หินเพอร์ไลต์และความสัมพันธ์กับภูเขาไฟบริเวณเขาฝาละมี อำเภอสระโบสถ์ จังหวัดลพบุรี

นางสาว จิตติกานต์ นราพันธุ์
รหัสประจำตัวนิสิต 513 27056 23

โครงงานนี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตร
ปริญญาวิทยาศาสตรบัณฑิต
ภาควิชาธรณีวิทยา คณะวิทยาศาสตร์
จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2554

PERLITES AND VOLCANIC ASSOCIATIONS AT KHAO FALAMEE, AMPHOE SRABOT, CHANGWAT LOPBURI

Miss Jittikan Narapan

ID 513 27056 23

A REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE

DEPARTMENT OF GEOLOGY, FACULTY OF SCIENCE

CHULALONGKORN UNIVERSITY

2011

__/__/__

Date of submit

__/__/__

Date of approval

....

(Asst.Prof.Dr. Chakkaphan Sutthirat)

Senior Project Advisor

ชื่อโครงการ: หินเพอร์ไลต์และความสัมพันธ์กับภูเขาไฟบริเวณเขาฝาละมี อำเภอสระโบสถ์ จังหวัดลพบุรี
ชื่อนิสิต: จิตติกานต์ นราพันธุ์ รหัสประจำตัวนิสิต 513 27056 23
ชื่ออาจารย์ที่ปรึกษา: ผศ.ดร. จักรพันธ์ สุทธิรัตน์
ชื่ออาจารย์ที่ปรึกษาร่วม: ผศ.ดร. สมชาย นาคะผดุงรัตน์
ภาควิชา: ธรณีวิทยา
ระดับการศึกษา: ปริญญาตรีบัณฑิต
ปีการศึกษา: 2554

บทคัดย่อ:

หินภูเขาไฟเขาฝาละมีเป็นส่วนหนึ่งของบริเวณศูนย์กลางแหล่งหินภูเขาไฟลำนารายณ์ซึ่งจัดเป็นหินภูเขาไฟชนิดอัลคาไลน์-แคลอัลคาไลน์ที่มีอายุอยู่ในช่วงยุคเทอร์เชียรีตอนปลาย หินเพอร์ไลต์ที่พบในบริเวณเขาฝาละมีนั้น พบอยู่ในลำดับชั้นหินภูเขาไฟโดยเรียงลำดับจากล่างขึ้นบนดังนี้ หินเพอร์ไลต์ส่วนล่าง หินพัมมิเซียสเพอร์ไลต์ หินเถ้าภูเขาไฟ หินเพอร์ไซต์ส่วนบน และหินเพอร์ไลต์แปรสภาพ จากการศึกษาทางด้านศิลาวรรณา หินเพอร์ไลต์ประกอบด้วยเนื้อพื้นที่มีลักษณะเป็นเนื้อแก้วประมาณร้อยละ 70 พบผลึกขนาดเล็กของแร่เฟลด์สปาร์และผลึกดอกของแร่เฟลด์สปาร์ แร่ไบโอไทต์ และเหล็กออกไซด์ได้ทั่วไป นอกจากนี้หินเพอร์ไลต์ดังกล่าวแสดงลักษณะการแตกแบบหัวหอม (Perlitic texture)

จากการศึกษาธรณีเคมี หินเพอร์ไลต์ในบริเวณพื้นที่ศึกษาซึ่งประกอบไปด้วย หินเพอร์ไลต์ส่วนล่าง หินพัมมิเซียสเพอร์ไลต์ หินเพอร์ไลต์ส่วนบน และหินเพอร์ไลต์แปรสภาพ มีองค์ประกอบทางเคมีที่คล้ายคลึงกัน โดยประกอบด้วยซิลิกาออกไซด์ร้อยละ 70-79 ไทเทเนียมออกไซด์ร้อยละ 0.2 อลูมิเนียมออกไซด์ร้อยละ 10-13 แคลเซียมออกไซด์ร้อยละ 0.5-0.8 แมกนีเซียมออกไซด์ร้อยละ 0.2-0.6 เหล็กออกไซด์ร้อยละ 0.4-1 โพแทสเซียมร้อยละ 4-6 โซเดียมออกไซด์ร้อยละ 0.2-4 และแมงกานีสออกไซด์ร้อยละ 0.01-0.04 จากสัดส่วนขององค์ประกอบทางเคมีที่พบ สามารถสรุปได้ว่าหินเพอร์ไลต์บริเวณเขาฝาละมีเป็นหินไรโอลิติกเพอร์ไลต์ นอกจากนี้ จากการวิเคราะห์ทางธรณีเคมี หินเถ้าภูเขาไฟที่พบร่วมกับหินเพอร์ไลต์บริเวณเขาฝาละมีนั้นประกอบด้วยองค์ประกอบทางเคมีคล้ายกับหินเพอร์ไลต์ แต่มีช่วงองค์ประกอบที่หลากหลายมากกว่า โดยพบหินเถ้าภูเขาไฟที่มีองค์ประกอบทั้งแบบเดซิติกและแอนดิซิติก

Title: Perlites and Volcanic Association at Khao Falamee, Amphoe Srabot, Changwat Lopburi

By: Jittikan Narapan ID 513 27056 23

Advisor: Assistant Professor Dr. Chakkaphan Sutthirat

Co-advisor: Assistant Professor Dr. Somchai Nakaphadungrat

Department: Geology

Degree: Bachelor's degree

Academic Year: 2011

Abstract:

Khao Falamee volcanics is situated in the central part of Lam Narai volcanic field which has been categorized as Late Tertiary alkali-calc-alkali volcanic. Perlites occur within a volcanic succession consisting of lower perlites, pumiceous perlites, pyroclastics, upper perlites and devitrified perlites, respectively. Petrographic investigation shows that perlites are composed mainly of more than 70% silica-glass groundmass with microcrystalline lath-shaped feldspars and alkaline feldspar phenocrysts, biotite and iron oxides. Perlitic cracks are clearly observed in these rocks.

Geochemical analyses show that majority of the studied perlites including lower perlites, pumiceous perlites, upper perlites and devitrified perlites, similarly comprise major and minor oxides which contain about 70-79% SiO_2, 0.2% TiO_2, 10-13% Al_2O_3, 0.5-0.8% CaO, 0.2-0.6% MgO, 0.4-1 wt% FeO_{total}, 4-6% K_2O, 0.2-4% Na_2O and 0.01-0.04% MnO. Consequently, Falamee perlites are mostly named as rhyolitic perlites. In addition, based on geochemical analyses, pyroclastic rocks associated with these perlites are also composed of rhyolitic components with a wider range which can be classified as dacitic and andesitic pyroclastic rocks.

Keywords: Perlite; Khao Falamee; Lam Narai; Volcanic;

ACKNOWLEDGEMENTS

Through this acknowledgement, I would like to express my deeply sincere gratitude to my senior project advisor, Assistant Professor Dr. Chakkaphan Sutthirat and co-advisor, Assistant Professor Dr. Somchai Nakaphadungrat, Department of Geology, Faculty of Science, Chulalongkorn University for their supervisions, suggestions, encouragements and contributions, especially their kind-heartedness to make this study well completed.

Thankful and sincere acknowledgements are extended to Archan Malatee Taiyaqupt, guidance on geochemical study. Thank to Ms. Jiraprapa Neampan and Ms. Sopit Poompuang for helpful opinions and experiences on laboratory of geochemistry through which I received crucial for my study.

Furthermore, thanks to Department of Geology, Faculty of Science, Chulalongkorn University for financial and instrumental supports. Several persons, whose name cannot be entirely listed but have been associated and helped me with this project, are also deeply thanked.

Last but not least, I would like to express my whole-hearted thanks and appreciation to my parents for their moral encouragement to carry out this study.

CONTENTS

CONTENTS (cont.)

LIST OF FIGURES

LIST OF FIGURES (cont.)

LIST OF FIGURES (cont.)

Figure **Page**

LIST OF FIGURES (cont.)

LIST OF FIGURES (cont.)

LIST OF TABLES

CHAPTER I

INTRODUCTION

1.1 General Statement

The Lam Narai volcanic field consists of various types of volcanics which have been categorized as Late Tertiary alkali-calcalkali volcanics and covers an area of approximately 1,200 km^2 between Changwat Lopburi and Changwat Phetchabun, in central Thailand (Jungyusuk and Suriyashai, 1987). Falamee volcanic is situated in the center of the Lam Narai volcanic field; it contains perlite, a glassy volcanic rock, which is very useful for domestic industries. Perlite consists of high silica content with little amount of H_2O (Jungyusuk, 2010).

Perlites are valued as an industrial raw material in Thailand because of their ability to expand on heating to produce expanded perlites. The characteristic of expanded perlite is popcorn-like, very low-density inert material, light weight and refractory, so the expanded perlites have been used principally in construction as lightweight aggregate, insulation, horticulture, filter aids etc. As mentioned above, there are a lot of advantages of expanded perlite. However, the study of perlite in Thailand is limited and slightly reported. Therefore, the study of characteristics of perlite and its volcanic association at Khao Falamee, Amphoe Srabot, Changwat Lopburi, is required to be a database for further studies of perlite and the Lam Narai volcanic field.

1.2 Objectives

The main objectives of this project are:

- To study the characteristics and the alterations of perlite at Khao Falamee, Amphoe Srabot, Changwat Lopburi; and
- To study the relationship between perlite and volcanic association at Khao Falamee, Amphoe Srabot, Changwat Lopburi

1.3 Study Area

1.3.1 Location and Accessibility

The study area is located at Khao Falamee, Amphoe Srabot, Changwat Lopburi in central Thailand, covering an area of approximate 0.25 square kilometers as shown in Figure 1.1. The area lies on the topographic map scale 1:50,000, sheet number 5139 I, series L7018 of Amphoe Khok Charoen (Royal Thai survey Department) (Fig. 1.2). The study area is bounded by the latitudes between 15°17’17’’ and 15°17’40’’ and the longitudes between 100°52’38’’ and 100° 52’54’’.

Accessibility to this area can be carried by the Highway no.1, about 173 kilometers to the north from Bangkok to Saraburi and Baan Dilang. Then, turning northward to Amphoe Srabot takes the Highway no. 3326 approximately 16 kilometers. After passing Amphoe Srabot about 1 kilometer, we turn right and take the road about 9 kilometers to Baan Mahaphot. Moving eastward can be taken by the road along the Lam Wang Ang canal approximately 4 kilometers. Finally, the study area, Khao Falamee, is on the left side of the road (Fig. 1.3). Total distance from Bangkok to the area is approximately 205 kilometers.

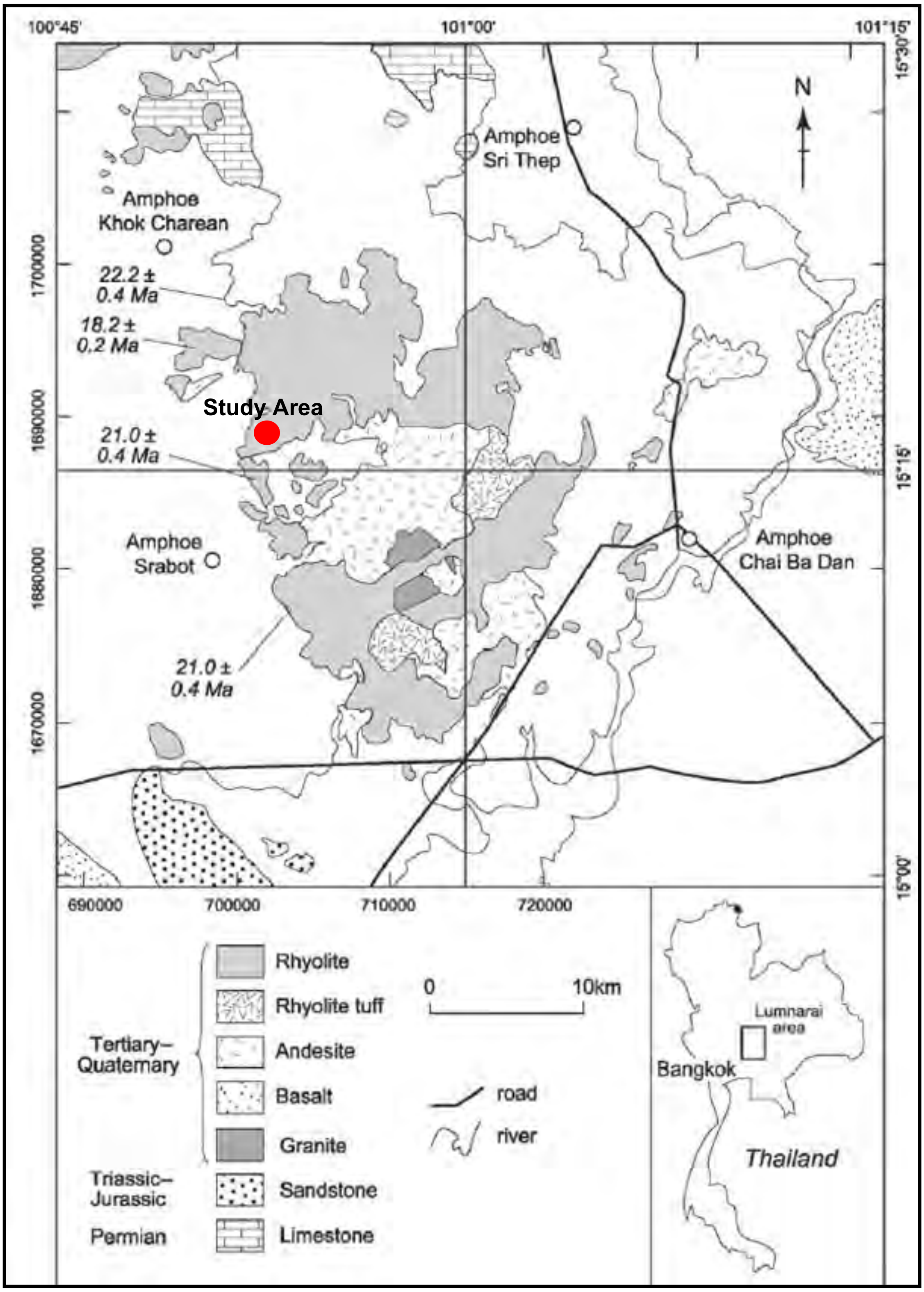


Figure 1.1 Simplified geologic map of the Lam Narai area, showing the study area, Khao Falamee, Amphoe Srabot, Changwat Lopburi, and (where available) $^{40}Ar/^{39}Ar$ dates (Saisuttichai and Manning, 2007)

