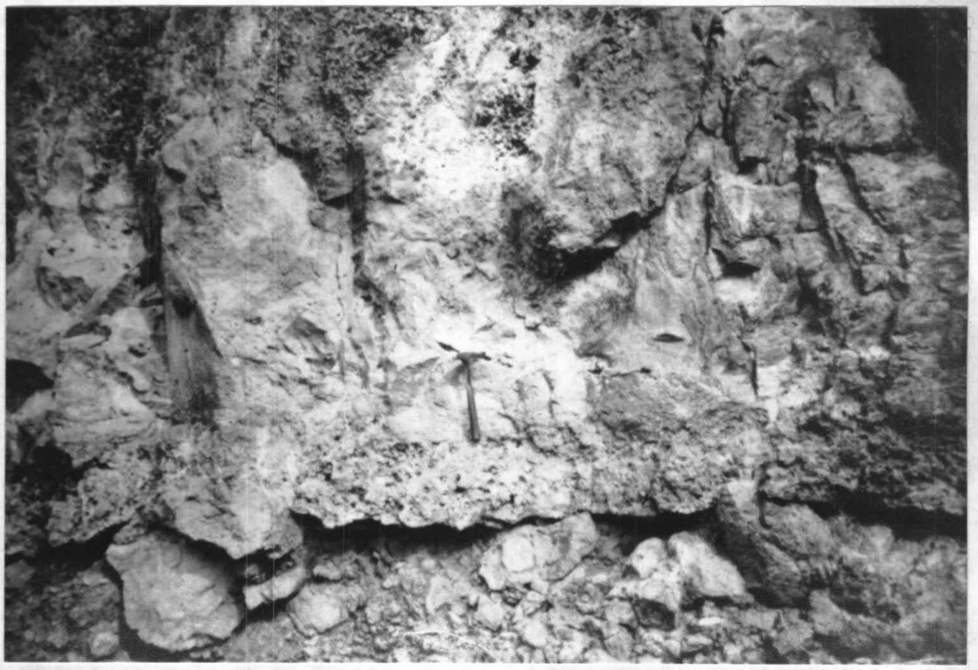

Figure 3.8 An aa lava flow,massive lava body sandwiched between layers of fragmented lavas which were locally welded together, Khao Takon, Grid reference 967930.

Figure 3.9a Highly weathered of the early basaltic andesite is overlain by late basaltic lava flow, Grid reference 233855.

Figure 3.9b Close-up, pillow lavas developed radial and concentric cooling joint.

3.3.2 Andesite

Andesite of the early intermediate-composition lavas is given to the monotonous sequences of mostly andesite lava flows and flow breccias that crop out at the central and the southeastern parts of the volcanic field (Figure 3.2). It apparently represents one of the first major lava eruptions of the initial volcanic activity of the volcanic field as well as of the early basaltic andesite, just described. This rock is equivalent to andesite and quartz latite proposed by Nikom Jungyusuk and Panya Suriyachai (1987).

At the central portion of the volcanic field, many sequences of andesite, the probable vent areas, apparently align in the northeast-southwest direction. Some areas the andesite lavas are extruded and cut-through the Permian limestones. In general, sequences of andesite are sharply overlain by silicic tuffs or silicic lavas. This volcanic succession is similar to the successions that deposit in the southeastern part of the volcanic field. At this part, a sequence of andesite distributing in the northeast-southwest direction is mostly overlain by silicic lava flows, while its lower eastern flank is covered by late basaltic lava flows.

Andesite lavas usually occur as small-volume, short block lava flows, and as domes. These features indicate that andesite lavas have been extremely viscous and have high yield strength when extruded. Andesite lavas have steep flow-fronts with screes of autobrecciated lava. Internally, behind their flow fronts, andesite lavas are usually massive. Andesite lavas sometimes have a well developed, steep or flat-lying, sheeted structure with aligned tabular and platy phenocrysts. This flow foliation is generally attributed to shear partings developed during laminar flow.

3.3.3 Dacite

Dacite of the early intermediate-composition lavas is named for a small group of monotonously uniform sequences of dacitic lava flows and flow breccias that is confined to extrude along the northeast-southwest fault at the central portion of the volcanic field (Figures 3.2 and 3.10). It seems to represent the last stage of the major lava eruptions of the initial volcanic activity before changing to the eruption of more silicic rocks. This rock is equivalent to quartz trachyte as proposed by Nikom Jungyusuk and Panya Suriyachai (1987).

The northeast-southwest fault, which confined the extrusions of dacite is probably a small fissure vent system, in similar manner to that observed in basaltic andesite. The northeast-southwest dacite is later cut-through by late andesitic dyke at its central part, and intruded by a small body of shallow pluton (microgranite) in the south. Along the lower eastern flank of which range the dacite is covered by silicic lava flows, while in some localities is subsequently overlain by successions of silicic tuffs.

Dacite lavas usually form as domes (Figure 3.10). Their lava flows have steep flow-fronts. Internally, dacite lavas are massive, usually developed, often flat-lying, discontinuous

Figure 3.10 Dacitic domes appearently align in the northeast-southwest directon, the central portion of the volcanic field.

laminated structures. This flow foliation, as well as mentioned in andesite, is also attributed to shear parting developed during laminar flow.

3.4 Silicic Tuffs

After eruptions of the early intermediate-composition lavas had ceased or nearly ceased, the eruptive activity of the volcanic field changed notably to the violent pyroclastic explosions of more silicic rocks. These explosive pyroclastics consist of variable proportions of ash shards, and ash-, lapilli-, and block-sized clasts of varying vesicularity of juvenile pumice and lithic materials. The term silicic tuffs used in this study are, therefore, applied to the deposit successions of all silicic pyroclastic rocks with irrespectively their grainsizes and other accompanying compositions which being exploded and deposited during this eruptive activity. The interbedded epiclastic sediments which was re-deposited during this time are also included.

In fact, the deposits of silicic pyroclastic rocks apparently widely distributed throughout the volcanic field and vicinity. However, the deposit successions of these pyroclastic rocks have been eroded extensively and/or perhaps they have been completely covered by subsequent lavas.

From the field observation, the deposit successions of silicic tuffs usually expose along the edges of the high rhyolitic volcanic terrain, particularly at the northwestern and western parts of the volcanic field, or rest on the tops of the preceeding intermediate-composition lavas. These deposit successions of silicic tuffs, in general, form as the steepest topographic terrains on which their tops are mostly or completely overlain by the following rhyolite lavas. Therefore, it is considerably difficult to separate the silicic tuffs from the overlying lavas. However, they are mappable wherever their depositional margins exposed as shown in Figure 3.11.

The deposit successions of silicic tuffs, in general, are composed of a great variety of different depositional facies and also differences in deposit sequences. The different depositional facies of silicic tuffs, for instance, pyroclastic fall, flow, and surge deposits, suggests that these deposits originated from different depositional processes, as well as the differences in deposit sequences reflect their differences in eruptive events. However, the general deposit succession of silicic tuffs in the volcanic field are very similar.

In the present study, the deposit succession of rhyolitic pyroclastic rocks at Khao Rawang is selected to study in detail, representing the type section of the volcanic field.

3.4.1 The Deposit Succession of Rhyolitic Pyroclastic Rocks at Khao Rawang

The deposit succession of rhyolitic pyroclastic rocks at Khao Rawang is the only largest erosional remnant of a once nearly continuous succession that still preserved and well exposed on the steep slope of Khao Rawang, while its nearby area has apparently

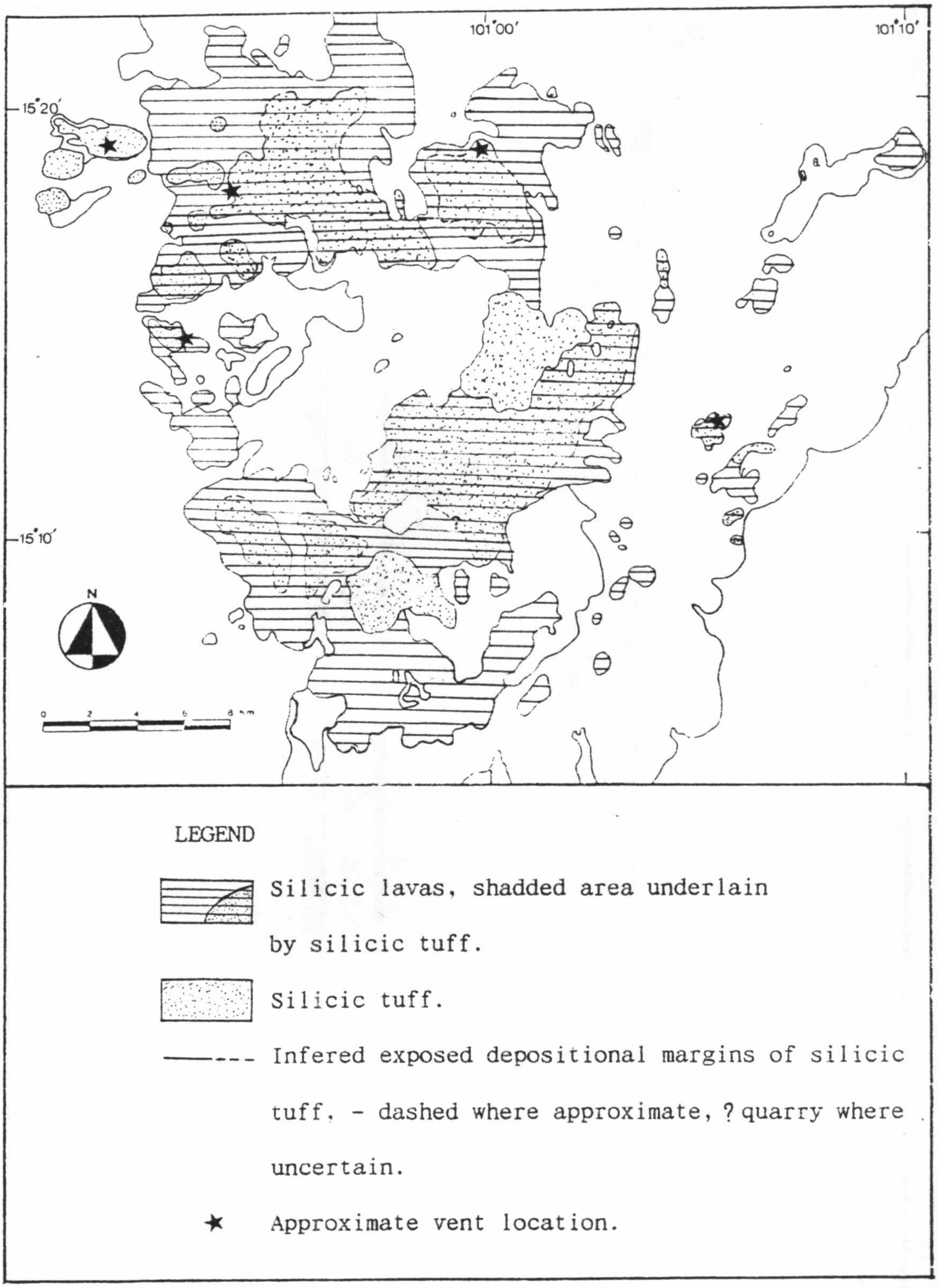

Figure 3.11 Outcrop areas and exposed depositional margins of silicic tuffs, based on mapping by Nikom Jungyusuk and Panya Suriyachai (1987).

been eroded. The excellent exposure of pyroclastic deposits is lying along the southern steep slope of Khao Rawang at where the succession has been studied in detail (Fig 3.12).

3.4.1.1 Stratigraphy of the Deposits

The successive section of rocks at Khao Rawang is composed of a lower sequence of the early basaltic andesite lava flows, follow by the overlying of the deposit succession of rhyolitic pyroclastic rocks, and subsequently covered by a single rhyolite lava flow at the top (Figure 3.12). The succession of pyroclastic deposits starts from the elevation of about 150 m above mean sea level. The lower sequence of the deposits has been exposed and covered partially by soils and sediments of their weathered products. Therefore, some informations of the earlier deposits will be lacking.