Figure 1.2 Topographic map of the study area (scale 1:50,000, sheet number 5139 I, series L7018 of Amphoe Khok Charoen) (Royal Thai Survey Department)

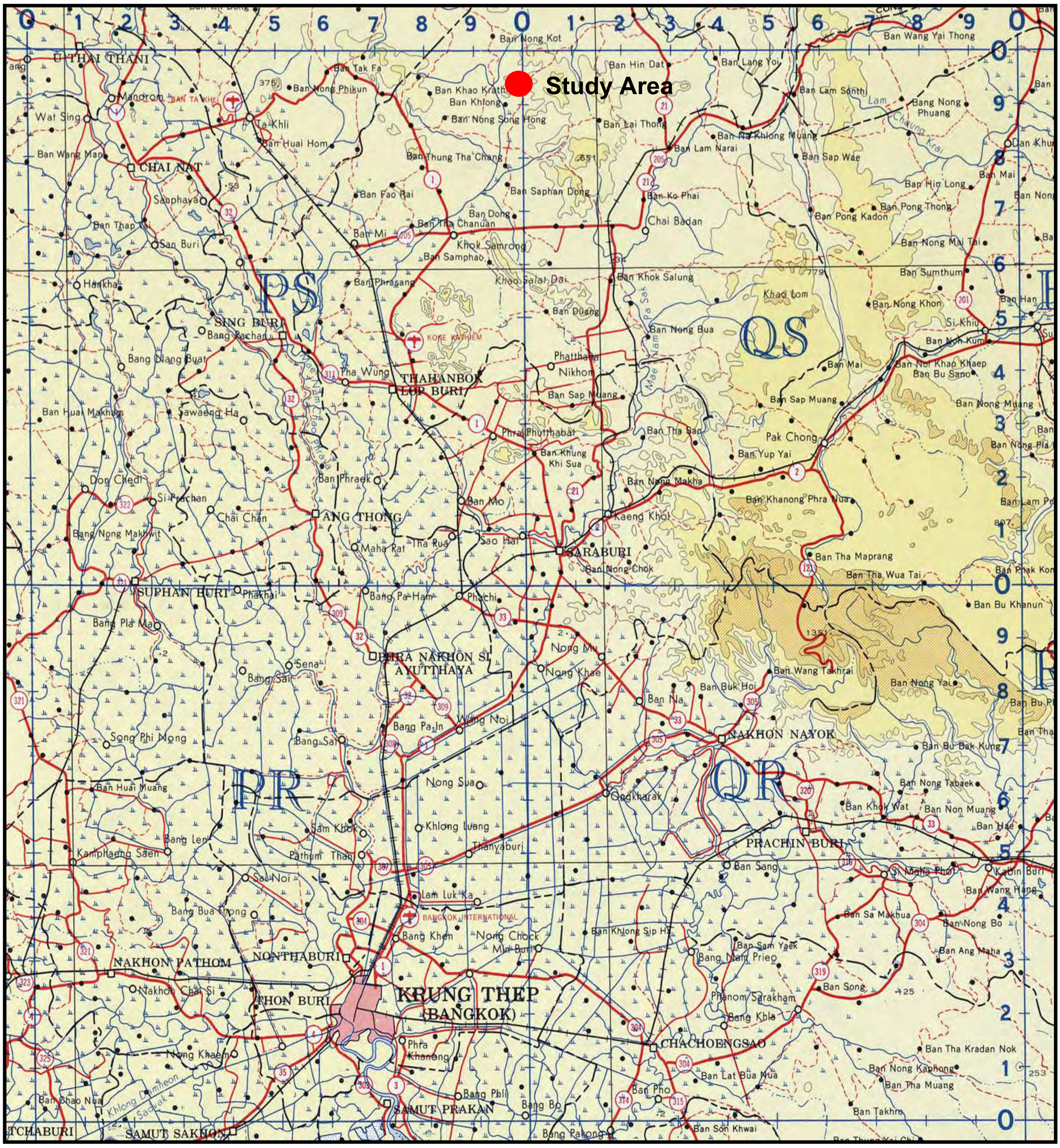


Figure 1.3 Highway map of Thailand showing main routes accessible to the study area. (topographic map scale 1:1,000,000, series 1301, sheet ND 47) (The U.S. Army Topographic Command, 1971)

1.3.2 Physiography

The feature of Khao Falamee, also called as Khao Phanomchat, is similar to a rhombus, approximately 450 meters width and 550 meters length. Upper part of Khao Falamee is quite flat and the highest is about 235 meters above mean sea level. The flat area around Khao Falamee is approximately 100 meters above mean sea level.

Khao Falamee is a mountain which is separated from the mountain range in the east side by the small narrow valleys. In the northern and southern parts are separated to two sides by Huai Lhua and Lam Wang Ang, respectively.

1.4 Literature Reviews

1.4.1 Regional Geology

The Lam Narai volcanic field is categorized as alkali – calc-alkali (Jungyusuk, 1995) which aged in Late Tertiary (during 24.1 ± 1 - 13.6 ± 0.1 million years) (Intasopa, 1993). The volcanic complex covers an area approximately 1,200 square kilometers, located in area of Amphoe Khok Samrong, Amphoe Srabot and Amphoe Chaibadan, Changwat Lopburi and also Amphoe Srithep, Changwat Phetchabun (Jungyusuk and Suriyashai, 1987). The Lam Narai volcanic field occurred after the collision of Shan-Thai and Indochina micro-continents, in Late Triassic (Bunopas, 1992) and after the deposition of sedimentary rocks in Jurassic - Cretaceous of Khorat Group which covers mostly area in the eastern part of Thailand. In the other words, there was the important rupture in many areas in Late Tertiary (Bunopas, 1992), especially in the area of eastern Chao Praya’s floodplain and the area of Changwat Lopburi and Changwat Phetchabun at present. This rupture is the way that magma from the inside of the earth erupted onto the surface and become the Lam Narai volcanic field which consists of basic (basalt) and basaltic andesite which slightly changed from basalt, andesite, dacite and rhyolite. In addition, alkali volcanic rocks can be hardly found such as quartz-latite, quartz-trachite and alkali-feldspar rhyolite (Jungyusuk, 2010). Geology of Changwat Lopburi is shown in Figure 1.4.

In Lopburi area, volcanic rocks are distributed along a north-south trend. The field relationships between volcanic rocks and the other rock units are poorly informed. They occur as lava flows and dikes associated with pyroclastic deposits. The associated plutonic rocks are granite and are exposed sporadically as small shallow intrusive bodies. Jungyusuk and Suriyashai (1987) mentioned the name of the volcanic rocks in this area as the Lam Narai Volcanic Formation. The volcanic rocks vary in composition from mafic and felsic. The intermediate volcanic rocks, which are overlain by rhyolite, pyroclastic rocks and basalt, are believed to be the oldest rocks of the Lam Narai Volcanic Formation (Jungyusuk and Suriyashai, 1987). The rhyolitic rocks are massive rhyolite, pitchstone perlite and associated pyroclastic rocks. It is believed that basalts which overlie rhyolite, trachyandesite, andesite and unconsolidated Quaternary beds are the youngest volcanic rocks in this area. The basalt also occurs as dikes cutting through the volcanic rocks and Quaternary sedimentary beds (Intasopa, 1993).

Rhyolite lavas of the Lam Narai Volcanic Formation, which are usually associated with pyroclastic deposits, cover an area of approximately 300 square kilometers. A variety of lithologies and textural features of the rhyolite can be distinguished. The rocks include massive rhyolite, glassy breccias, pitchstone perlite and pyroclastic deposits. The eruption of acidic volcanic materials locally produced a layered structure characterized by layers of pyroclastic rock at the bottom, overlain by glassy layers with massive rhyolite layers on the top (Intasopa, 1993).

Generally, the pyroclastic deposits are poorly sorted and contain more than one flow units. Each flow unit is distinguished as the deposit of a single pyroclastic flow. In Lam Narai area, there are two types of pyroclastic unit including lithic lapilli and ash-flow tuffs. The pyroclastic flow units are composed of lithic and pumice clasts at the bottom with an upper fine-ash layer. The lithic lapilli layers are contained mostly of variable sizes and concentration rock fragments such as pumices, glassy rocks and rhyolites etc. in ash matrix (Intasopa, 1993).

Glassy rock or rhyolitic perlite is always found associated with pyroclastic flow deposits and also rhyolite. It overlies pyroclastic flow units and form thick layers as chilled glassy rhyolite lava and as glassy brecciated beds varying in thickness from 10-20 meters. A large amount of perlites that found among the pyroclastic deposits indicates that while the rhyolite lava was developing, the explosive eruptions may also have continued. These glassy rocks are varied in color such as light green, greenish black etc. which these colors can help to define flow layers. The glassy layers are usually folded and shown as banding. The phenocrysts are plagioclase and biotite. Pitchstone perlites that found in this area are dull luster, flat fracture perlitic structure and composed of rhyolitic components. Rhyolite lava occurs as both dome and mesas. The rhyolite commonly illustrates low-angle or quite horizontal flow layers overlying pyroclastic flow units and glassy beds (Intasopa, 1993).

In the Lam Narai area, sparse outcrops of predominantly basalts, andesites and rhyolites occur in vegetated hills that lie between the alluvial plains of the Pasak river to the east and the Chao Praya river system to the west. Structurally, the volcanic complex occurs at the southwestern boundary of the Tertiary Wichian Buri basin (Remus *et al*., 1993; Morley *et al*., 2001). This small basin, about 20 kilometers wide, is a north-south trending graben, on the east side of which is the Mezosoic block of the Khorat Plateau (Saisuttichai and Manning, 2007).

General geology and occurrence of perlite in this area have been reported by Jungyusuk and Suriyachai (1987), Jungyusuk (1995) and Premmanee and Wijitchareampong (1997). $^{40}Ar/^{39}Ar$ dates ranging from 18-24 Ma (Perlitic rhyolites; Early Miocene) to 11-13 Ma (basalts; Middle Miocene; Intasopa, 1993) of these volcanic rocks correspond broadly to others reported from oil exploration wells from the adjacent Wichian Buri basin (15-11.6 Ma; Remus *et al*., 1993). Three-dimensional relationships at outcrop are very poorly exposed and have not been investigated in detail. Where observed, there is a general sequence in which a basal perlitic rhyolite is overlain by pyroclastic deposits, a second perlite and a non-perlitic rhyolite. This is broadly equivalent to the central part of the sequence described for rhyolite domes by Fink and Manley (1987). Other parts of the rhyolite volcanic complex have been removed by erosion or are obscured by vegetation (Saisuttichai and Manning, 2007).