Throughout the succession of pyroclastic deposits exposed on the cliff of Khao Rawang, the lower unit and the upper unit of the deposits are primarily identified and divided (Figure 3.13). The lower unit are further subdivided into 6 thin eruption units numbering 1 to 6 in ascending order, whereas the uppermost unit is identified as the only one eruption unit, number 7, at the top (Figure 3.14). Many of the small eruption units (units 1 to 6) are separated by thin oxidized fine ash layers occurring at their tops, and have a sharp upper contact with the overlying eruption unit. The thickness of eruption units 1 to 7 range from 20 cm up to 20 m. The first six eruption units are relatively thin, ranging from 20 to 90 cm, whereas the eruption unit 7 is very thick

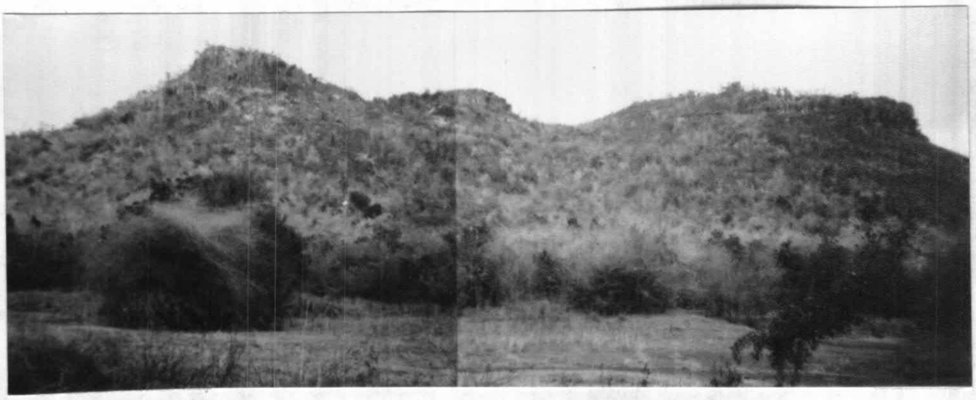

Figure 3.12 The successive section of Khao Rawang consists of the lower sequence of the early basaltic andesite lavas (mostly covered by talus), the deposit succession of rhyolitic pyroclasts, and a rhyolite lava flow overlying at the top, view to the east.

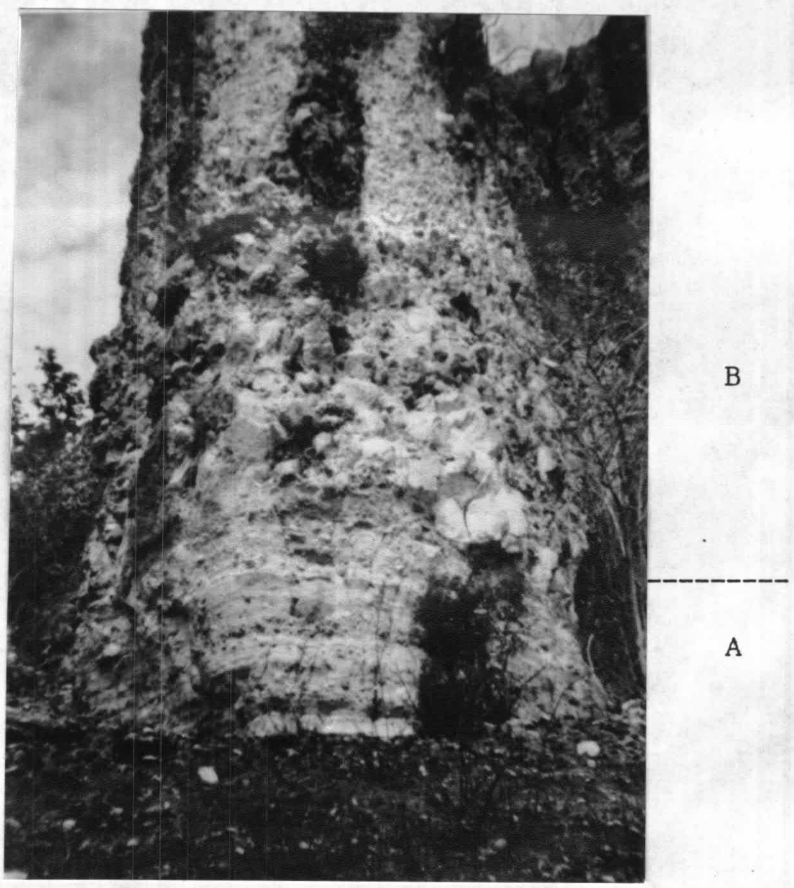

Figure 3.13 The succession of pyroclastic deposits exposed on the southern cliff of Khao Rawang are subdivided into the lower unit and the upper unit.

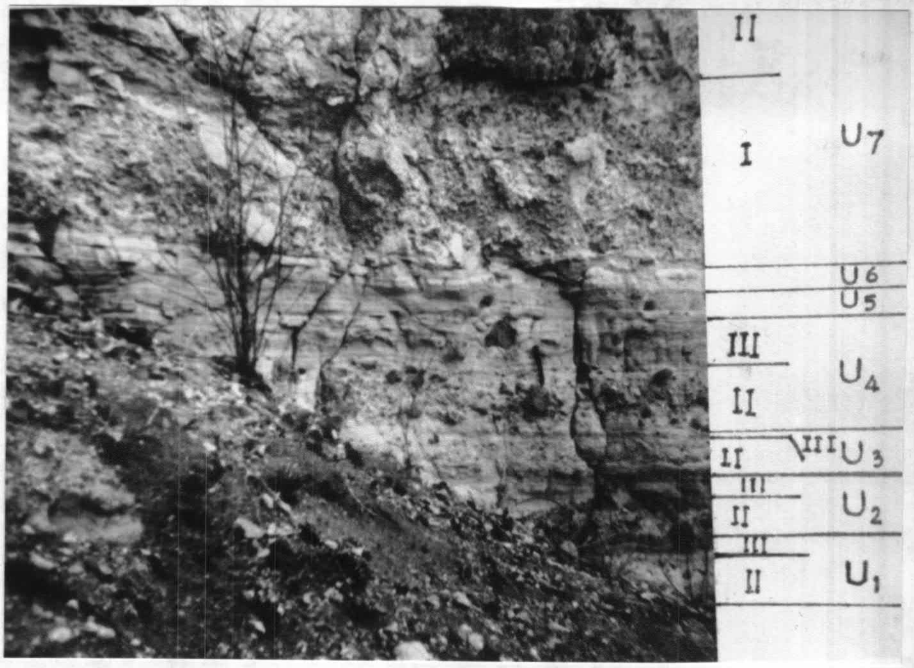

Figure 3.14 The lower unit consists of eruption units 1 to 6 (U 1-6), while the upper unit is a single unit (U7). Beds I, II and III represent a layering scheme in the pyroclastic flow unit proposed by Sparks et al. (1973).

and has a thickness of about 20 m. The eruption unit 1 is the basal lowermost exposed unit in the studied section, it shows a sharp contact with the top of the precursory deposits which mostly are now covered by talus. Its top is marked by thin, pink ash layers which are immediately overlain by the overlying eruption unit 2. These top feature markers are also characterized in the overlying eruption units 2, 3, 4 and 5. However, for the upper eruption unit 7, the oxidized fine ash layers is absent at the top instead it is continuously overlain by a single rhyolite lava flow.

Eruption unit, a term used in the present study is referred to a deposit that originates from an eruption pulse, phase, or an eruption (Fisher and Schmincke 1984). The term is neither a rock-stratigraphic unit nor a volcanic unit, but an entity that relates to both, and may consist of one or several beds.

Bed, the rock-stratigraphic unit, will refer to stratified deposits that are composed of relatively homogeneous material, and separated by well-defined planes from the other beds.

3.4.1.2 Depositional Characteristics of the Eruptive Units.

Eruption Unit 1

The basal eruption unit 1 is made of two beds in sharp contact. The lower bed (II, U1, Figure 3.14) is the thicker bed of this eruption unit, averaging 45 cm. It contains lapilli and coarse ash of juvenile pumice and cognate basaltic lithic clasts of

Figure 3.15 Eruption unit 1 is composed of two beds in sharp contact. The lower bed(bedII) shows slightly reverse grading of lapilli, coarse pumice ash and basaltic lithic clasts. The upper bed is marked by pink, pumice ash. The knife points to the contact between the lower bed and upper bed.

varying vesicularity set in white fine pumice ash matrix. The lower bed is massive and poorly sorted, but lapilli and coarse ash of both pumice and lithic clasts are slightly reversely graded (Figure 3.15) while the proportion of the fine pumice ash matrix increases from base to top. At its very top the more massive bed is composed mostly of fine pumice ash and has a sharp upper contact with the overlying upper bed.

The upper bed(III, U1, Figure 3.14) is irregular in thickness, ranging from 4 to 11 cm. It is essentially composed of pink coarse and fine pumice ash that represents the finest fraction of the eruption unit. The deposit is generally stratified and may locally formed as pinch and swell structures. Its top surface irregular, and sharply overlain by the overlying eruption unit 2.

Eruption unit 2

The eruption unit 2 averages 40 cm thick. It rests with sharp contact on the oxidized upper bed of the underlying eruption unit 1. It is also made up of two beds.

The lower bed(II, U2, Figure 3.14) is relatively thicker than the upper bed, averaging 25 cm thick. It is characterized by massive and poorly sorted, particularly of fine ash matrix, whereas the larger clasts both of pumice and basalt show reverse coarse-tail grading that tend to concentrate at the top of the bed. At the top it is cut by the overlying upper bed (Figure 3.16). The large pumice and basaltic clasts in this bed are higher in number and larger in grain size when compared with the lower bed

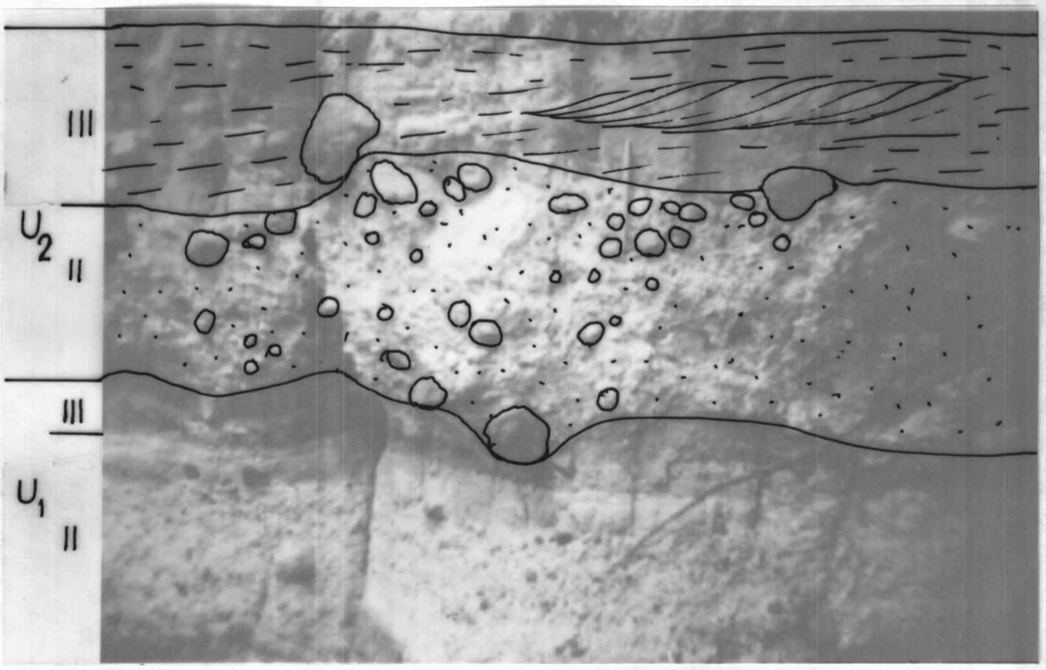

Figure 3.16 Eruption unit 2 consists of two beds in sharp contact. The lower bed is massive, poorly sorted, but show reverse grading of the larger clasts. The upper bed shows dune form and cross stratifications.

of the underlying eruption unit 1.