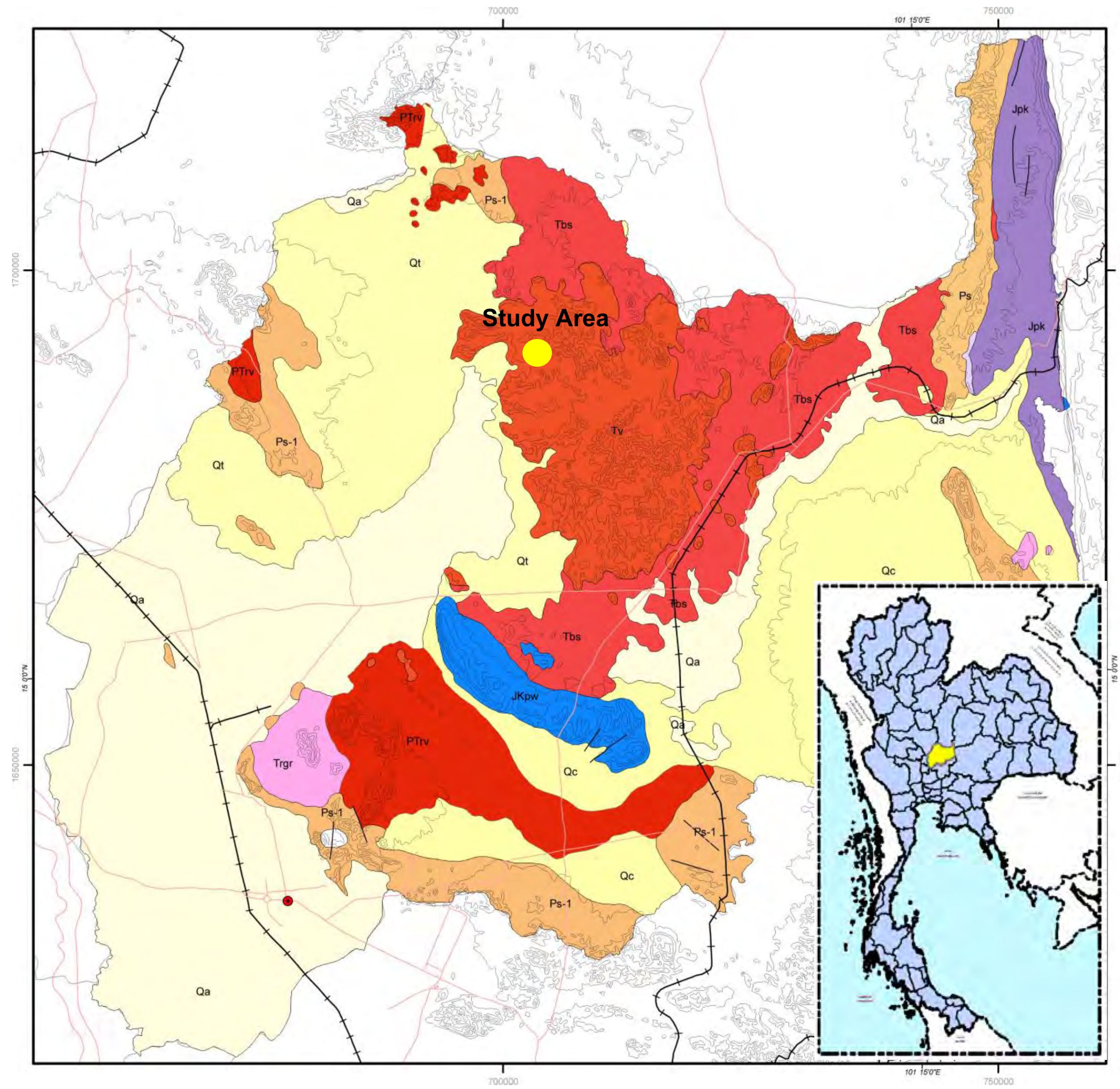


Figure 1.4 a) showing the Geological map of Thailand scale 1:250,000, sheet ND-47-4, Changwat Lopburi (Department of Mineral Resources, 2007)

EXPLANATION

SEDIMENTARY AND METAMORPHIC ROCKS

Qa	Alluvial deposits, gravels, sands, silts and clays
Qc	Colluvial and talus deposits, gravels, sands, silts, laterites and rock fragments
Qt	Terrace deposits, gravels, sands, silts, clays and laterites
JKpw	Sandstone with white, pink and grey quartz, shows cross-bedding, interbedded with conglomeratic sandstone
Jpk	Silty sandstone, purple and reddish purple, sandstone, greenish grey, brownish yellow and conglomerates with calcrete along horizontal
Trhl	Basal conglomerates, agglomerate, shale, claystone, siltstone, grey, brown, brownish yellow, greywacke sandstone, clayey limestone and marl
Trl	Basal conglomerates, red, shale, grey, interbedded with siltstone and sandstone
Ps-1	Limestone, chert, shale ,sandstone, lapilli and volcanic rocks
Ps	Fossilliferous limestone, chert, pillow lava basalt, ultrabasic and serpentinite

IGNEOUS ROCKS

Tbs	Basalts, dark grey to black, vesicular
Tv	Rhyolites, rhyolitic tuffs, andesitic tuffs
Trgr	Biotite granite, tourmaline granite, granodiortie, biotite-muscovite granite, muscovite-tourmaline granite, biotite-tourmaline granite
PTrv	Rhyolites, andesites, ash-flow tuffs, agglomerate, rhyolitic tuffs, andesitic tuffs

Figure 1.4 b) Explanation of the Geological map of Changwat Lopburi (Figure 1.4a) (Department of Mineral Resources, 2007)

1.4.2 Geology of Study Area

Considering the geological map of Department of Mineral Resources (2007), the study area is categorized as igneous rocks (Tv) which consist of rhyolites, rhyolitic tuff and andesitic tuff. (Geological map of Thailand scale 1:250,000, sheet ND-47-4, Changwat Lopburi) (Fig. 1.5)

The feature of Khao Falamee is lid-like shape and the cliff is appeared in the western part. The middle part of Khao Falamee is shown as quite horizontal bed. However, the upper and lower parts of Khao Falamee are not appeared obviously as bed, but generally shown as quite horizontal. Moreover, the change in slope in each part of Khao Falamee is because of the different rock types which can be distinguished into 5 parts: coarse-grained perlite and devitrified perlite; pumice and pumiceous perlite; pumiceous tuff and pumicite; fine-grained perlite; devitrified perlite (Jungyusuk, 2010).

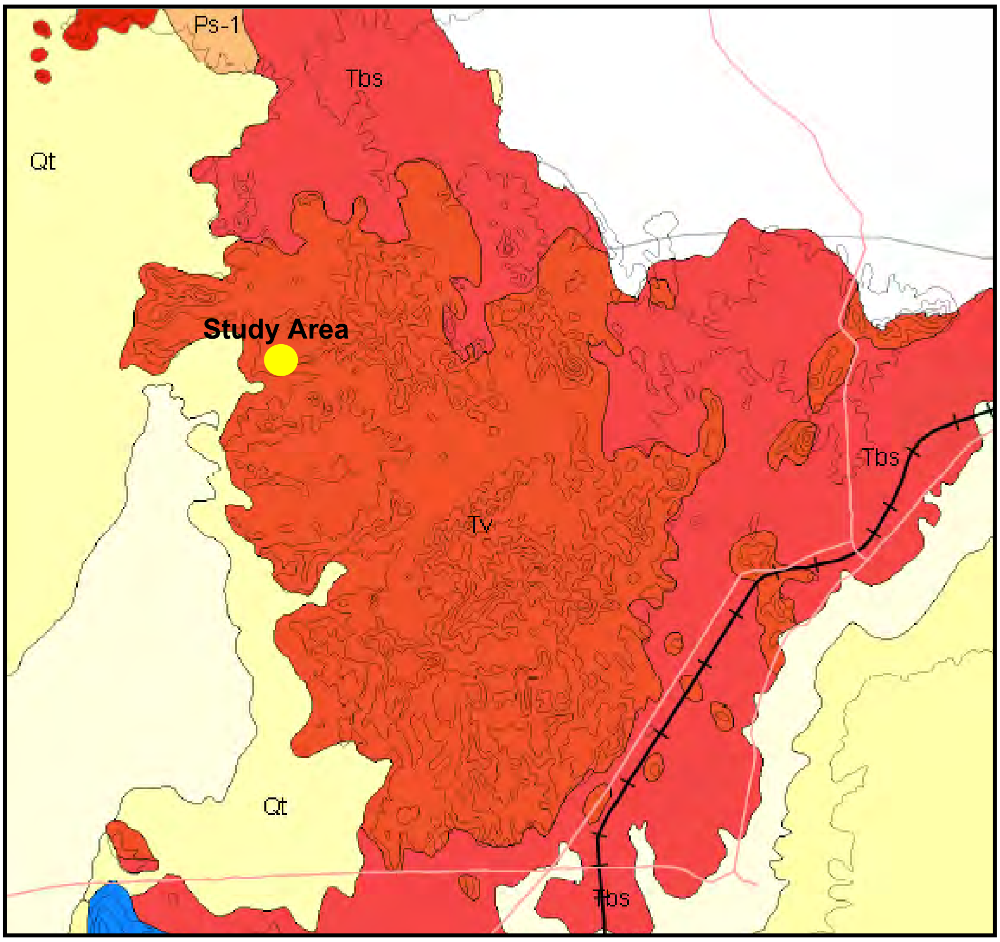


Figure 1.5 Showing the geological map of the study area (partly from Department of Mineral Resources, 2007)

1.4.3 Perlite

The occurrence of perlites is closely associated with collision related volcanism and the presence of obsidian. Perlite, bodies form volcanic flows, domes, dykes, sills and pipes, is sometimes found in the external border areas of obsidian deposits (Fig. 1.6a). The geological setting suggests that the volcanism and formation of perlites took place in submarine environments. For example, some hundred perlite bodies are known from the 1300km collision zone of the Late Paleogene (35–28 Ma), that extends from the Alps to Eastern Turkey and Armenia (Heide and Heide, 2011)

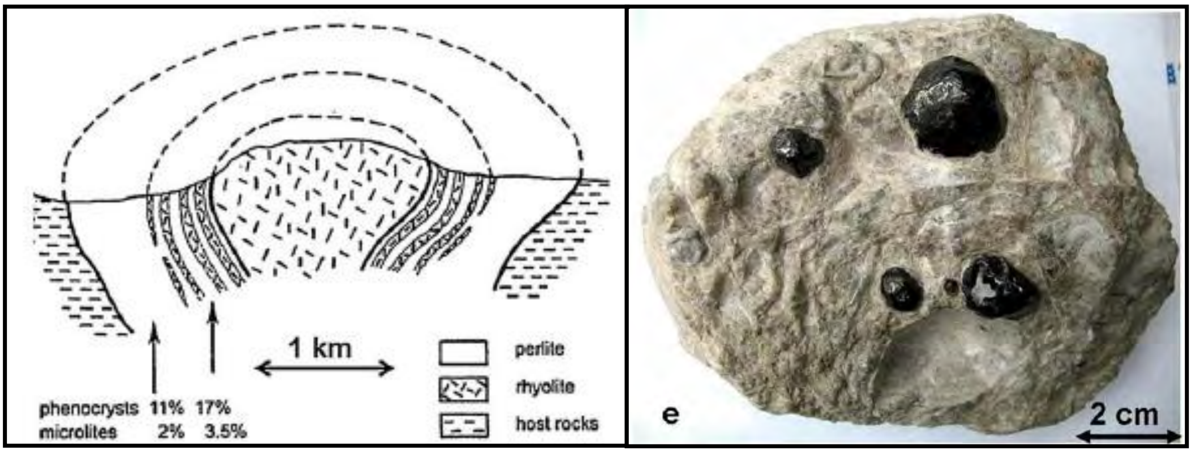


Figure 1.6 a) Schematic cross-section of a rhyolitic dome (Bulgaria) with perlite formation b) Apache tears in perlite, Utah, USA (Heide and Heide, 2011)

Perlite can be considered as hydrated obsidian. In the natural deposits the existence of obsidian perlite "couples" was observed according as was shown in experiments (e.g., Armenia, Argentina): obsidian +H2O ↔ perlite. Small obsidian nuggets are described in the latter perlite deposit as "Apache tears" (Fig. 1.6b). (Heide and Heide, 2011).

Two processes are thought to be responsible for the formation of perlites in the Tokaj Mountains. During a high-energy eruption, where mainly tuffs are formed, the melt still has a comparatively high volatile content before it solidifies to a green perlite. In a later decaying volcanic phase, the melt has a lower content of volatiles, and solidifies as grey perlite. The development of perlitic cracks is interpreted as evidence of later dehydration (Heide and Heide, 2011).

Perlites and pitchstones have a characteristic “perlitic” texture, i.e., concentric fissures in a vitreous matrix break up the perlite and its transformation into pearl-like spheres with a size of 1–10 millimeters. The perlitic fissures destroy the original texture of the perlite and form a glassy detritus, whereas pitchstones may form cliffs like those formed by obsidians (Heide and Heide, 2011).

Perlite and obsidian are volcanogenic mining rocks that consist predominantly of volcanic glasses containing tightly bound constitutional water. The high viscosity of perlite-containing melts, which is associated with the high content of silica (SiO_2, 73–74%) and alumina (Al_2O_3, 13.5–14.0%), led to a rapid cooling of the lava. As a result, the melts had no time to crystallize, the rocks remained predominantly in a glassy state, and only a small part (2–4%) of the lave crystallized. Apart from the glassy and crystalline components and the constitutional water, these rocks contain volatile components, i.e., CO, CO_2, H_2, I_2, Cl_2, and F_2, which are absorbed from air during rapid cooling of the melts. At high temperatures, water and the aforementioned volatile components are the main foaming and swelling agents, which are extremely undesirable in glass making. Upon heating to a temperature of 500°C, perlite and obsidian-containing glass batches, as a rule, behave precisely like the industrial batch from the former Borzhomi glass-container plant. At temperatures above 500°C, the bound water begins to escape and the batches behave differently depending on the mineral composition of the rocks (Dalakishvili, 2005).

Devitrification, or crystallization, of natural or artificial glasses may take place, provided that conditions permit the formation of stable nuclei, simply because an undercooled liquid or melt is thermodynamically unstable, and therefore may occur within a closed system; many spherulites in volcanic glasses must have formed under such conditions. Devitrification of natural glasses has been attributed to heat, pressure, circulating fluids, "power of spontaneous crystallization" or a combination of these factors (Simons, 1962).

Saisuttichai and Manning (2007) studied about geochemistry and the expansion characteristics of perlitic rhyolites in Changwat Lopburi using EPMA methods. The results showed that perlitic rhyolites consist of 12.9% K_2O contents and very small amount of Na_2O (0.9%). And also found that when perlitic rhyolites have been altered, the spherulites, which are red-rounded clasts distributed generally in alteration zone, can be shown. The analysis of spherulites using EPMA methods showed that the Na_2O contents are increased (<6.9%), while the K_2O contents are decreased (2.9 %).

1.5 Scope of Work

The characteristics of perlite and volcanics that found in the study area are studied. Collection of both perlite and volcanic rocks in each part of Khao Falamee was taken place. Subsequently, petrographic investigation was carried out using a polarizing microscope. Determination of major and minor oxide contents in perlites and volcanics was done using X-ray Fluorescence Spectrometry (XRF). Moreover, Electron Probe Micro-Analyzer (EPMA) is used to analyze mineral chemistry of perlite and volcanics at Khao Falamee. In addition, geologic data obtained from field investigation and geochemical analyses are used to determine the relationship between perlite and volcanic association.

1.6 Output

Characteristics and alteration of perlite as well as relationship between perlite and volcanic association at Khao Falamee, Amphoe Srabot, Changwat Lopburi can be obtained from this study.

CHAPTER II

METHODOLOGY

2.1 Methodology

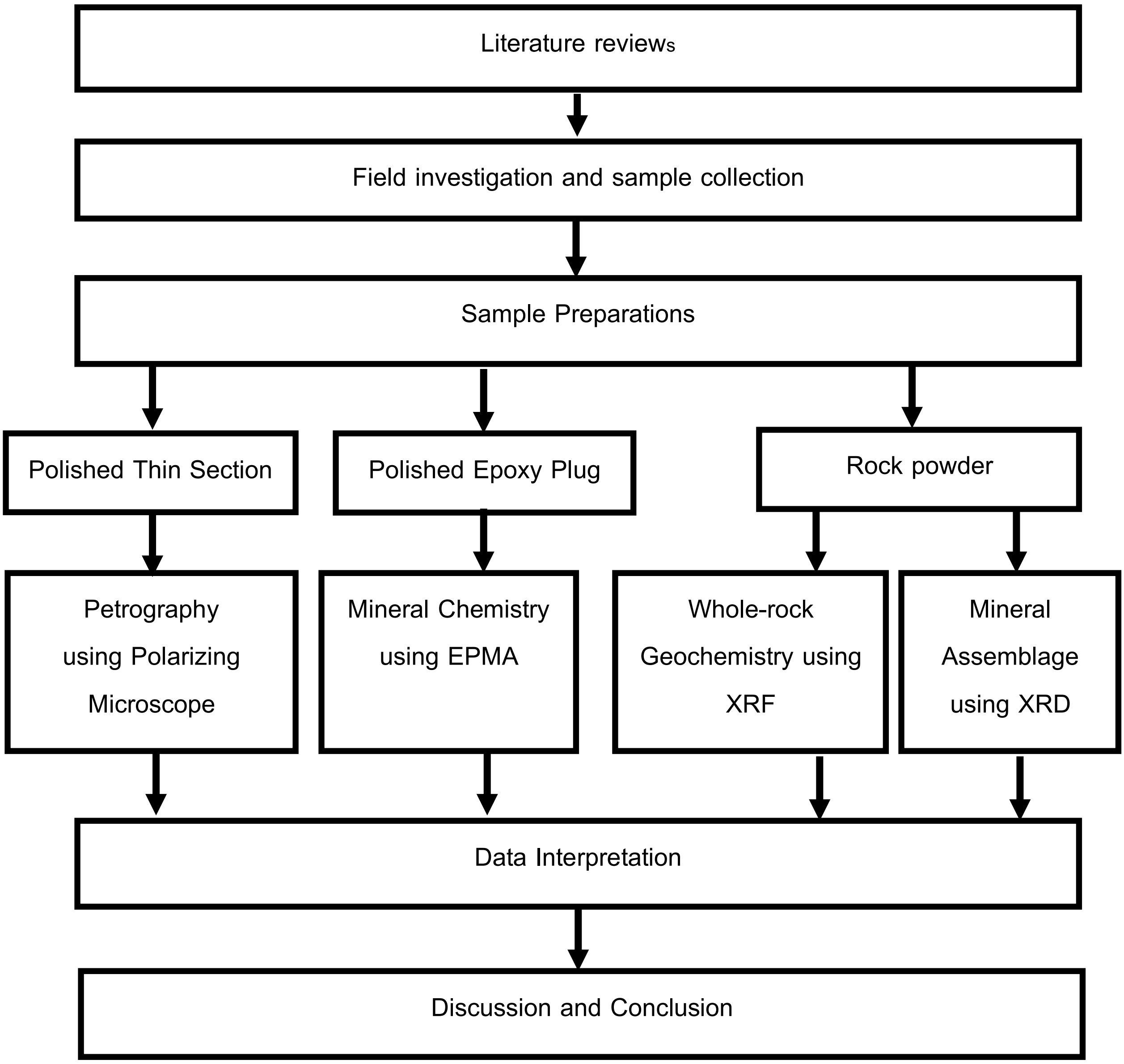


Figure 2.1 Schematic diagram showing steps of work under this study

Methodology under this project can be summarized and shown in the schematic diagram (Fig. 2.1). They are composed of 9 steps which details of each step are informed below.

1. Literature reviews

1.1 Previous works related to the study had been reviewed.

1.2 Fundamental data were acquired such as the geology of the study area, characteristics of perlite, etc. This step could lead to basic knowledge and guidelines for this study.

2. Field investigation and samples collection

2.1 Field investigation which had carried out during 12 - 14 august 2011 was needed to study geology of the study area and to collect the samples

2.2 Rock samples were collected for study of physical property and analyses in laboratory.

3. Samples preparation

The samples preparation was divided into three parts including polished-thin sectioning, rock powdering and epoxy plug polishing.

3.1 Polished-thin sections were used for petrography analysis and mineral chemical analysis.

3.2 Rock powders were used for whole-rock geochemical analysis and mineral identification using XRF and XRD, respectively.

3.3 Polished epoxy plugs were used for mineral chemical analysis.

4. Petrography

Petrography was carried out using a polarizing microscope at Department of Geology, Faculty of Science, Chulalongkorn University. Rock-forming minerals and their textures were described and reported. The results would be fundamental data prior to further analysis.

5. Whole-Rock Geochemistry

Rock powdered samples were analyzed for whole-rock geochemistry using XRF, Model Bruker AXS S4 PIONEER based at Department of Geology, Faculty of Science, Chulalongkorn University. These quantitative analyses were operated at 220/380 V, 50 Hz, 8 kvA and internal standards were used for calibration prior to report wt% oxides of the major and minor elements. The results were used for indicating chemical compositions of rock samples.

6. Mineral Assemblages

Mineral assemblages were additionally identified using a XRD, model Bruker AXS, Germany Model D8 based at Department of Geology, Faculty of Science, Chulalongkorn University. Analytical condition was set at 40kV with about 30mA. This is because all mineral in the rock samples are very tiny and difficult of optical identification.

7. Mineral Chemistry

Mineral chemistry was analyzed using an EPMA, Model JEOL JXA-8100, based at Department of Geology, Faculty of Science, Chulalongkorn University. Analytical condition was set at 15kV with about 2.4*100 A and focus beam (10^{-8}< 1μm). Pure oxides and mineral standards were selected for calibration prior to automatic ZAF correction and reported as %wt oxides.

8. Data Interpretation

The results from the field investigation and laboratory were acquired and corrected prior to interpretation. Characteristics of perlite and its related volcanics were the main focus of data interpretation.

9. Discussion and Conclusion

Previous research on general geology and perlites were also taken into account and correlated with the data gained from this project. Then, conclusions in some crucial aspects were pointed out. Finally, the study report was then wrapped up as seen herein.

2.2 Data Acquisition and Analysis

2.2.1 Field Investigation and Samples Locality

Localities of sampling are located at Khao Falamee, Amphoe Srabot, Changwat Lopburi, as shown in Figure 2.2. The topographic map scale 1:50,000, sheet number 5139 I, series L7018 of Amphoe Khok Charoen (Royal Thai survey Department) covering the study area was used for this field investigation. Khao Falamee volcanic succession exposed as quarry outcrop (Fig. 2.4). Samples collection was taken place in six stations and twenty six samples were collected.

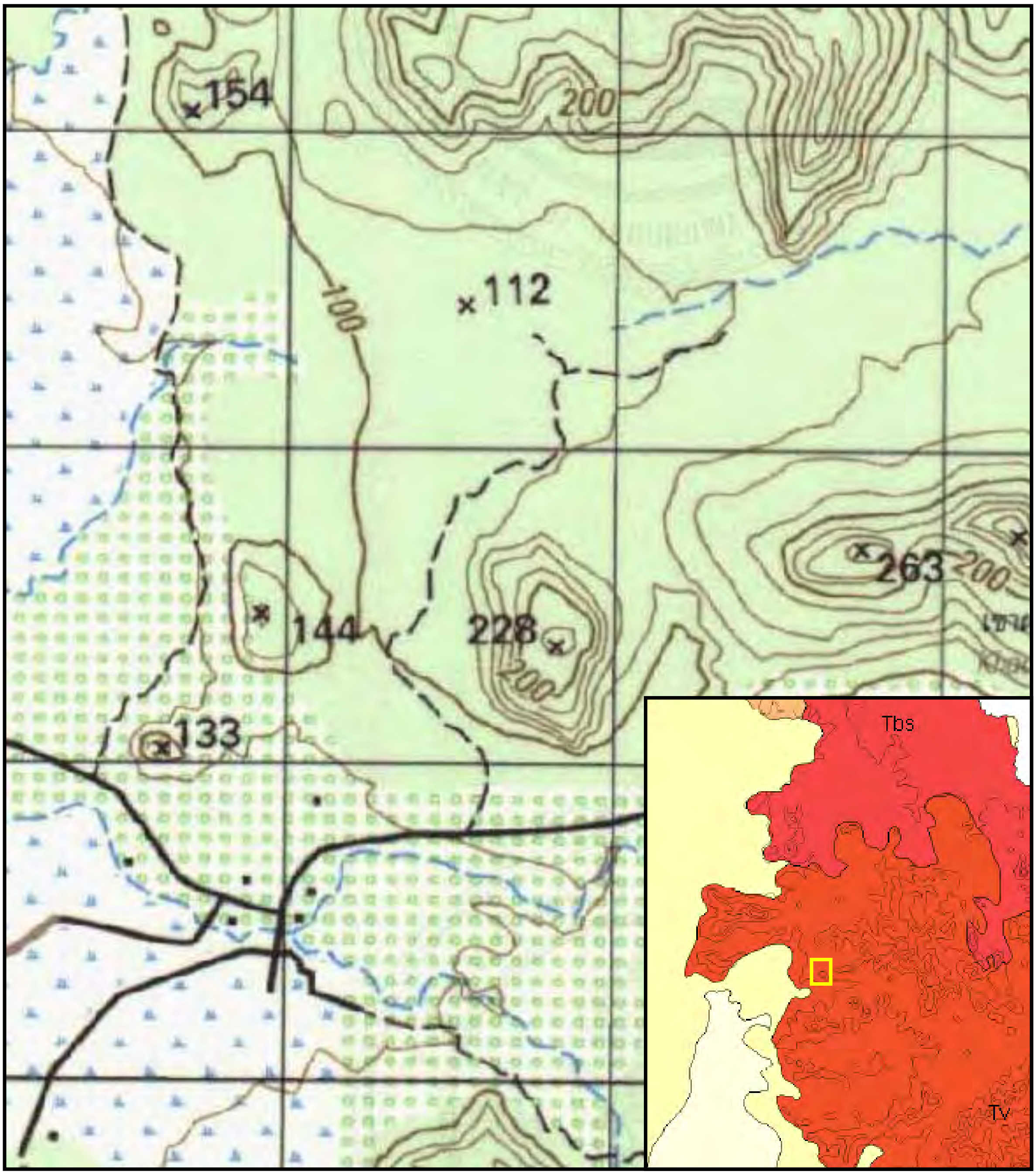


Figure 2.2 Topographic map (scale 1:50,000, sheet 5139 I, series L7018 of Amphoe Khok Charoen from Royal Thai survey Department) showing sample localities at Khao Falamee, Amphoe Srabot, Changwat Lopburi

Figure 2.3 Khao Falamee, Amphoe Srabot, Changwat Lopburi

Figure 2.4 Mining quarry of volcanic outcrop at Khao Falamee, Amphoe Srabot, Changwat Lopburi

Volcanic rocks at Khao Falamee, observed as quarry outcrop, can be distinguished into five categories based on hand specimens, namely, lower perlite, pumiceous perlite, pyroclastics, upper perlite and devitrified perlite. Based on field investigation, the distribution of each rock is shown in Figure 2.5.