The upper bed (III, U2, Figure 3.14) averages 20 cm in thickness. It contains pink fine pumice ash, the finest fraction of the eruption unit, which average content increases from base to top of the bed. The upper bed is typically well-stratified or laminated. Low-angle cross lamination and dune-forms are generally present at the base of the bed and gradually transform upwards to planar lamination at the top. This upper bed is sharply truncated and overlain by the eruption unit 3.

Sorting of the deposit generally improves gradually from base to top of the eruption unit and becomes better in the finer-grained upper part of the deposit.

Eruption unit 3

The eruption unit 3 (Figure 3.17) is made of two beds in sharp contact, averaging 30 cm for the total thickness.

The lower bed (II, U3, Figure 3.14) the thicker bed of the unit, is composed of lapilli and coarse ash of juvenile pumice and basaltic lithic clasts set in fine pumice ash matrix. The deposit is typically characterized by massive and poorly sorted. However, it may show slightly reverse grading of the larger pumice and lithic clasts.

The upper bed(III, U3, Figure3.14) is relatively thin planar stratified of pink fine pumice ash. Its top is sharply

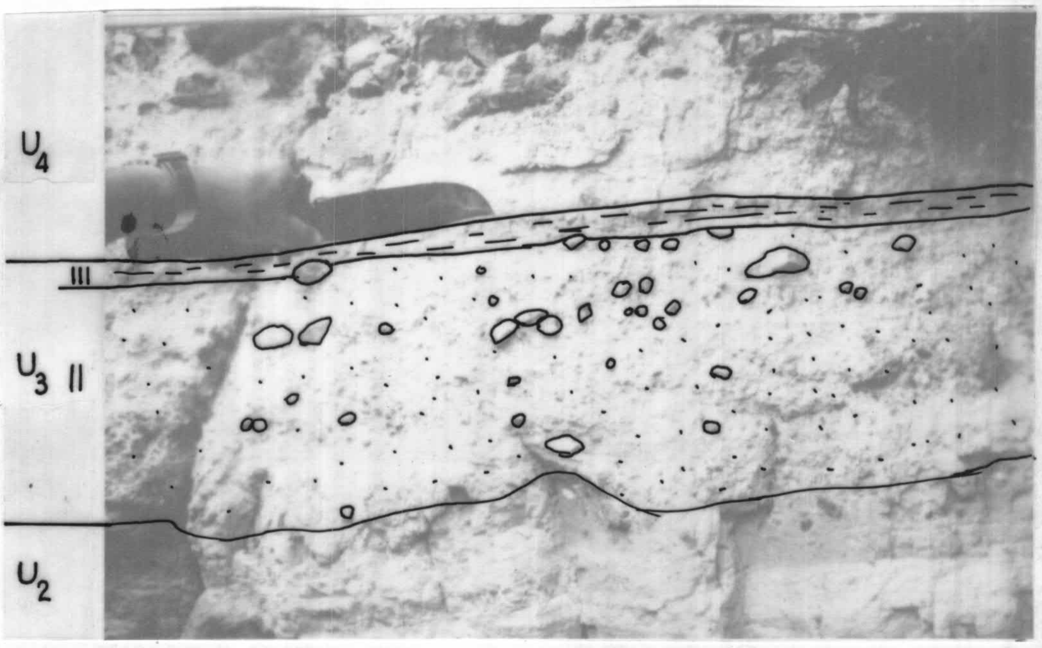

Figure 3.17 Eruption unit 3, the lower bed is typically poorly sorted, but show coarse-tail reverse grading of the larger clasts. The upper bed is relatively thin, stratified, and sharply truncated by the eruption unit 4.

overlain by the eruption unit 4.

Eruption unit 4

The eruption unit 4, averaging 60 cm thick, is made of two beds in sharp contact. The unit is similar in composition and depositional characteristics to the underlying eruption units (units 1, 2, 3). Comparing to the eruption unit 1, 2 and 3, basaltic lithic clasts of the eruption unit 4 increases both in proportion and grain size. Diameters of most lithic clasts are commonly larger than 2 mm with the average of 4 cm. The largest clasts may possibly be up to 55 cm in size. These clasts range in vesicularity from very high vesicular to dense.

The depositional characteristics of the eruption unit 4 is characterized by: the lower bed (II, U3, Figure 3.14), averaging 34 cm thick, is generally poorly sorted with the larger lithic clasts tend to concentrate at the central portion of the deposit and bringing about feature of reverse grading from the basal to the central part of bed and normal grading from the central to the upper part of bed; the upper bed (III, U3, Figure 3.14) with a regular thickness of 30 cm, generally contains cross lamination at the base of the bed and gradually becomes to planar laminaetion at the uppar part (Figure 3.18). Sedimentary structures, for instance, pinch and swell structures or dune forms are common. Bomb-sag structures are also occasionally found where the bed has been impacted by the large ballistic lithic clasts (Figure 3.19).

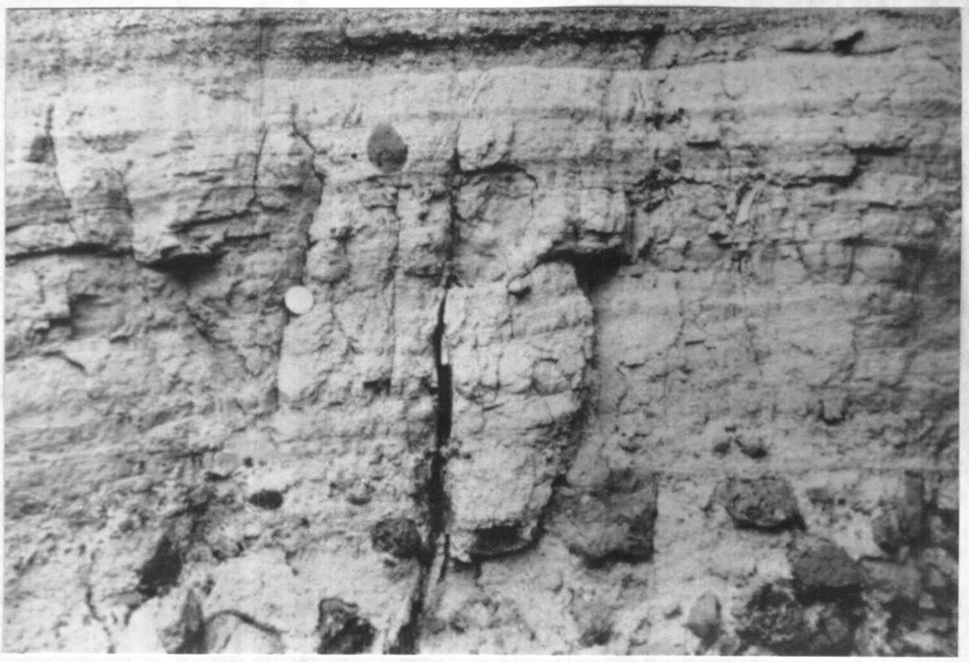

Figure 3.18 The upper bed of eruption unit 4, showing cross laminations gradually transform upward to planar laminations.

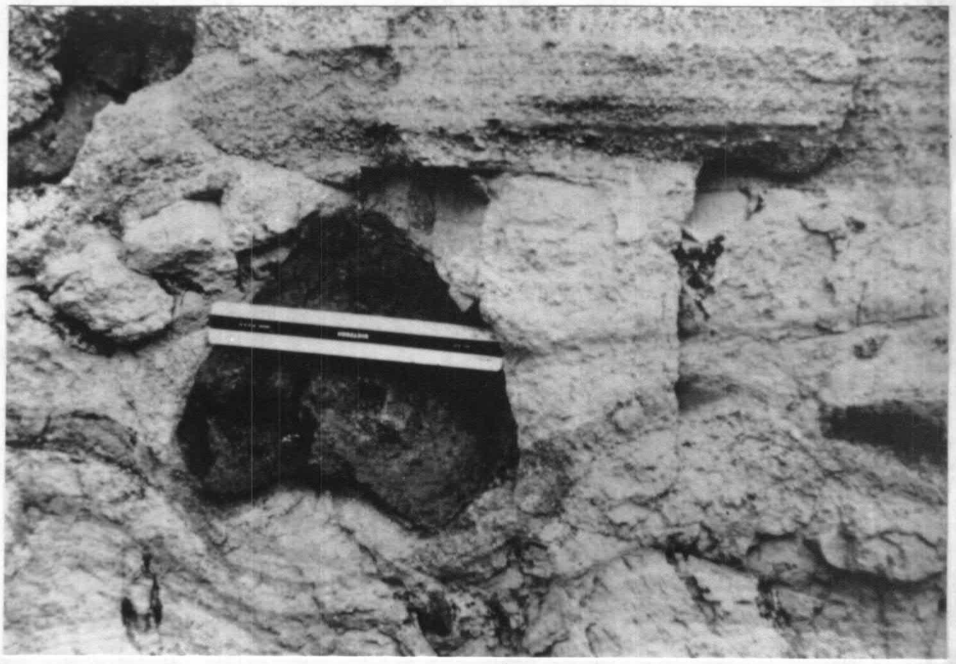

Figure 3.19 Ballistically lithic block emplaced in the upper bed causing a bomb-sag structure. Asymmetrical bomb-sag structure indicate the direction of ballistic ejection from right to left.

Eruption unit 5

The eruption unit 5 (U5, Figure 3.14), bounded by two sharp contacts, has a regular thickness of 25 cm. The unit, with a yellow color characteristic, is made of two beds.

The lower bed is composed of thin divisions, 5-6 mm of planar laminated coarse and fine pumice ash. Individual lamina distinguished by variations in grain size are well sorted (Figure 3.20).

The upper bed, the thicker bed of the eruption unit, has a consistent thickness of 18 cm. The deposit is well sorted and also develops faint stratifications of lapilli and coarse pumice ash, with increasing in grain size from base to top. It is sharply overlain by the next eruption unit 6.

Eruption unit 6

The eruption unit 6 (U6, Figure 3.14), the thinnest unit of the studied section, has a invariable thickness of 15 cm. However, the continuity of this eruption unit along lateral extent is interrupted partly by erosion. The unit is made up of 2 beds of white fine pumice ash which are separated by laminae of yellow coarse and fine pumice ash, 0-3 cm thick. Two bed of white fine pumice ash are massive, may locally be stratified and are included into one bed where laminae of yellow coarse and fine pumice ash are absent (Figure 3.20).

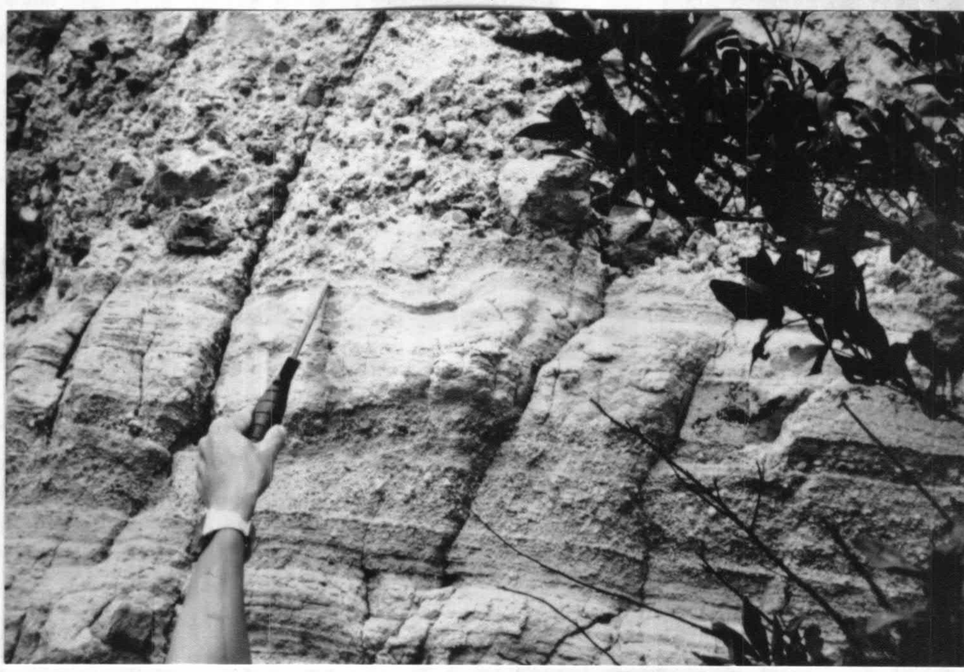

Figure 3.20 Eruption unit 5 with a characteristic yellow colour showing planar laminations, and sharply overlain by eruption unit 6 (white colour).