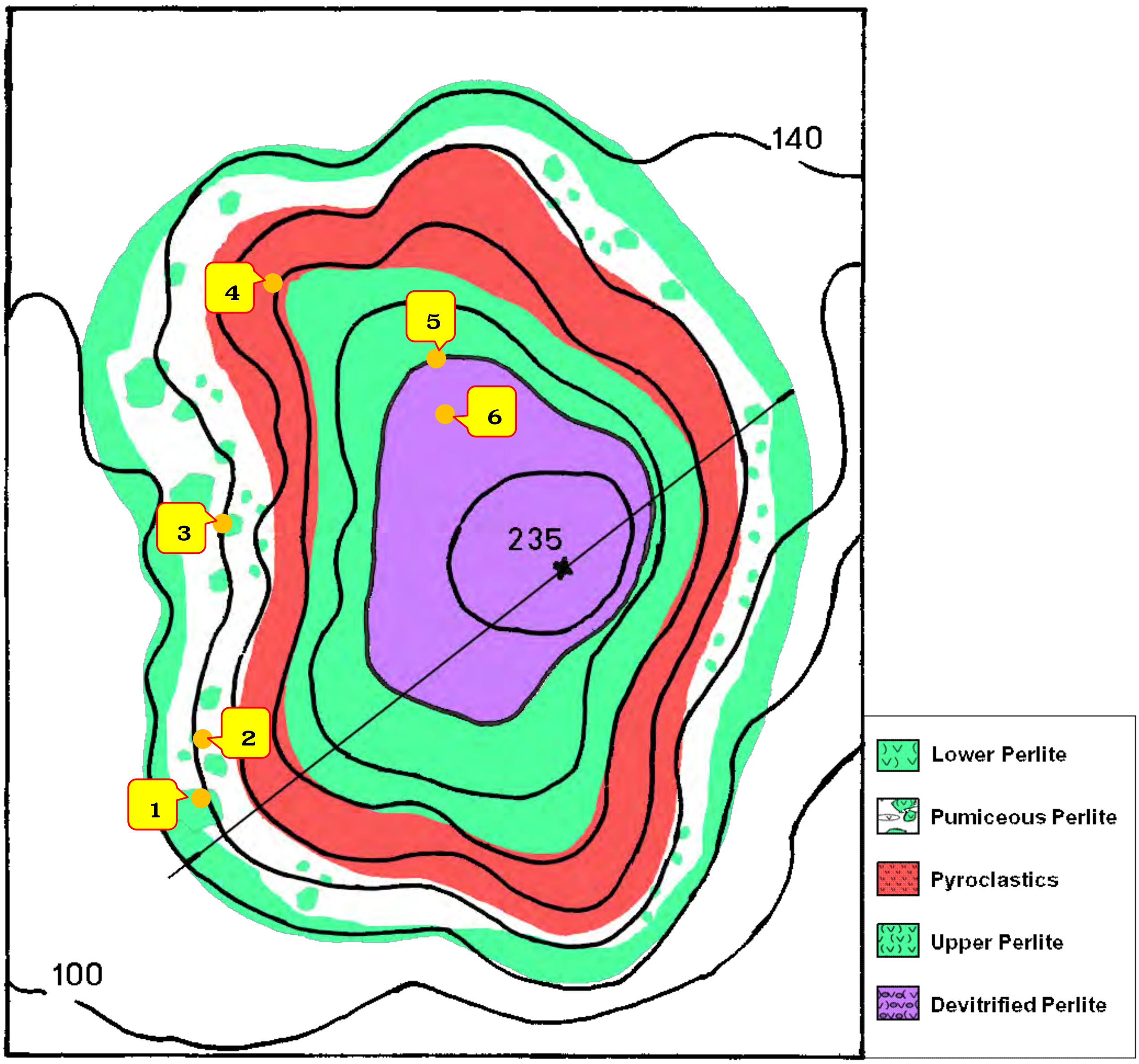


Figure 2.5 Simplified topographic map showing sample locations and distribution of rocks at Khao Falamee, Amphoe Srabot, Changwat Lopburi (modified from Jungyusuk, 2010)

The studied perlites and other volcanic rocks belong to the Lam Narai Volcanic Formation, Late Tertiary volcanics (Jungyusuk and Suriyashai, 1987). Based on field investigation and hand specimens, the volcanic succession is constructed and shown in Figure 2.6.

Lower Perlite: occurs at the lower part of Khao Falamee. It usually shows dark green - greenish grey glassy texture with conchoidal fractures and perlitic cracks also visible under a hand lens. Reddish brown spherulites (up to 1 cm in diameter) are commonly found. Phenocrysts of feldspars varying in size from 0.5-1 cm are visible with the naked eye (Fig. 2.7).

Pumiceous Perlite: are generally associated with lower perlites. They show white - pale green fibrous texture under a hand lens. The pumiceous perlite breccias, which perlites are clast setting in pumice matrix, can be generally found. Thus, it is believed that pumice exploded along lower perlites fractures which introduced alteration in lower perlites and becoming pumiceous perlites. They usually show more obvious in fibrous texture (Fig. 2.8).

Pyroclastics: quite horizontally sit on the lower perlites and pumiceous perlite. They show a layered structure distinguished by colors and types of pyroclastic deposits. Their colors vary from white to pale brownish yellow. They are composed of three major layers which commonly present normal graded-bedding from lapilli to tuffs in each layer. The clasts setting in the lapilli, about 3-8 cm across, include rhyolites, greenish grey perlites, pumices etc (Fig. 2.9).

Upper Perlite: exposes overlying the pyroclastic layers. They usually show a light green - greenish grey glassy texture with perlitic cracks visible under hand lens. Spherulites are observed in minor amount whereas phenocrysts of feldspars and biotites, about 0.5 cm across, are visible in the naked eye. In comparison with the lower perlite, the upper perlite is harder and shows less alteration as indicated by small amount of spherulite occurrences. Moreover, biotite phenocrysts are commonly found in the upper perlite but are rarely found in the lower perlite (Fig. 2.10).

Devitrified Perlite: presented at the top of Khao Falamee shows wholly devitrification. They usually show reddish brown spherulitic texture visible under the naked eyes. Feldspar phenocrysts, up to 0.5 cm in size, are commonly found. It appears to have altered from the upper perlites underneath (Fig. 2.11).

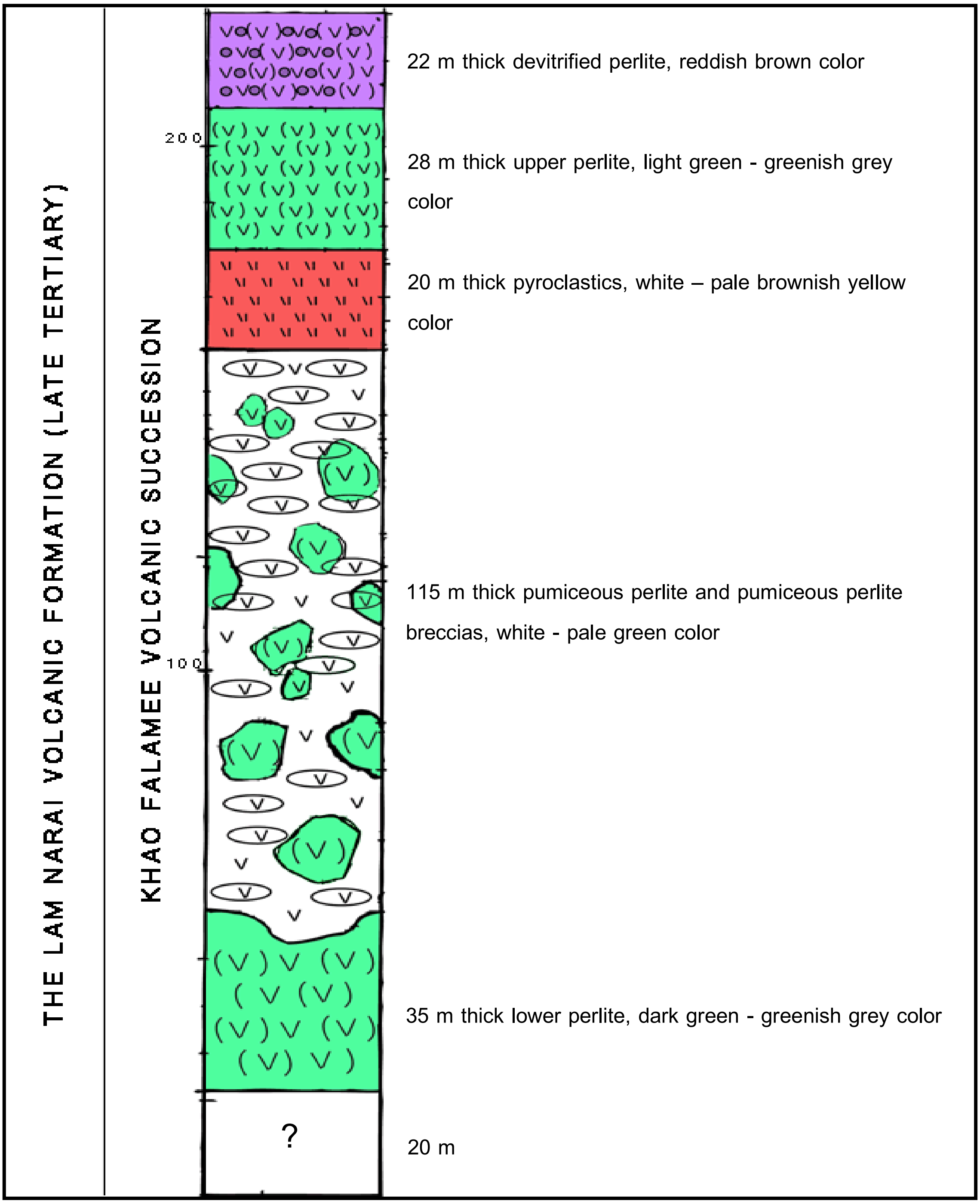


Figure 2.6 Model of volcanic successions at Khao Falamee, Amphoe Srabot, Changwat Lopburi

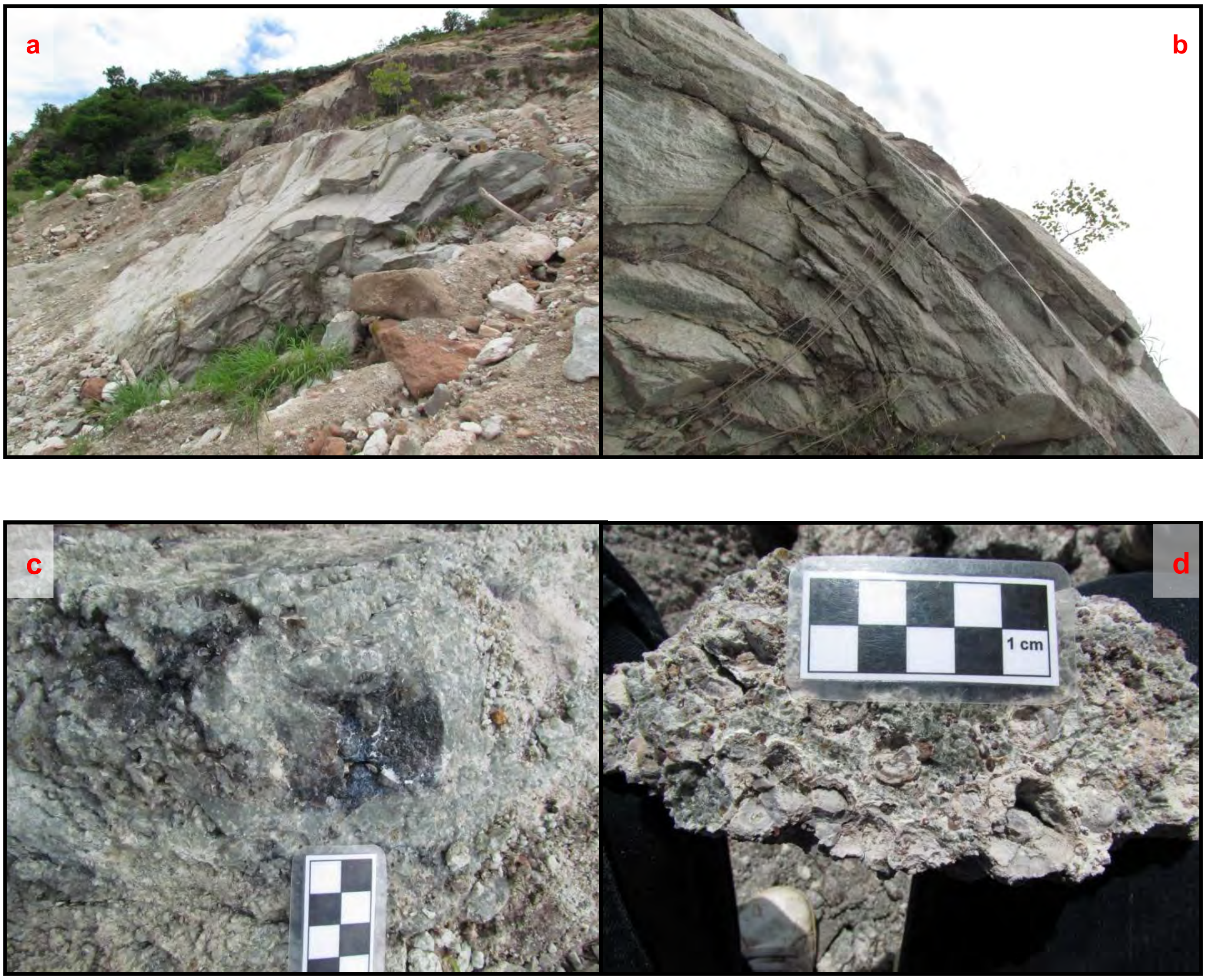


Figure 2.7 Lower perlite at Khao Falamee showing: a) quarry outcrop; b) flow layers**;** c) glass recrystallization; d) spherulites