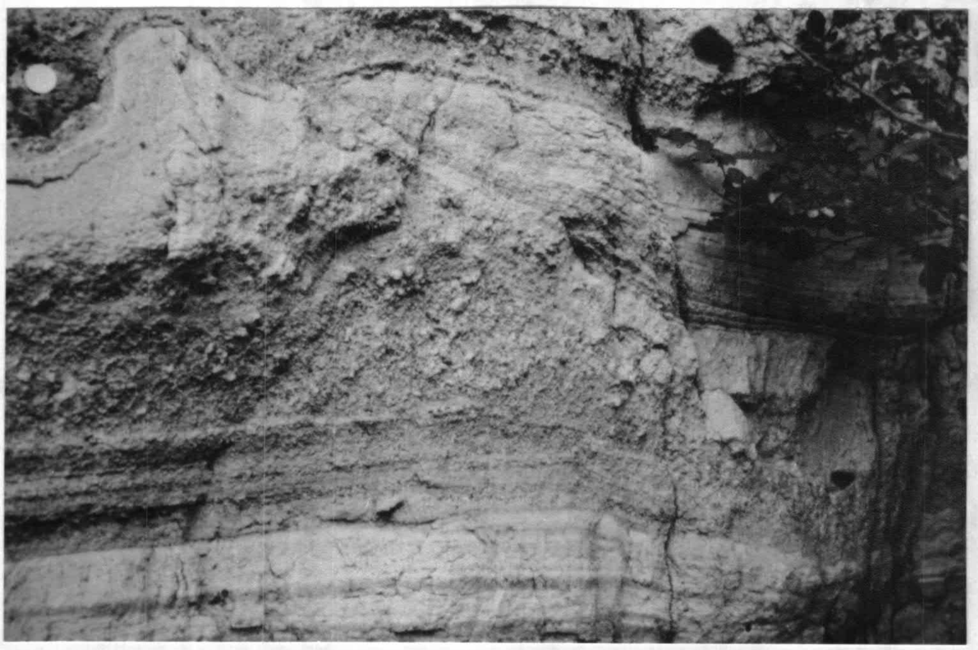

Figure 3.21 Fragments of the eruption unit 5 were swept up and incorporated into the deposit of eruption unit 6.

Many places of the upper parts of the eruption unit 6 were eroded, or found as pinch and swell structures, chute and pool structures and bomb-sag structure on the top. Some places the fragments of the underlying deposit (unit 5) have been swept up and incorporated into its deposit (Figure 3.21), and later sharply overlain by the eruption unit 7.

Eruption unit 7

The eruption unit 7 is the thickest unit of the studied section, about 20 m thick (Figure 3.13). The unit consists of variable proportions of block, lapilli and ash of pumice and basaltic lithic clasts. Block-juvenile pumice clasts make up most of the volume of the eruption unit, many blocks can reach up to 1 m in diameter. The bread-crust texture of juvenile pumice clasts are also recognized (Figure 3.13). Basaltic lithic clasts observed only in the lower bed of the eruption unit are rather rare and small in proportion. They are also smaller in grain size when compare with the juvenile pumice clasts in the same eruption unit. Its largest clast is merely up to 10 cm in diameter.

The eruption unit 7 is made of two beds. The lower bed (I, U7, Figure 3.14) is irregular in thickness, ranging from 50 cm to 100 cm. It is composed of a mixture of block, lapilli and coarse ash of pumice and basaltic clasts. Fine pumice ash matrix is relative rare or absent (Figure 3.20). The deposit is poorly sorted and may locally be superimposed by lenses of fine-depleted, lapilli lithic rich. At its base sometimes show slightly reverse grading of both pumice and lithic clasts which often aligned parallel to the top of eruption unit 6 (Figure 3.21).

The upper bed (II, U6, Figure 3.14) is the thickness bed of the eruption unit and also of the studied section, averaging 14 m thick. The depositional characteristics is typically poorly sorted, homogeneous composition, clasts-supported texture, and fine-depleted. Pumice clasts are only one component of the upper bed composed of variable size of pumice ash, lapilli, and blocks. Block-pumice clasts are the most proportion of bed, and most of them are larger than 20 cm in diameter. Pumice ash is rather rare or absent.

Finally, the top of the upper bed is immediately overlain by a single rhyolite lava flow. The flow is characterized by basal flow breccia of rhyolitic obsidian, rhyolitic obsidian, and stony rhyolite from base to top. It is thought to be the last eruptive phase of rhyolite which will be describe in more detail in next section.

3.4.1.3 <u>Paleocurrent Direction and Source Vent Area</u>

The cross-bedded structure, orientation of pumice and basaltic clasts, and also bomb-sag structure which present in many eruption units, particularly in the upper beds, are the most significant evidences to be used to indicate the directional transportation of pyroclastic deposits. The cross-bedded structure, a parallel laminated division and alignment of lithic clasts suggest that they originated from pyroclastic flows. The result on cross-bedding measurements on pyroclastic deposits which exposed along the southern cliff of Khao Rawang indicates that the flow has moved from the north to the south. Asymmetrical deformation of some bomb-sag structures that showing the angle and direction of impact also supports the southernly-flow direction. All of the results are concluded that the pyroclastic deposits exposed along the southern cliff of Khao Rawang originated from the source vent area to the north (Figure 3.22).

3.4.1.4 Discussion of Origin of Eruption-Unit Deposits.

Origin of eruption units 1,2,3 and 4

The eruption units 1, 2, 3 and 4 are all made of two beds in sharp contact, and generally have similar depositional characteristics.

The lower bed is the thicker bed and commonly contains the largest grain size of the unit. The deposit is generally massive and poorly sorted, but sometimes shows coarse-tail reverse grading of the larger pumice and basaltic clasts. These depositional characteristics suggest that the deposit of the lower bed accumulated from a laminar flow with poor sorting is attributed to high particle concentration. The transport mechanism of the lower bed may be similar to that of sedimentary debris flows. The minor different is that in the sedimentary debris flows all materials are carried by a matrix of mud and water, whereas in the pyroclastic flows they are carried by fine ash and gas.

Reverse or normal grading which affect only the

Figure 3.22 Photograph took from the north of Khao Rawang. Rhyolite dome (arrow) inferred the source vent area.

larger clasts known as "coarse-tail grading" is the only conspicuous internal structure of the lower bed in all eruption units. Reverse grading of the larger pumice clasts and normal grading of the larger and dense basaltic clasts are commonly present. These types of gravitational grading must have resulted from the density contrast between the larger clasts and the matrix. In general, the larger pumice clasts of all lower beds show only poor sorting or only reverse grading throughout the flow unit. This implies that the matrix of the lower bed can not be greatly expanded in the moving pyroclastic flow, otherwise the density contrast will be lost. Therefore the matrix is an upper limit for the density of the moving pyroclastic flow and is also homogeneous throughout the flow unit.

Reverse grading of the larger and dense basaltic clasts is also present. This type of grading suggests that the moving flows are of only marginally expanded with high shear-strain rate. Cas and Wright (1987) suggested that in such flows high shear-strain rate will be imposed through their thickness and shear-induced grading of the larger clasts will result.

In every eruption units, their lower beds show reverse grading of both low density pumice and high density basalt. This suggests that two mechanisms producing coarse-tail grading, including gravitational-induced grading and shear-induced grading, can operate together in the same moving pyroclastic flow. These mechanism are thought to be controlled by the degree of expansion of the flow (or the amount of fluidization).

In upper bed, the deposit is relatively regular in thickness and is always thinner than the lower bed when it is present. It contains the finest fraction of the deposits and is commonly oxidized. Internal sedimentary structures, including cross-stratification or planar lamination, are very typical and only observed in the upper bed. Cross laminations are generally present at the base of bed and grade upward to planar lamination at the top of the bed. Pinch and swell structures and chute and pool structures are commonly found at the top surface of the bed. Plastic deformations, for instance, bomb-sag structures, of which formed by the impact of the larger ballistic blocks, are also found.

Well-stratification or lamination of the finest fraction are the most conspicuous primary structures in the upper bed of many eruption units. These depositional characteristics suggest that the upper bed accumulated from a turbulent flow. This does not mean that turbulence was the sole mechanism supporting the grains in suspension. But it means that sharp scoured contact, better grading and sorting in finer grained fraction and sequences of tractional sedimentary structures such as dune form and cross-stratification, evince that the flows were of relatively low particle concentration in order for the grains to settle more or less freely, and that traction was present during the accumulation of the deposits. For these structures to form the flows has to be turbulent.

It is now concluded that both lower bed and upper bed of the eruption units 1, 2, 3 and 4 have been accumulated from a pyroclastic flow. Following the layering scheme for the pyroclastic flow unit of Sparks et al. (1973) and Sparks (1976) evinces that the lower bed of all eruption units is the deposit of the body of pyroclastic flow (layer 2), and the upper bed is the deposit of the overriding ash-cloud surge (layer 3). But the deposit of ground surge which moved in advance of pyroclastic flow (layer 1) is absent in any eruption units 1, 2, 3 or 4.

Origin of eruption unit 5

The eruption unit 5 has a regular thickness. The deposit is composed of lapilli and coarse ash of juvenile pumice, relatively homogeneous and well sorted layer. At its base it is well developed planar laminations which show mantle bedding. These depositional characteristics suggest that the eruption unit 5 was accumulated from subaerial air-fall deposit.

Although the depositional characteristics of eruption unit 5 are resemble to "parallel-bedded" surge deposits. A surge origin is rejected because the sedimentary structures, for instance, lenticular beds, primary low-angle truncations or pinch and swell bedding are virtually absent across its entire thickness and length.

Origin of eruption unit 6

The eruption unit 6 is fine-grained, stratified, relatively poorly sorted pumice ash deposit. Sedimentary structures, for instance, pinch and swell structures and chute and pool structures are present. In some places fragments of the underlying deposits were swept up and incorporated into its deposit (Figure

3.21). All of these evidences suggest that the deposit has been accumulated from a turbulent flow of low particle concentration. Pinch and swell or chute and pool stratifications indicate that most of ash deposits do not originated by subvertical fallout, but in large part are formed from subhorizontal transport of ash. Sweep up the underlying fragments to incorporate them into its deposit is attributed to the flow must has been turbulent.

According to its composition and its position in the deposit succession, it is possible to be the deposit of a dilute ground surge which move in advance of the overlying pyroclastic flow (the eruption unit 7).

Origin of the eruption unit 7

The eruption unit 7 is the thickest unit and represents the last deposit unit of the explosive period before the eruption changes to a period of rhyolite lava effusion. The eruption unit 7 is made of two beds contrasted by a sharp contact.