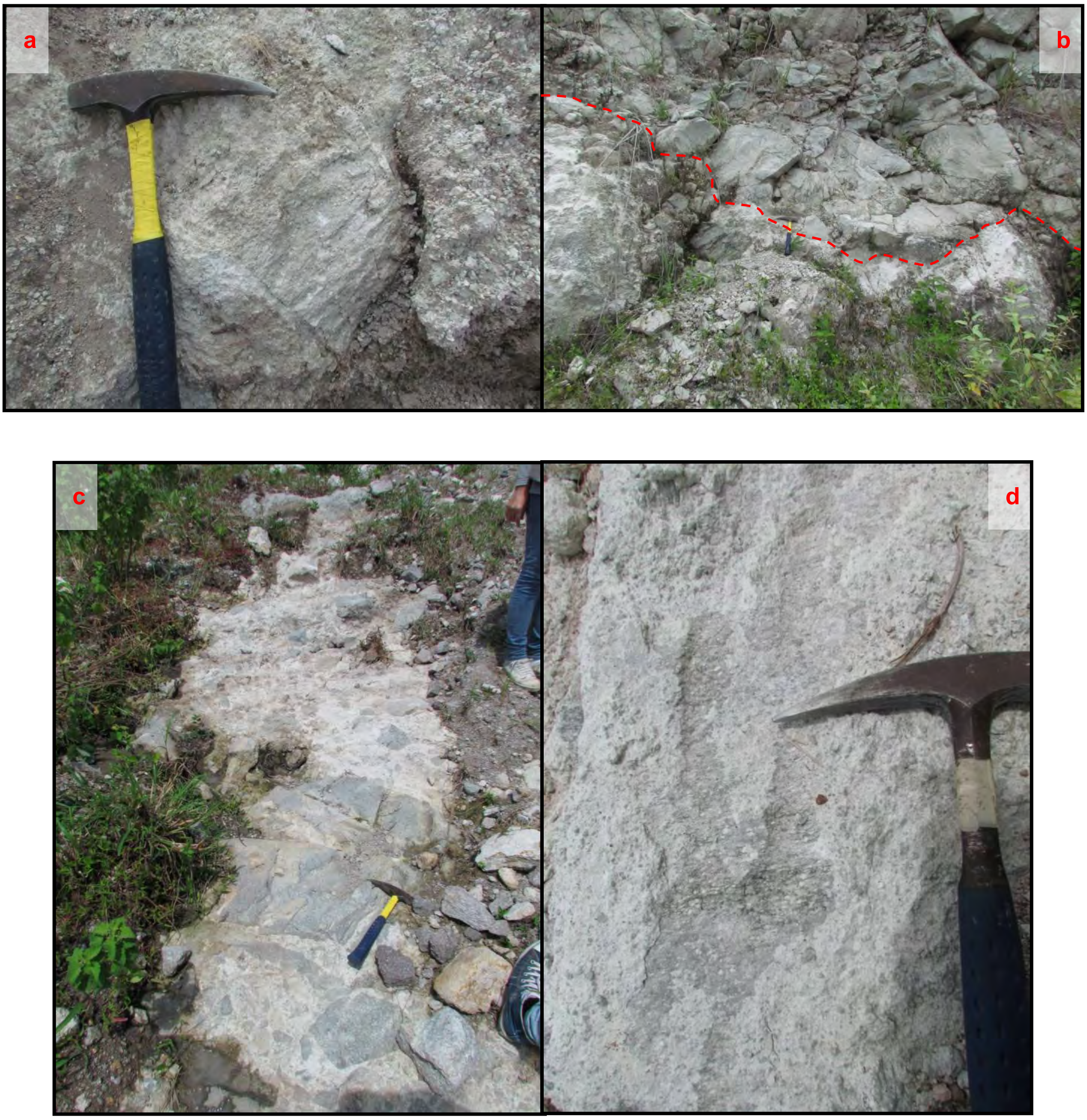


Figure 2.8 a) Pumiceous perlite at Khao Falamee; b) boundary between lower perlite and pumiceous perlite; c) pumiceous perlite breccias; d) pumiceous perlite in pumice

Figure 2.9 Pyroclastics at Khao Falamee: a) horizontally layered structure; b) quarry outcrop; c) normal grading structure; d) Lapilli with perlite clast

Figure 2.10 a) quarry outcrop of upper perlite at Khao Falamee; b) close-up view of upper perlite

Figure 2.11 a) quarry outcrop of devitrified perlite at Khao Falamee; b) spherulitic texture of devitrified perlite

2.2.2 Samples Preparation

Thin Sections: From twenty six collected hand specimens, forty eight thin sections (Figure 2.12) are prepared for further petrography description.

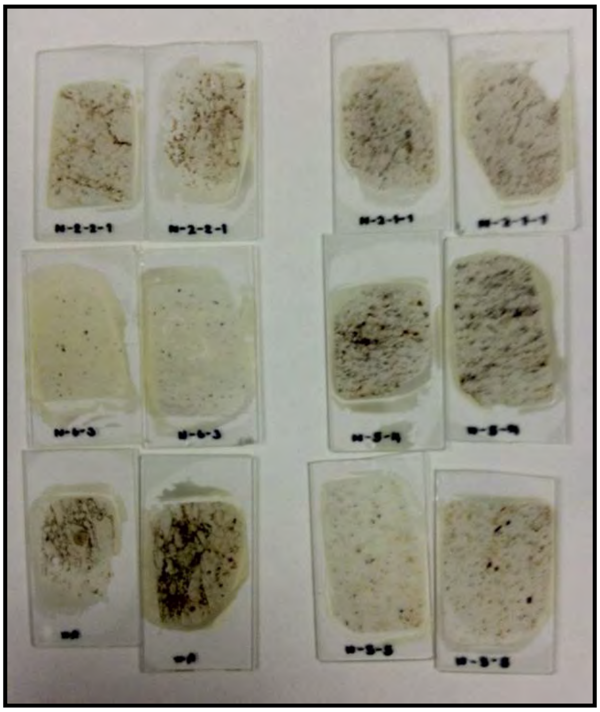


Figure 2.12 Thin sections of volcanic samples

Rock Powders: From twenty six collected samples, seventeen samples were selected for rock powdering (Figure 2.13) in order to whole-rock analysis using XRF and mineral identification using XRD.

Figure 2.13 Rock powdered samples for XRF and XRD

Polished Epoxy Plugs: From twenty six collected samples, ten samples were selected and prepared as polished epoxy plugs (Figure 2.14) in order to use in mineral chemical analysis using EPMA.

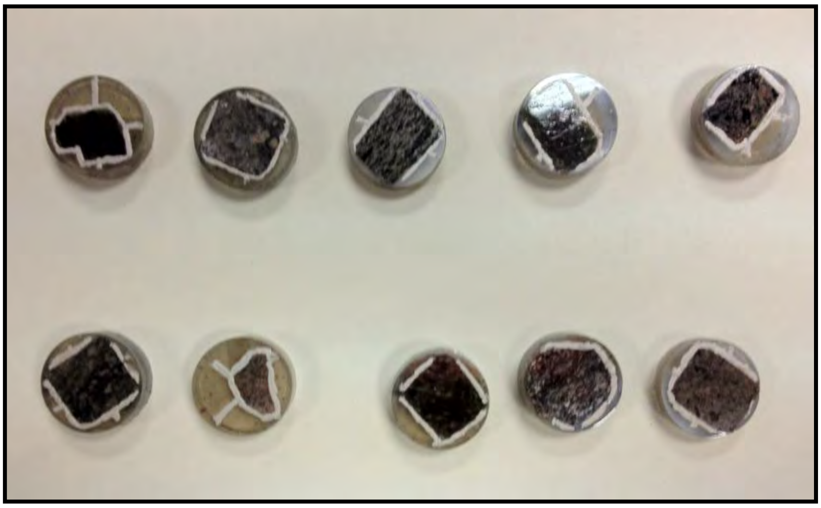


Figure 2.14 Selected polished epoxy plugs for EPMA analysis

CHAPTER III

RESULTS

3.1 Petrography

Rock samples collected from the study area, Khao Falamee, can be distinguished based on physical property and texture into five categories, namely, lower perlite, pumiceous perlite, pyroclastics, upper perlite and devitrified perlite. Fourteen representative thin sections are selected for petrographic description under the polarizing microscope. Details of each category are reported below.

Lower Perlites: The Lower Perlites are characterized by perlitic texture which is clearly recognized in the studied perlite. Major phenocrysts of alkali-feldspar (sanidine) and plagioclase are usually euhedral to subhedral crystals. Feldspar phenocrysts usually form as nucleus at the core of spherulites. Groundmass showing cryptocrystalline texture contains about 60-70% of the whole volume. Some opaque iron oxides also present (see Figures. 3.1 to 3.3).

Pumiceous Perlites: are composed of perlite patches in tuffaceous groundmass which is the main composition about 70-75%. Subhedral feldspar crystals usually form as phenocrysts set in this glassy groundmass (see Figures. 3.4 to 3.6)

Pyroclastics: are characterized by tuffaceous texture, which comprises of the very fine to glassy silica groundmass. Glassy groundmass is majority of the samples. Main phenocrysts of feldspar usually show embayment texture suggesting corrosion of magma during transportation to the surface. Euhedral to subhedral crystals are scattered in the silica groundmass forming porphyritic texture; they range in size from 0.1 to 0.7 mm and comprise feldspar and opaque minerals (Fig. 3.7).

Upper Perlites: glassy groundmass, about 70-75% of the rock volume, in the upper perlites usually shows perlitic cracks and cryptocrystalline texture. Feldspars (alkali feldspar and plagioclase), biotite and iron oxide usually form as phenocrysts in these samples. They are euhedral to subhedral crystals. Spherulitic texture is rarely observed (see Figs. 3.8 to 3.10).

Devitrified Perlites: are characterized by spherulitic texture which are mostly found in the studied samples. They usually consisted of radiated crystal fibers. Cluster of feldspar, biotite and iron oxide may be found growing in the samples. Fan- or sheaf-shaped spherulites occur around the margin of spherulites (see Figs. 3.11 to 3.13).

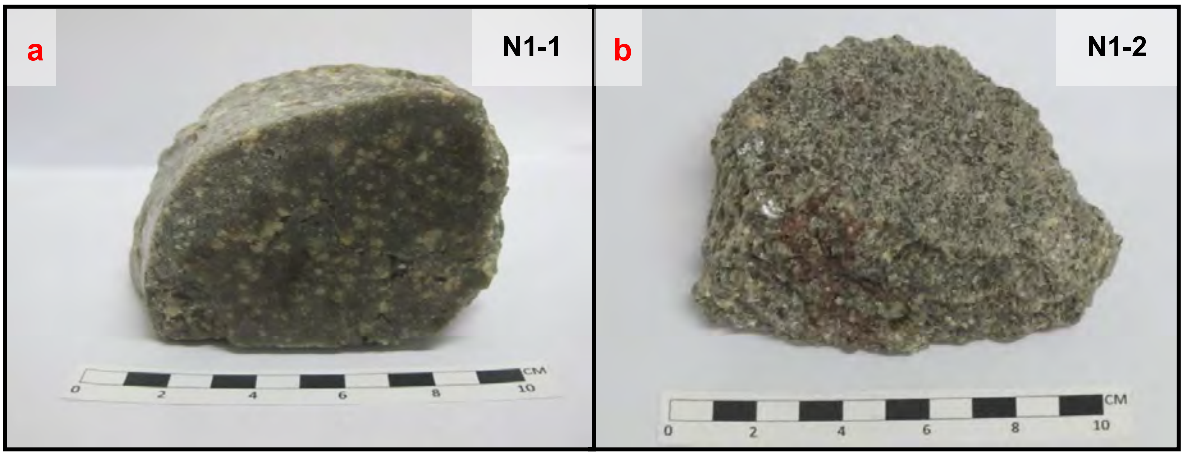


Figure 3.1 Lower perlite showing: a) green specimen with glassy texture and feldspar phenocrysts (0.3-0.5 cm) (UTM: 016915); b) dark green specimen with moderately weathered glassy material with reddish brown spherulites and feldspar phenocrysts (0.3-0.7 cm) (UTM: 016914)