As aforementioned, the depositional characteristics of the eruption unit 7 are typically homogeneous composition of juvenile pumice clasts. They are poorly sorted, internal structureless and clast-supported textures. Fine matrix is rare or absent, although at its basal part (the lower bed) it is fine-depleted and rich in basaltic lithics which mix with juvenile pumice. These depositional characteristics suggest that the eruption unit 7 was accumulated from a laminar flow of high particle concentration, while the fine-depleted and lithic-rich portion at its basal part (the lower bed) suggest turbulence flow.

The turbulent flow at the basal part of the eruption unit is thought to be the result of strong fluidization caused by ingested air at the head of the moving flow. Wilson and Walker (1982) suggested that a fast-moving pyroclastic flow is likely to develop a lobe and cleft structure at its front, with air being preferentially ingested through the cleft. The ingested air will expand rapidly due to sudden temperature increase, and this causes strong fluidization, as well as variable degree of turbulence. Sedimentes deposited out of the flow-head should, therefore, be more fine-depleted and enriched in lithics than those deposited by the remaining portions of the flow (the upper bed).

The segregation of dense basaltic lithics which recognized only in the lower bed also suggests that the lower bed is deposited within the head of the moving pyroclastic flow, does not jet forward from the head of flow. Walker et al (1989 a) proposed the name "ground layer" for this type of deposit.

In layering scheme of Sparks et al. (1973), Wilson and Walker (1982) suggested that the ground layer, in fact, is a variant of layer 1. The lower bed of eruption unit 7, therefore, is one depositional facies of layer 1, caused by strong fluidization by ingested air at the head of the moving flow and the upper bed is the depositional facies of the remaining portion or the body of the flow (layer 2).

According to the sequenceof deposition and the different deposional facies of the eruption unit 6 which has been previouslygrouped as ground surge, and of the eruption unit 7 which has been grouped into the ground layer and the flow body. It is now possible to illustrate the schematic model for this pyroclastic flow unit (Figure 3.23).

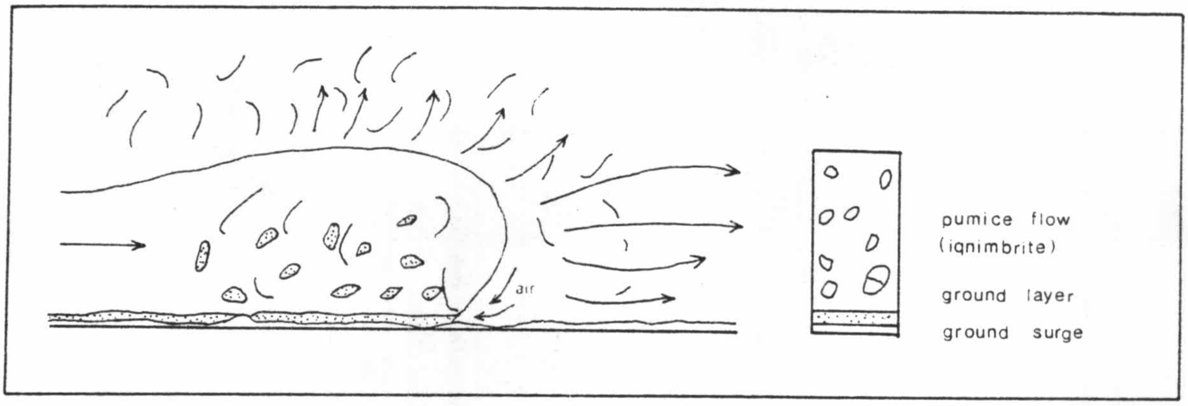

Figure 3.23 A pyroclastic flow and formation of various layer 1 facies. As a fast-moving pyroclastic flow, some amounts of air ingestion cause fluidization and dilute surge to be generated from the front of the moving flow, producing ground surge deposit (unit 6). Segregation within the head forms a ground layer (bed I, unit 7), while the remaining portion forms pumice flow deposit (or ignimbrite, bed II, unit7).

3.5 Silicic Lavas

After the depositions of the last silicic pyroclastic explosions, the eruptive activities of the volcanic field changed subsequently to the extrusions of rhyolitic-composition lavas. In various places, rhyolite lavas commonly rest on the deposit successions of silicic tuffs (pumice cones), and on sequences of the early intermediate-composition lavas. Locally, rhyolite lavas are interlayered with the layers of pumice deposits, however, the top layers of these successions are commonly a single flow of rhyolite lava. According to the facies of these volcanic successions it suggests that the extrusions of rhyolite lavas in the volcanic field are liekly to be the terminal event or the final phase of silicic eruptive activities.

In this study, silicic lavas in the volcanic field can be subdivided based on their occurrences and emplacements into the following; the high rhyolitic volcanic landforms at the central north and south, the rhyolite lava domes and coulees at the central west, and the isolate rhyolite lava domes along the east of the volcanic field (Figure 3.24).

The high rhyolitic volcanic landforms at the central north and south are some of the largest forms of most rhyolite lavas which were extruded in the volcanic field. They are composed of rhyolite lava domes, coulees and pumice cones, which together the basal parts connected by wide-spread flows (Figure 3.25). These rhyolitic hills generally rise above the deposit successions of silicic tuffs,but may locally rise above the sequences of the early intermediate-

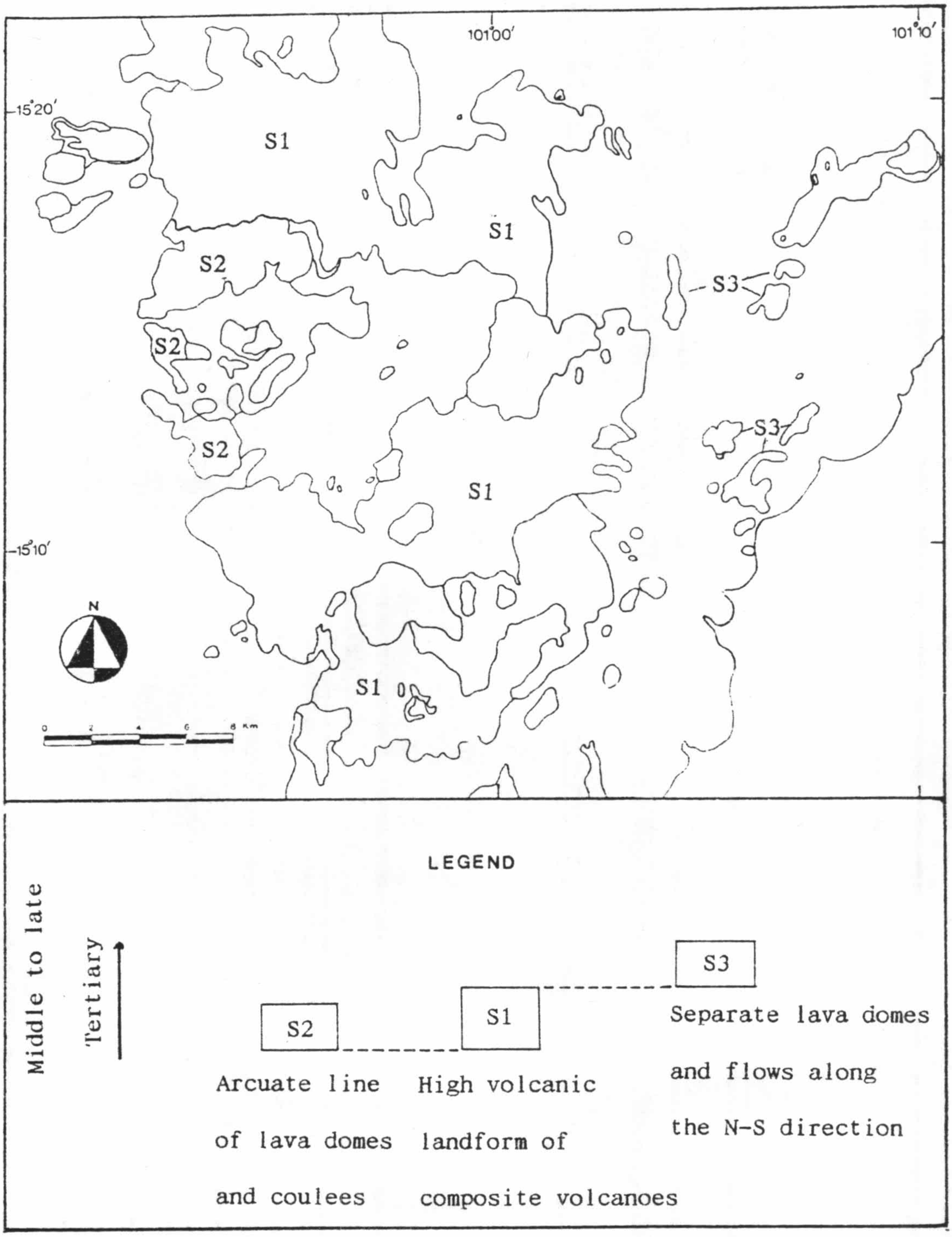

Figure 3.27 Approximate subdivisions of rhyolite lavas into high rhyolitic volcanic landforms, arcuate line of lava domes and coulees, and separate lava domes and flows along the N-S direction.

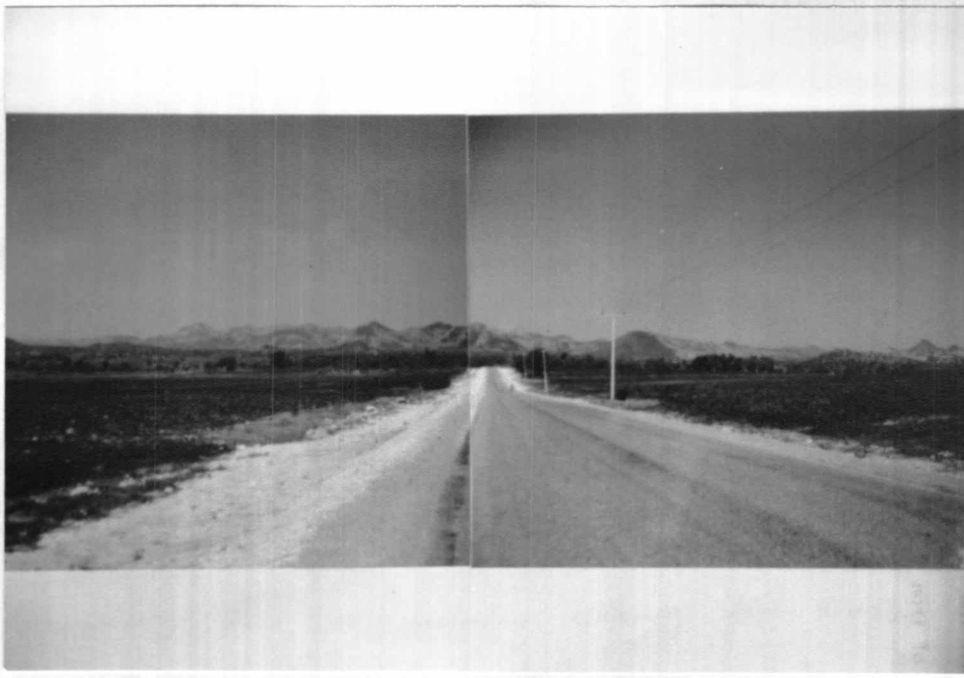

Figure 3.25 High rhyolitic volcanic landform, including coalescing lava domes, coulees and pumice cones, which their basal parts are connected together by widespread flows. They were subsequently covered by widespread, flat-lying lava flows of late basalt, which have mostly been weathered to black sediments.

composition lavas (usually forming as domes or coulees). However, many rhyolite lavas do not appear to be associated with an earlier pyroclastic deposits, but it is possible that such a feature could have been completely submerged beneath these succeeding lava domes and flows. The rhyolitic hills, particularly rhyolite lava dome and coulees, can approximately represent the eruption point or volcanoes. Therefore, the whole form of these composit hills is thought to be the volcanic centre of rhyolite lava extrusions which consisting of multiple eruption vents.

At the central western part of the volcanic field, many rhyolite lava domes and coulees seem to occur in arcuate distribution about the volcanic depression (Figure 3.26). This arcuate line probably is part of the caldera ring fault or fracture, which the eruption vents of both pumice pyroclasts and rhyolite lava were confined. In many situations on this arcuate line, a typically single rhyolite lava flow overlie relatively sharply on and conform to the underlying layers of pumice deposits. It clearly indicates that the extrusions of these lavas commonly and immediately follow resergence of magma after the last phase of climactic pumice explosions.

The eastern part of the volcanic field, rhyolite lavas mostly occur as isolate lava domes with gentle lava flows. These lavas apparently align on linear trend extending from the north to south (Figure 3.27). Individual lava domes can represent individual eruption vents or volcanoes. The linear trend of these lava domes and flows, therefore, is probably the restricted fissure vent system, in similar manner to what observe in the early intermediate-

Figure 3.26 The distribution of rhyolite lava domes, coulees, and pumice cones apparently aligned in arcuate fracture surrounding the central volcanic depression.

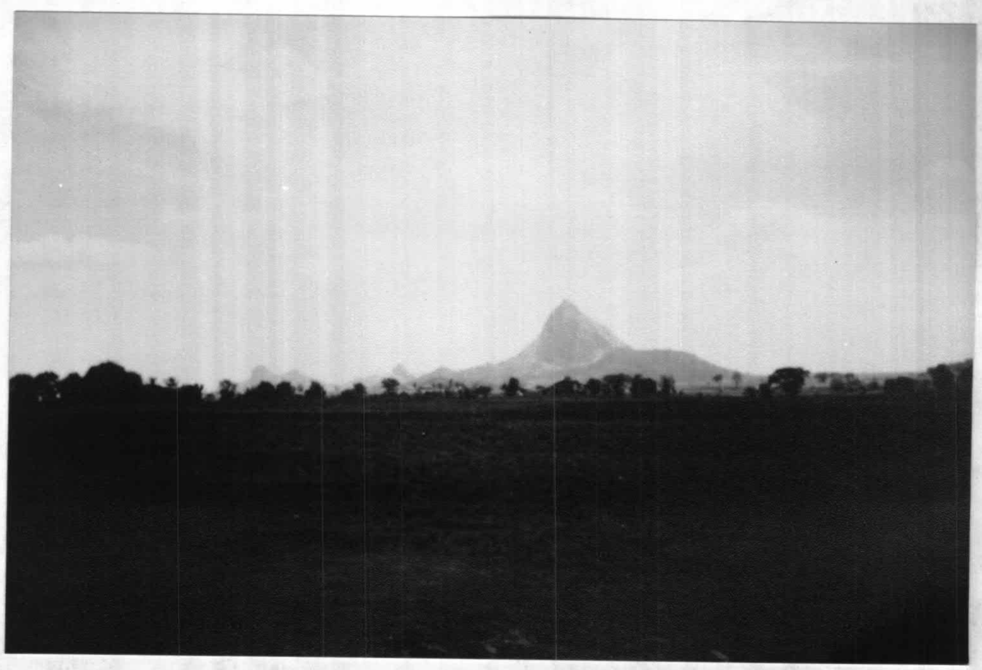

Figure 3.27 Isolate rhyolite lava domes along the eastern part of the Lam Narai volcanic field.

composition lavas.

At one locality in this linear trend, inclusions of basalt are found scatteringly throughout a single flow unit of rhyolite lavas, and forming rhyolite-basalt mixed lavas (Figures 3.28 a and b). These basic inclusions are thought to be of basaltic andesite of the early intermediate-composition lavas. These basaltic inclusions exhibit many different shapes and sizes. However, most of these shapes show embayed and crenulate margins, indicating that the inclusions of basalt were still fluid while the host rhyolite lava was liquid. The dissemination of these basaltic inclusions is not merely observed at the surface of rhyolitic lava, but scattered throughout the whole mass of the lava flow. This evidence also clearly indicates that the bimodal association of rhyolite and basalt resulted from mixing of magmas prior to eruption rather than from surficial coalescence between rhyolitic and basaltic lava flow.

3.5.1 Features of Rhyolitic Lava Flows.

Description of the features of rhyolite lava flows can be subdivided into the following : shape, lithology, surface features and growth and internal sturctures.

3.5.1.1 Shape

Following Veerote Daorerk (1972), and Cas and Wright (1987), rhyolite lavas can be subdivided according to their shapes into : dome, mesa lava and coulee. The term dome is used for the viscous protrusion of lavas which is circular in plan with a

Figure 3.28a Rhyolite-basalt mixed-lavas, mafic inclusions are thought to be of the early basaltic andesite.

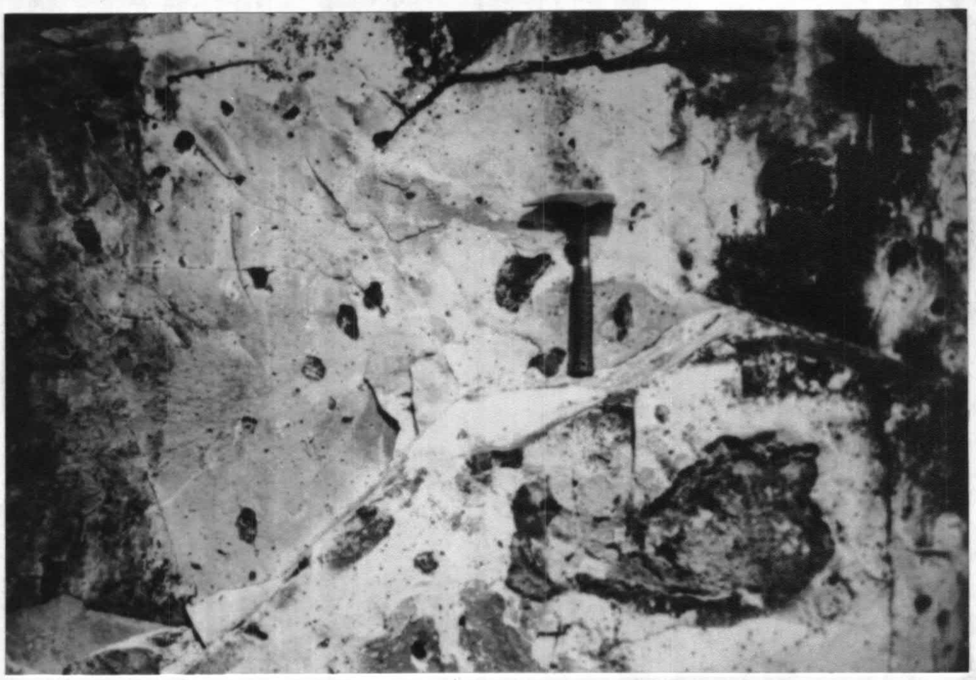

Figure 3.28b Close-up, showing the varying shapes and sizes of mafic inclusions,most of them show crenulate margins, indicating that the inclusions were still fluid while the host rhyolite lava was liquid.

small surface area (Figure 3.29); mesa lavas, which is lava with an approximately circula-plan forming biscuit-shaped body; and coulee is lavas which form when flow is asymmetric and concentrated to one side of the vent producing an extrusion which is elongate in plan (Figure 3.30). From the actual field observation, however, recognizable masa lavas are very few and may be difficult to distinguish from domes because both forms are closely related. The shape of rhyolite lavas in the volcanic field is, therefore, identified only as domes or coulees as mentioned previously.

Cas and Wright (1987) suggested that the different shapes of rhyolite lavas mentioned above can be related to three main controlling factors, including effusion rate, physical properties, and slope. However, in reality of the controlling factors of lava shapes are likely to be many, and they are complexly interrelated. For instance, effusion or lava discharge rate is itselt dependent on a large number of factors : vent shape and dimensions, viscosity, yield strength and magma pressure gradient within the volcano.

Cas and Wright (1987) also suggested that one of the factors which could determine the shape of rhyolite lava flows is the presence of a confining crater built by earlier pyroclastic explosion. This is probably true for smaller rhyolite domes, but larger ones may exceed the critical crater volume and flow laterally away from the crater area.

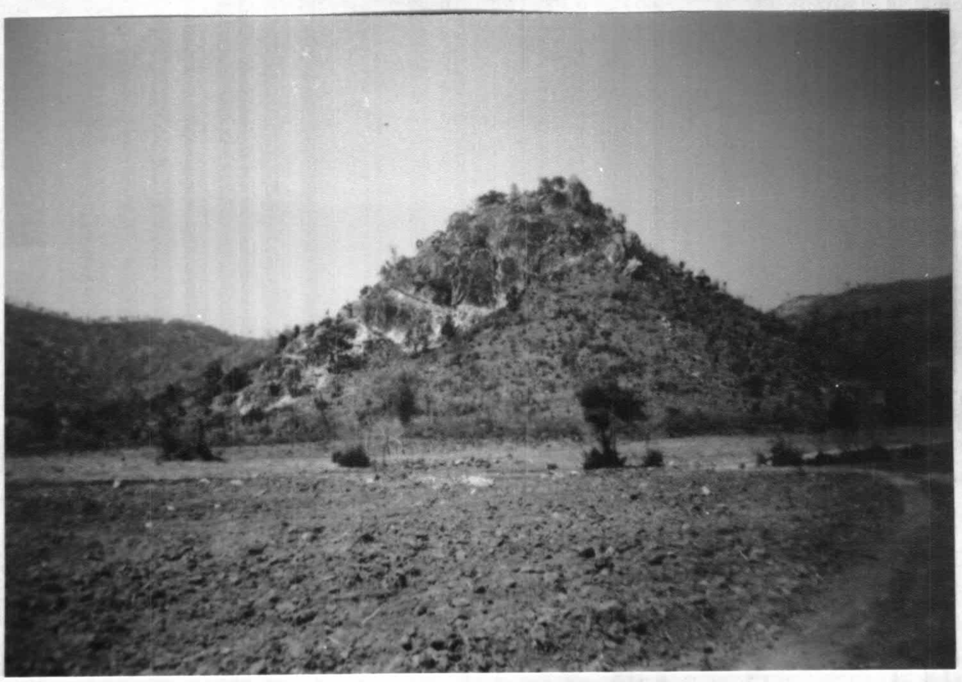

Figure 3.29 Rhyolite lava dome.

Figure 3.30 Coulee, Khao Wang Plae.

3.5.1.2 Lithology

In rhyolite lava flows a variety of lithologies and textural features can be recognized : obsidian, layers of composite spherulites, pumiceous layers, stony rhyolite, and perlite (the hydration of obsidian).

In general, obsidian is black or pale green, sometimes occurs as thick foliated layers, often interbanded with layers of other lithologies (Figure 3.31). This layering or flow foliation is frequently folded. Cas and Wright (1987) proposed that obsidian usually forms a chilled glassy carapace around rhyolite lavas, commonly about 10 m thick over the top and around the flow front, with a thinner layer along the base (Figure 3.32). However, rhyolite lavas which exposed in the volcanic field commonly form obsidian layer only at their bases, before changing to stony rhyolite when ascending upward (Figure 3.33). Moreover, the obsidian layer lying on the top of the rhyolite lava flow has not been found in the study area. Some of the obsidian flows may be totally glassy obsidian throughout their interiors, and these flows usually form as flow breccia or autobreccia (Fugure 3.34).

Spherulites are radiating aggregates of alkali feldspar, with or without cristobalite and tridymite. They are commonly found in obsidian especially at the basal part of rhyolite lava flows. They generally have diameter of about 0.1-2 cm. Composite spherulites often form specific flow layers which generally run parallel to the main layer of that flow. However, spherulites are usually superimposed on flow structures, and the flow

Figure 3.31 Interbanded and foliated layers of obidian, spherrulites and stony rhyolite.