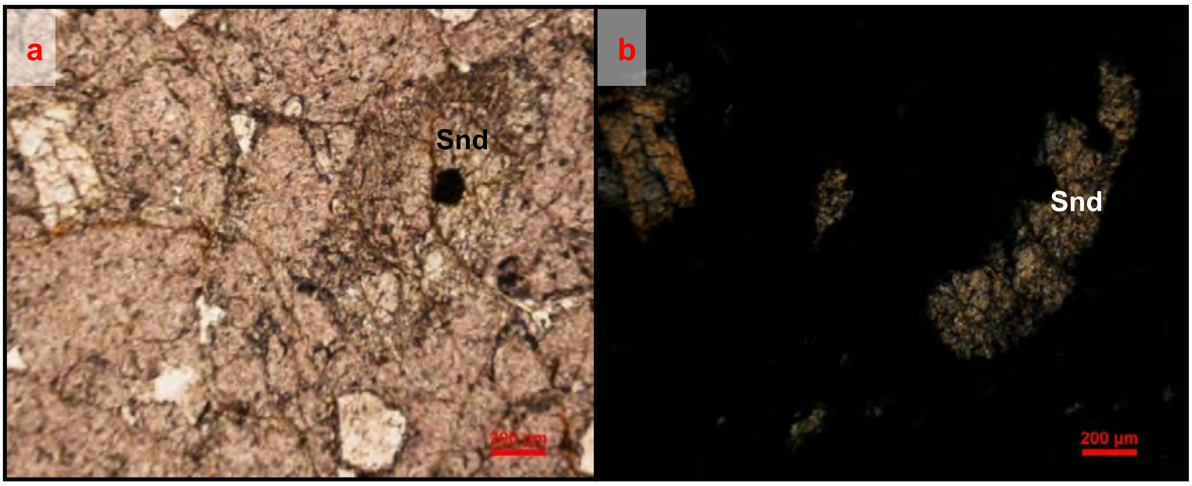
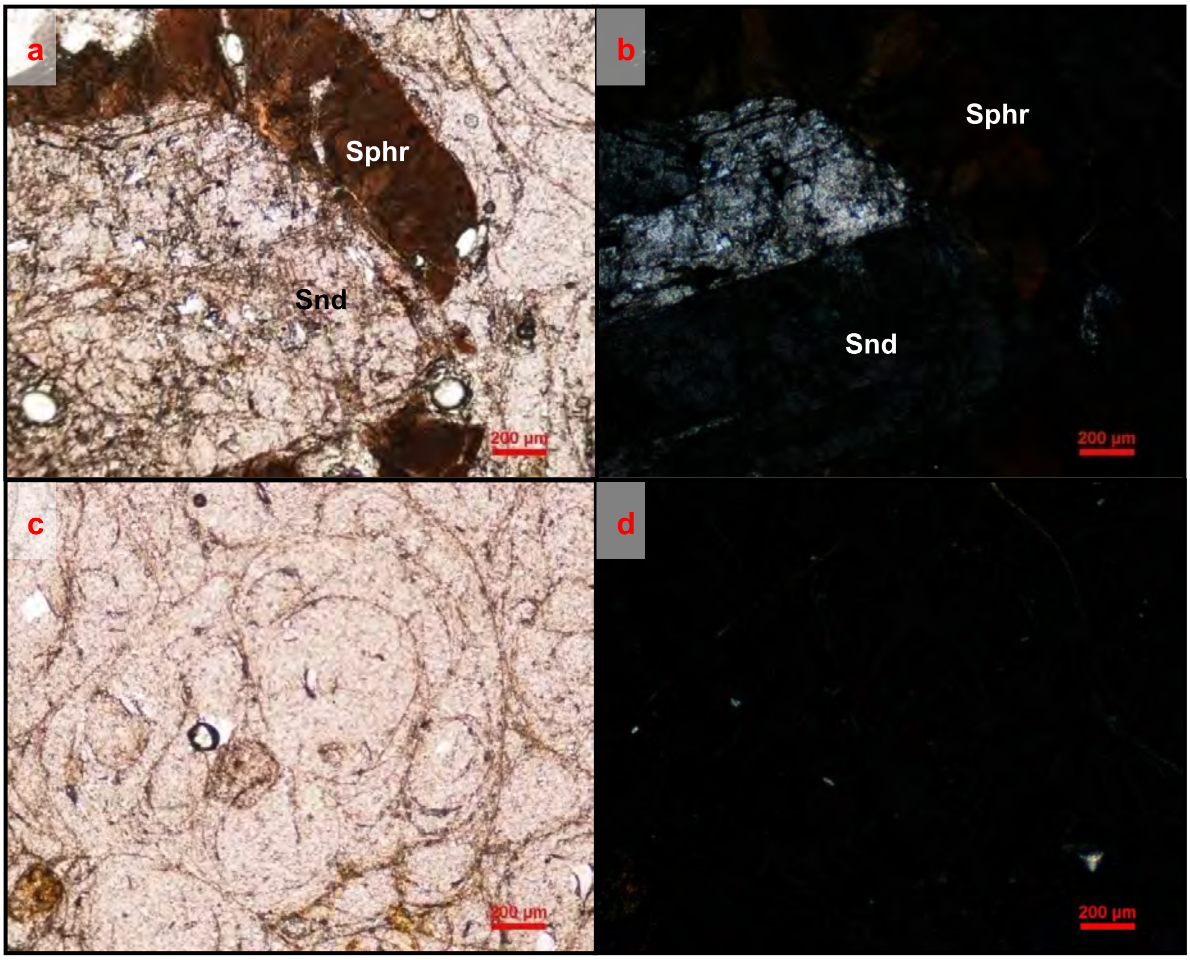


Figure 3.2 Photomicrographs of lower perlite showing sanidine phenocrysts set in glassy groundmass (Sample no. N1-1) (a: PPL, b: XPL)



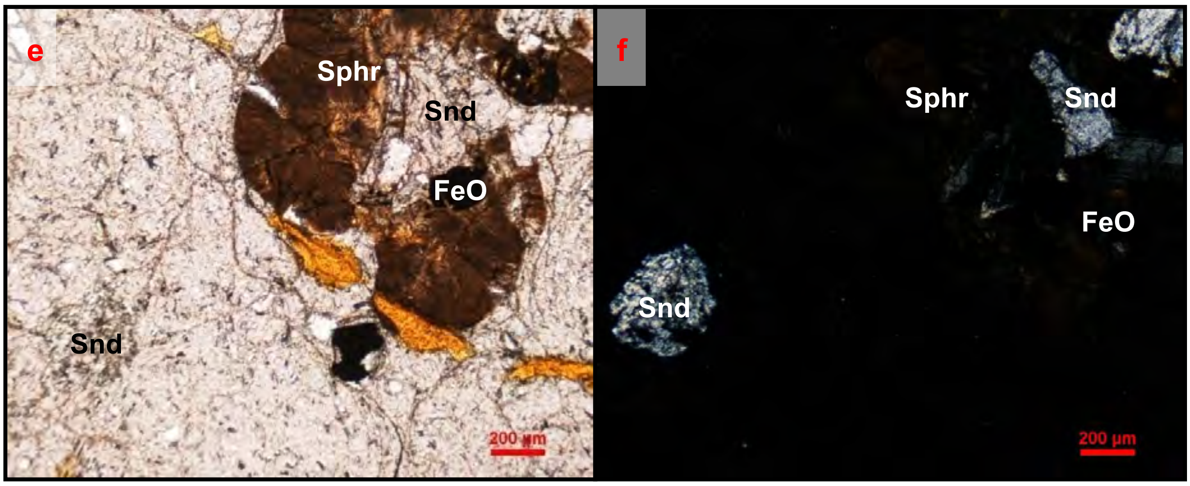


Figure 3.3 Photomicrographs of lower perlite showing sanidine phenocrysts formed as nucleus of spherulites (a: PPL, b: XPL); perlitic texture (c: PPL, d: XPL); sanidine and iron oxide phenocrysts (e: PPL, f: XPL) (Sample no. N1-2)

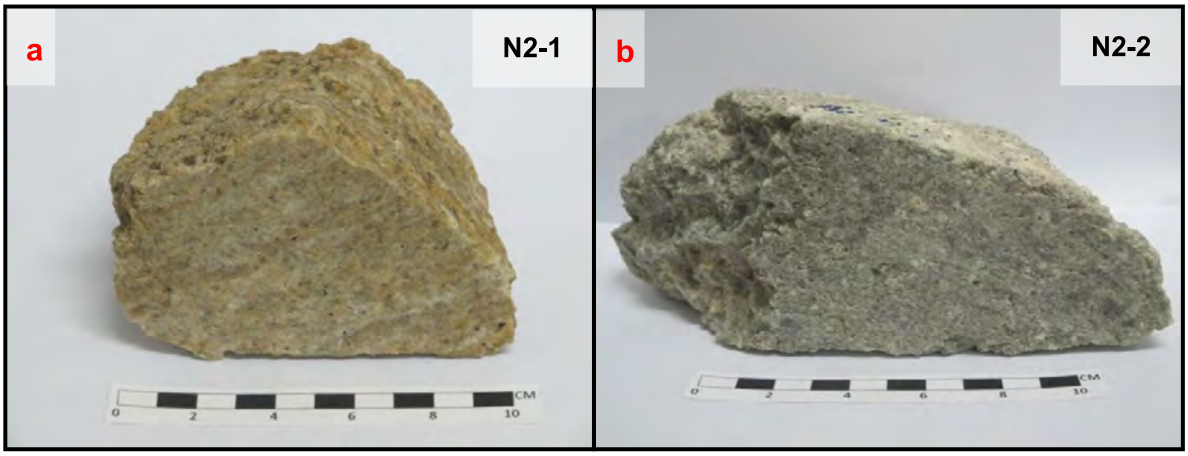


Figure 3.4 Pumiceous perlite showing: a) pale green specimen with fibrous texture (UTM: 016915); b) light green specimen with feldspar phenocrysts (0.3-0.5 cm) setting in pumice matrix (UTM: 016915)

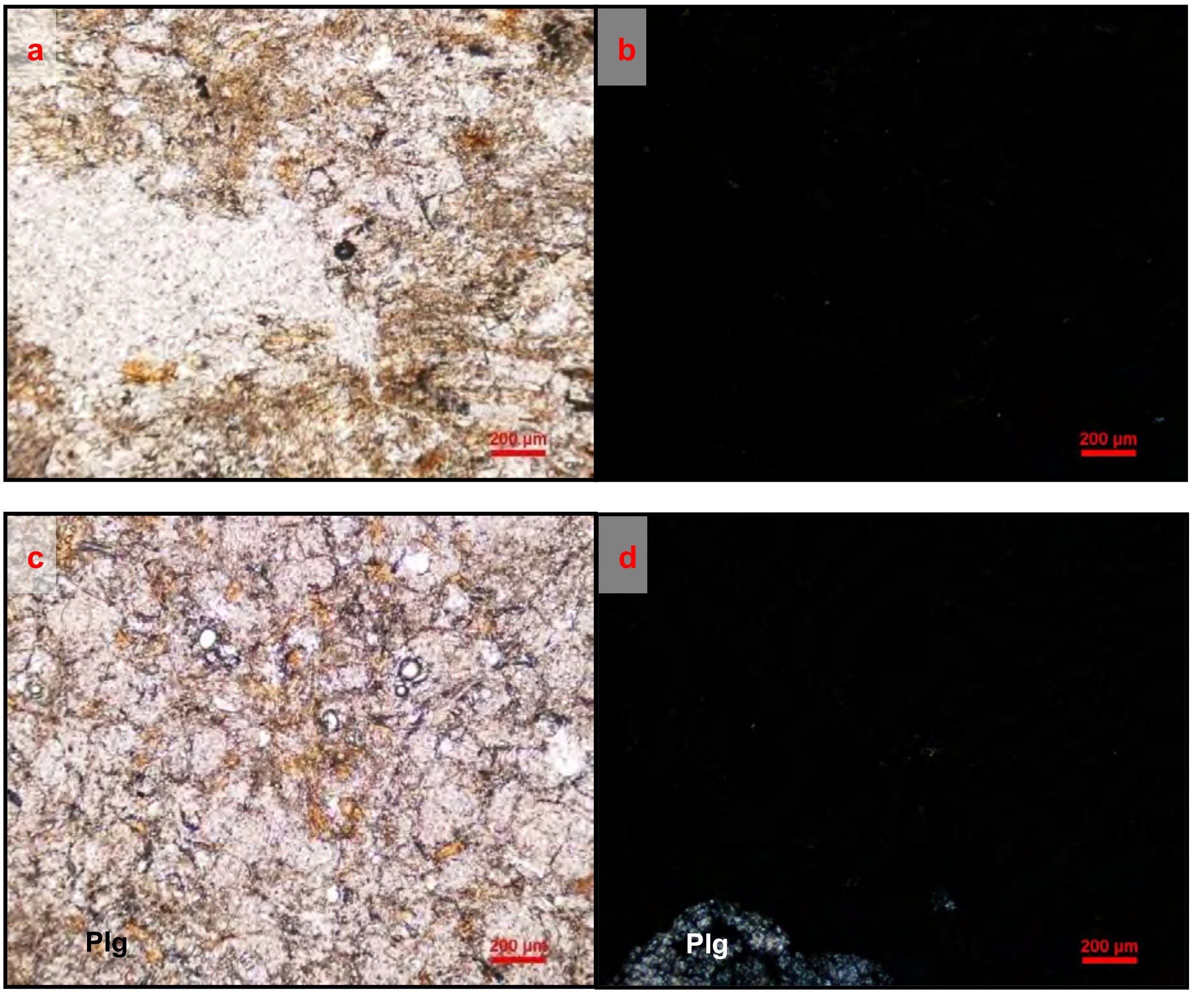


Figure 3.5 Photomicrographs shows cryptocrystalline groundmass (a: PPL, b: XPL); perlitic groundmass with embayment of plagioclase (c: PPL, d: XPL) (Sample no. N2-1)