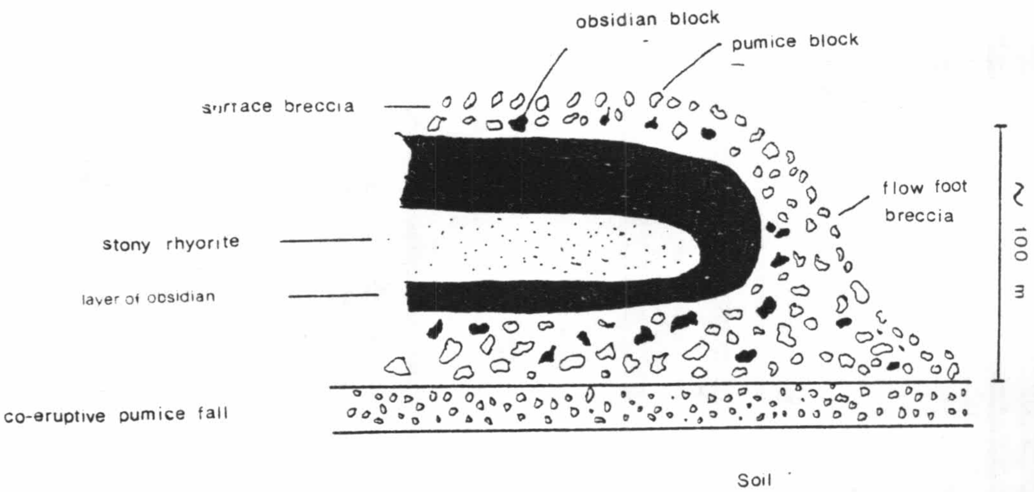

Figure 3.32 Schematic section of a single rhyolite lava flow showing distribution of different lithologies, proposed by Cas and Wright (1987).

Figure 3.33 A single flow of rhyolite lava consists of basal obsidian and upper stony rhyolite.

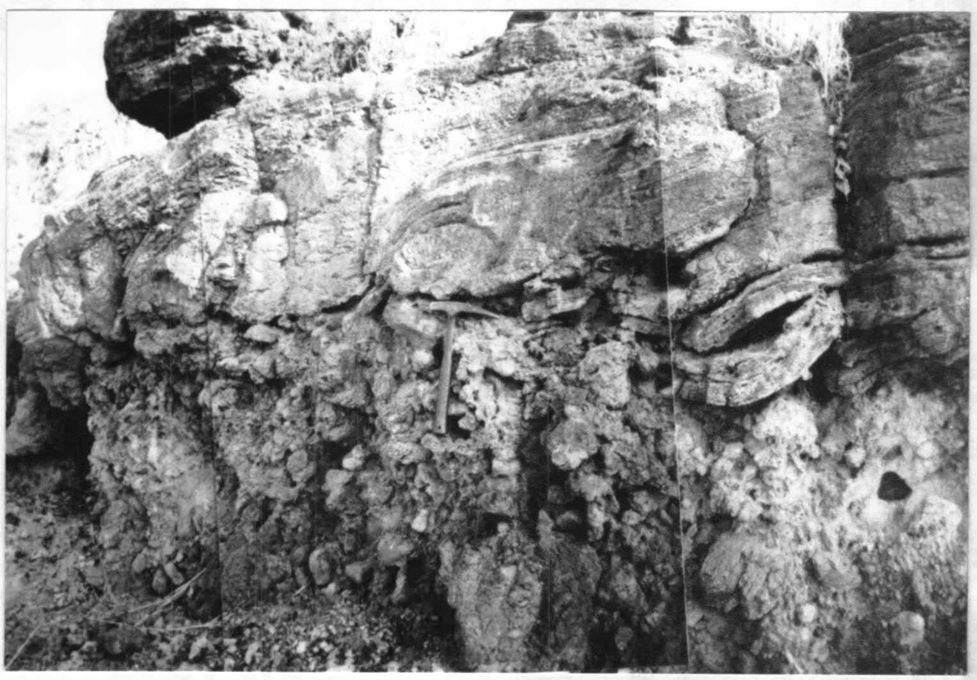

Figure 3.34 Obsidian shows fold-flow and lamination with autobreccia at its basal part. Flow direction from right to left.

foliation can be traced through out. This indicates that spherulites were formed after the flowage of lava had ceased (Veerote Daorerk, 1972)or nearly ceased (Cas and Wright, 1987).

In many rhyolite lava flows, some spherulitic growths are, in fact, lithophysae which are aggregates of fibrous crystals formed in vesicle (Figure 3.35). Cas and Wright (1987) suggested that these vesicles have been formed in a melt while it was still capable of flowing.

More-vesiculated pumice layers may be interbanded with obsidian and spherulitic layers. From the field observation, pumiceous breccias formed during flowage are usually found at the bases of many rhyolite lava flows, especially a single flow which lay over the top of pumice cones, as well as co-eruptive pumiceous pyroclastic deposits.

The principal lithological component of most rhyolite lava flows exposed in the volcanic field, particularly forming lava domes, is laminated stony rhyolite (Figures 3.36 and 3.37). This is formed by post eruptive crystallisation of the silicic melt to a finely crystalline rock during its emplacement and subsequent cooling.

In some obsidian, numerous discontinuous concentric cracks have developed. The so-called perlitic cracks may be probably originated by thermal stresses set up during cooling of the lava. Water then diffuses through these cracks into the glass, and an hydration front advances on non-hydrated obsidian. This front

Figure 3.35 Lithophysae, occurring in rhyolitic flows.

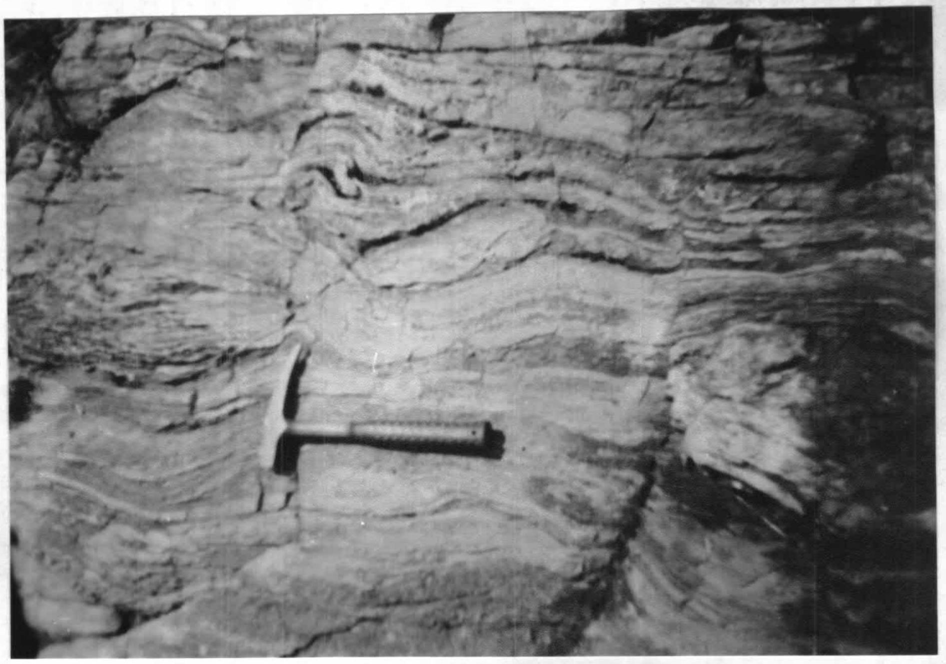

Figure 3.36 Flow-fold in stony rhyolite.

Figure 3.37 Stony rhyolite showing lamination occurring in rhyolitic lava dome.

is visible only in thin section because the refractive index of the hydrated glass is lower than that of the non-hydrated glass.

Some rhyolitic lava flows, especially the obsidian and rhyolitic lavas which overlying sequences of the early intermediate composition lavas (mentioned previously), contain a very small proportion, but significant, of basaltic inclusions. These mafic inclusions exhibit varying degrees of original fluidity. Angular mafic inclusions are predominantly and commonly found in obsidian indicating that they had sufficiently cooled to solidify while the silicic lava was still capable of flowing. Some show embayed and crenulate margins indicating that the inclusions were still fluid while the host obsidian was liquid. Although these mafic inclusions with their fluidal characteristics form only a volummetrically small proportion of their host lavas, their presence seem to indicate a mixed lava resulting from the coexistence of rhyolitic and the early basaltic magmas.

3.5.1.3 Growth and Internal Structure

As aforementioned, flow foliation in rhyolite lavas consists of interbanded and foliated layers of varying crystallinity (obsidian and stony rhyolite), spherulite content and vesicularity. Cas and Wright (1987) suggested that different lithological layers are the results of batches of physically heterogeneous lava with attendant variations in water content, crystal content, and perhaps, temperature. The prominent foliation are then generated during stretching, shearing and attenuation during flow. Nelson (1981) also suggested that lithological differences in rhyolite flow banding could result from thermal feedback (and temperature increases) in layers, due to shear stresses in the moving lava. Local temperature increases would have the effect of reducing local water solubility, increasing diffusion rates, and increasisng nucleation rates and growth rates of gas bubbles, thus causing highly vesicular bands to parallel shear planes.

The internal structure of rhyolite lavas, especially those formed as domes, sometimes clearly exhibit curve and concentric layers surrounding the domes. These concentric layers commonly incline towards the center of dome or concave in the upflow direction (Figures 3.38 a and b). The concentric structure of rhyolite lavas could be variously interpreted as ramp structure (Macdonald,1972), folds on the surface of the lavas (Fink, 1980 a) or as squeeze-up extrusions through cracks during stretching of the flow surface. However, in case of the internal flow-foliations of the lava which appear concentric at the margins when viewed in plan, are either vertical or steeply inclined in the core and dip inward at the basal margins. This is the so-called ramp structure (Cas and Wright, 1987).

The concentric structure of rhyolite lavas is the significant evidence to suggest that the volcanic dome has grown primarily by expansion from within and is characterized by a concentric arrangement of flow layers (figure 3.39). This has been called endogenous domes (Veerote Daorerk, 1972 ; Cas and Wright, 1987).

Figure 3.38a Concentric layers of rhyolite lava-flows incline toward the center of the dome, Khao Hin Khling.

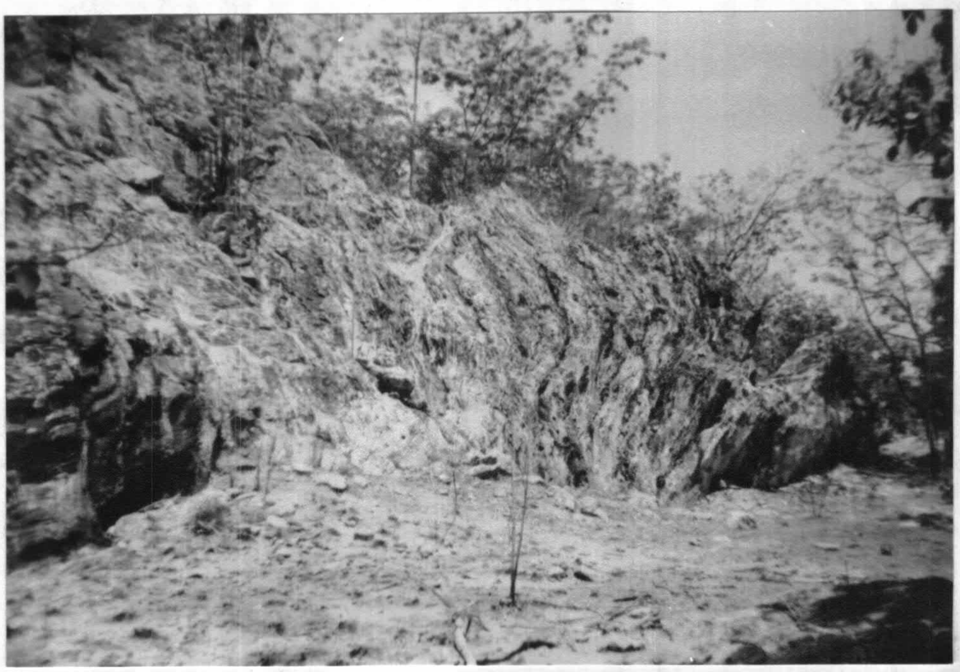

Figure 3.38b Another side of a rhyolite dome, Khao Hin Khling.

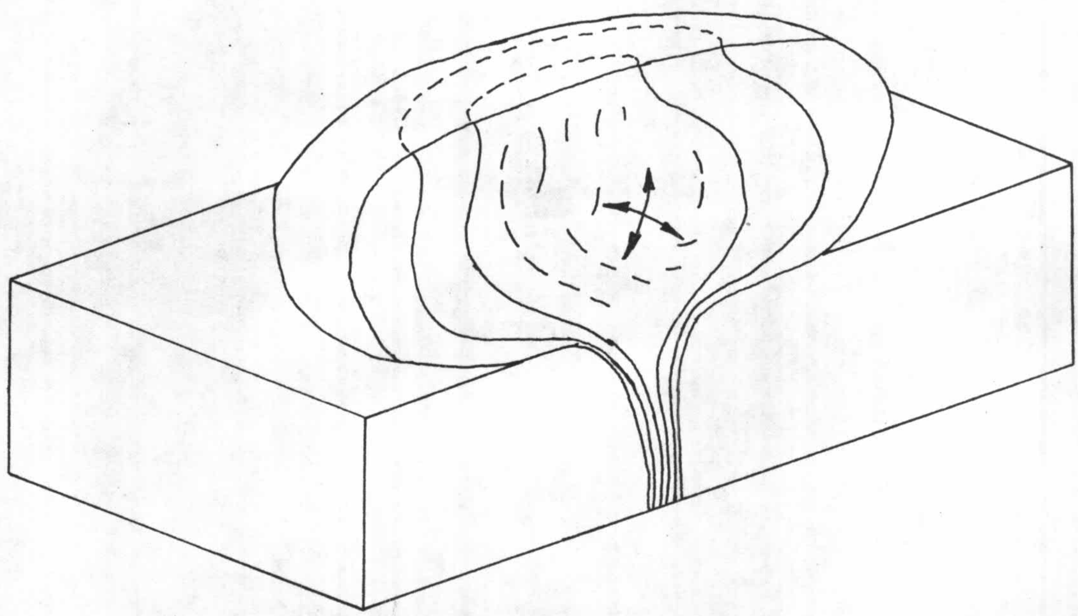

Figure 3.39 Tree-dimentional diagram showing the development and growth of endogenous rhyolite dome (after Cas and Wright, 1987).

On the other hand the extrusions of viscous lavas from a central vent may move slowly over the top of each other, and the growing dome is built up higher layer by layer (Figure 3.40). In this case the early viscous extrusion spread from the vent at low angles forming banks around the vent. The subsequent extrusions then will have more and more restricted space to move on as they continue building. The latest flow then move directly outwards from the vent at steeper angles. This manner is called exogenous domes (Veerote Daorerk, 1972).

The growth or the extrusion of rhyolite lavas exposed in the volcanic field may now be subdivided into two types; endogenous and exogenous domes. Veerote Daorerk (1972) described that endogenous domes are domes which grow essentially by expansion from within, whereas exogenous are domes which built up by surface effusion, usually from a central summit crater. Both types of domes are found in many parts of the world. In many cases, both forms can possibly occur together (Veerote Daorerk, 1972).

However, many rhyolite lava flows or rhyolite lava forming domes in the volcanic field do not show the concentric structure. They usually form only dome shape or other, but their internal structures do not develope.

3.6 Related Intrusive Rocks

The related intrusive rocks exposed in the volcanic field are composed of two small stocks of botite microgranite and hornblende microdiorite, about 2 and 3 km^2, in respectively, at

Figure 3.40 The extrusions of viscous lavas from the central orifice, some parts of lavas were injected into the preceeding lava body, while orthers moved over-ridding on top of each other. The eastern flank of this dome had collaped and moved down to the east. Southern part of Khao Hin Khling, which it is believed a composit-vent volcano.

the cliff of Khao Wang Plae, the central west of the volcanic field (Figure 3.1). Both stocks are closely associated with sequences of rhyolite lavas. Nikom Jungyusuk and Panya Suriyachai (1987) reported that inclusions of rhyolite lava are sometimes found at the margins of both stocks. Their field relations and their mineralogies and geochemistries suggest that these intrusive rocks are likely to be parts of rhyolite lavas. Their intrusions were concurrent with the extrusions of rhyolite lavas, only they have had cooled down at the shallow surface before extruded.

3.7 Late Basalt

Late volcanic activity of the Lam Narai volcanic field is the effusion of basaltic lavas that are widespread and flat-lying along the margin of the volcanic field (Figure 3.1). These basaltic lavas generally flow covering and surrounding at the basal parts of the higher rhyolite domes, coulees, pumice cones and sequences of the early intermediate rocks (Figure 3.25). In some localities, they are found to sharply rest on red-brown siltstone (may be Tertiary sediments ?, Figures 3.41 and 3.42) or intruded and interlayered with gravel beds of Quarternary (Nikom Jungyusuk and Panya Suriyachai, 1987). Late basalt also occurs as dykes that commonly extruded along the northwest-southeast fault and cut-through sequences of the older volcanic rocks (Figure 3.43). These field relations suggest that the early extrusions of late basalt may be concurrent with extrusions of late rhyolite, particularly of rhyolitic lava domes which extruded along the eastern part of the volcanic field, before the later extrusions produced the widespread basaltic lavas.

Figure 3.41 Compound lava flows of late basalt sharply rest on red-brown siltstone (may be Tertiary sediments?).

Figure 3.42 Relatively thick lava flow of late basalt overlies red-brown sediments.

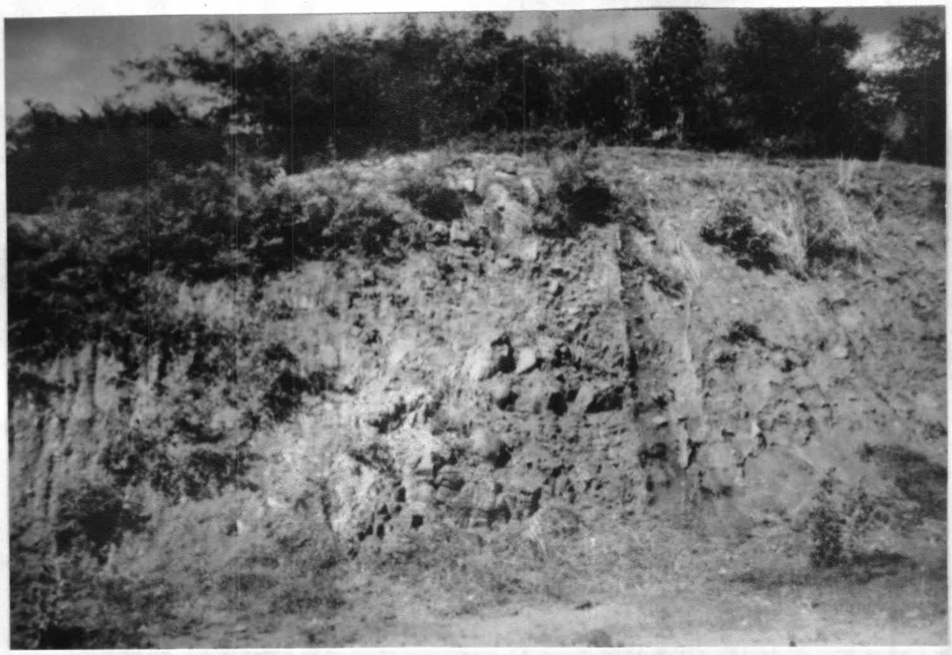

Figure 3.43 Late basaltic dyke cut-through volcani-clastic sediments (weathered silicic tuffs).

Vent areas for the widespread basaltic lavas particularly along the eastern margin of the volcanic field are mostly obscure except basaltic lavas which accumulated and formed as crudely stratified cones at the northern margin of the volcanic field. Individual basaltic lava cones can approximately represent their eruptive vent areas. Most of these basaltic lava cones, usually consist of two or three cones, are relatively aligned along the northwest-southeast direction as well as the extrusions of basaltic dykes. This may indicate that the effusions of late basalt related to the activity of the northwest-southeast fault. Nikom Jungyusuk and Panya Suriyachai (1987) also suggested that this fault is probably part of the Mae Ping major fault which extends from the northwest to southeast.

The features of late basaltic lava flows are commonly characterized by smooth, widespread and flat-lying parallel to the underlying surfaces of the older rocks. Individual flows are relatively thin, ranging from 5 cm up to 1 m thick, but most are no more than 50 cm thick. Many thin flows are generally classified as simple lava flows (Figures 3.44 a and b). However, they may locally accumulate as compound lava flows (Figures 3.45 a and b). The accumulation as simple lava flows suggest that basaltic lavas were produced at high effusion rate and they can spread far from the vent, whereas the compound lava flows were developed from low effusion rate, and their occurrences indicate that they are close to the source vent area. However, from the field observation, the most of late basaltic lavas, particularly widespread basaltic lavas along the eastern part of the volcanic field, have been weathered and changed to black sediments.

Figure 3.44a Simple lava flows of many thin basaltic lavas.

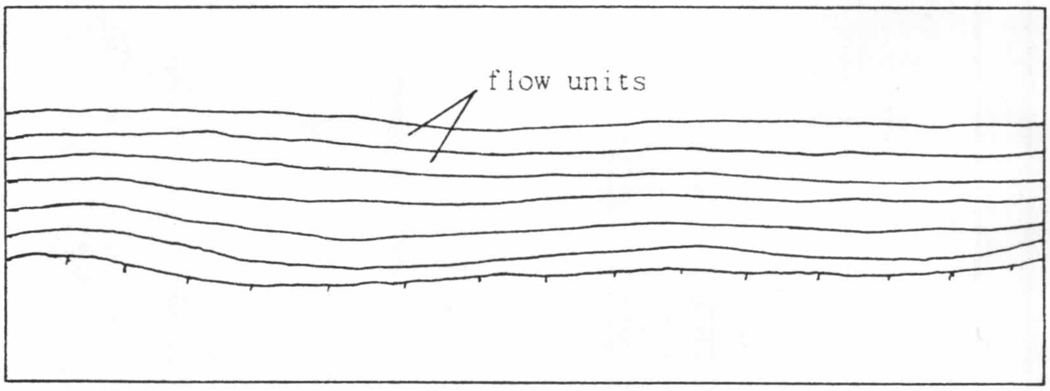

Figure 3.44b Sketch showing the characteristic of simple lava flows.

Figure 3.45a Compound lava flows of many thin basaltic lavas.

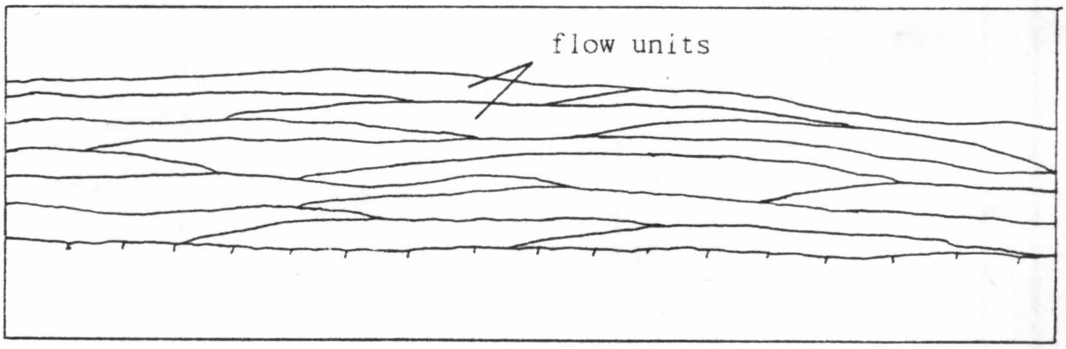

Figure 3.45b Sketch the characteristic of compound lava flows.