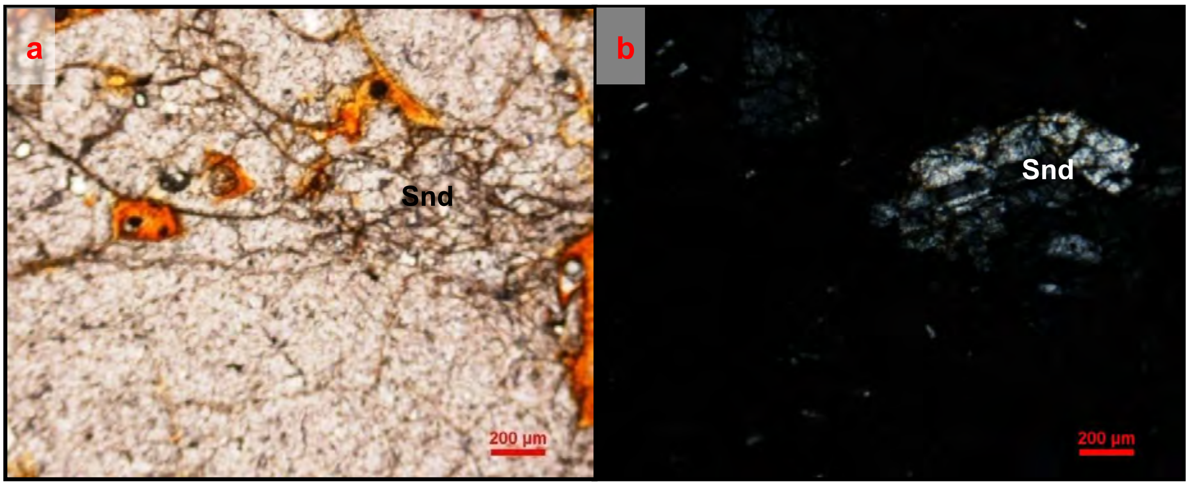


Figure 3.6 Photomicrographs shows sanidine phenocrysts set in perlitic and cryptocrystalline groundmass (a: PPL, b: XPL) (Sample no. N2-2)

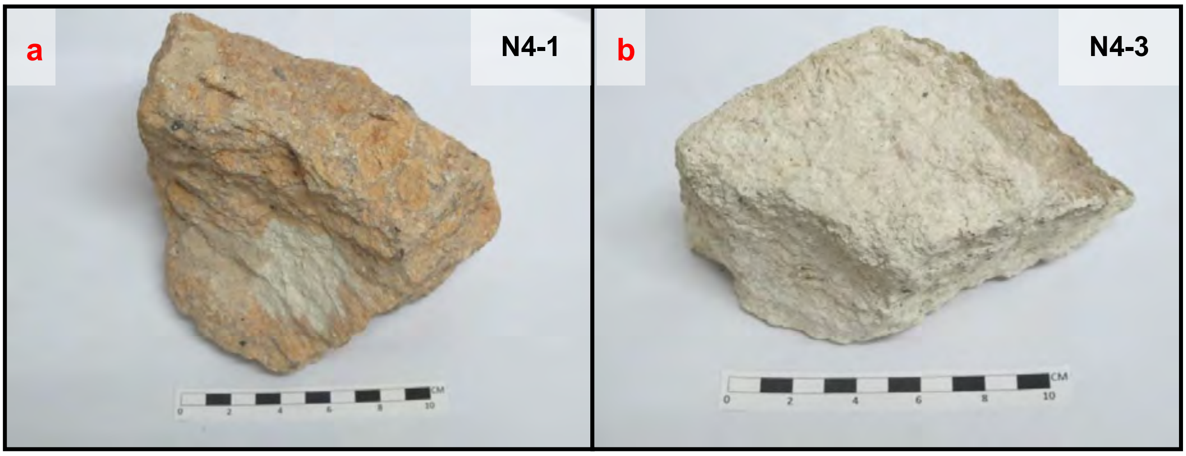


Figure 3.7 Pyroclastics showing: a) pale brownish yellow specimen with pumice clasts set in tuff matrix (UTM: 018917); b) white specimen with pumice matrix (UTM: 018917)

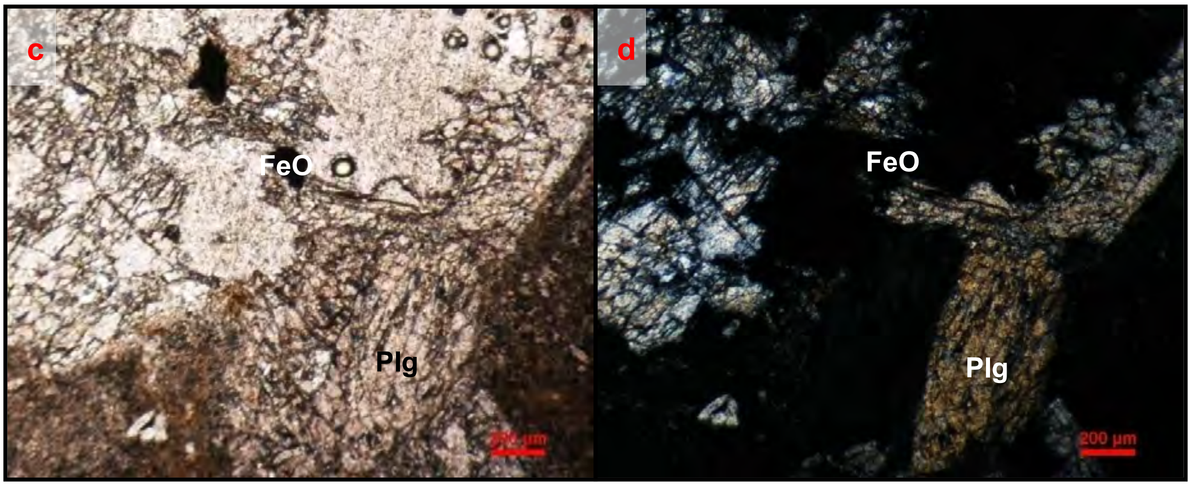


Figure 3.8 Photomicrographs shows embayment in plagioclase phenocrysts set in cryptocrystalline groundmass (a: PPL, b: XPL) (Sample no. N4-1)

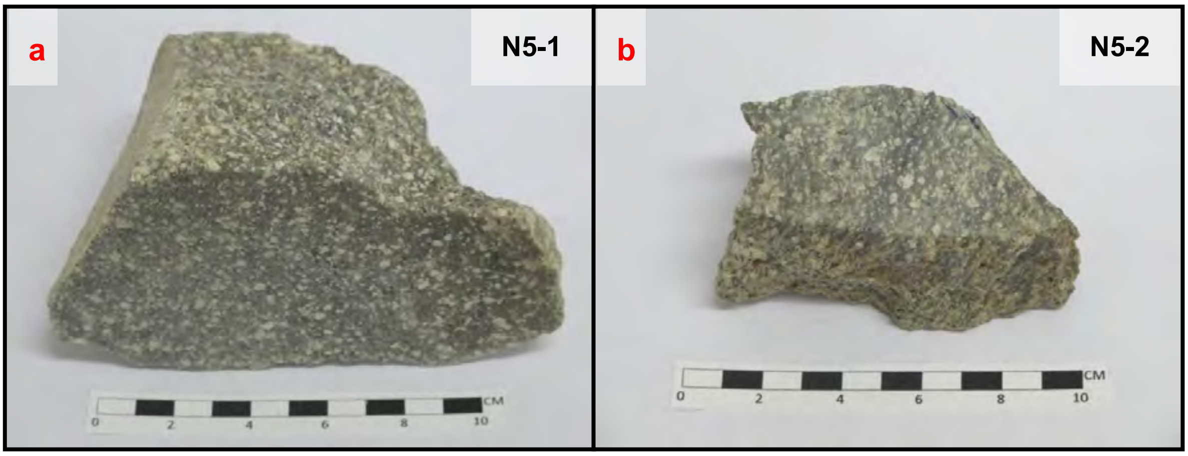


Figure 3.9 Upper perlite showing: a) greenish grey specimen with biotite and feldspar phenocrysts (0.2-0.5 cm) (UTM: 019915); b) greenish grey specimen with biotite and feldspar phenocrysts (0.2-0.5 cm) (UTM: 019915)

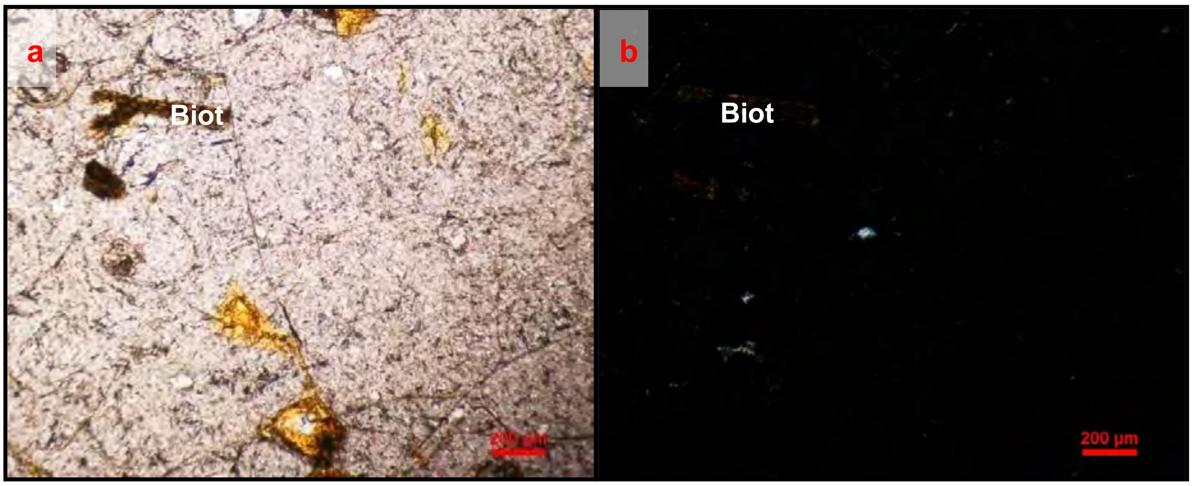


Figure 3.10 Photomicrographs shows biotite phenocrysts set in perlitic groundmass (a: PPL, b: XPL) (Sample no. N5-1)

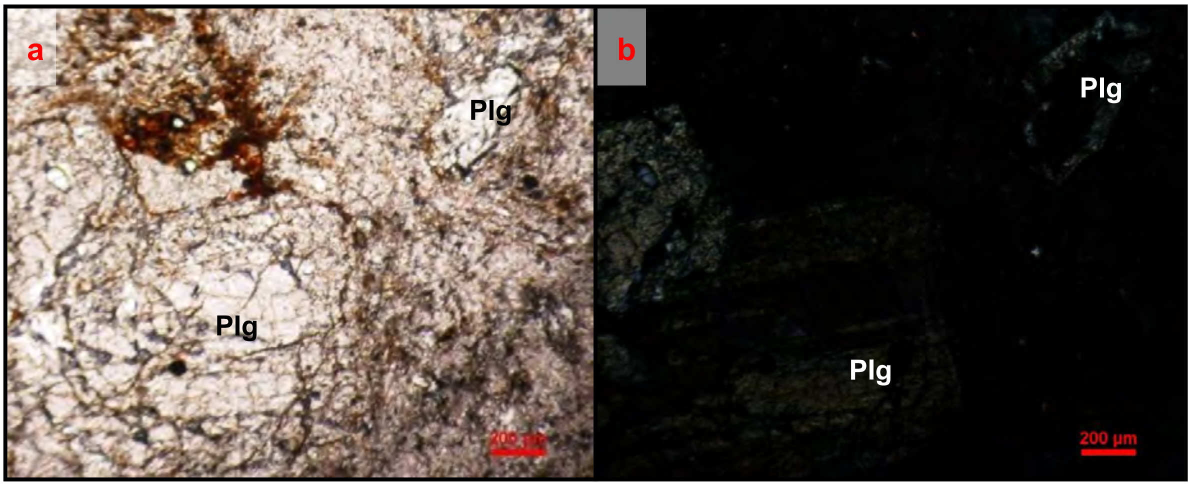


Figure 3.11 Photomicrographs shows embayment in plagioclase phenocrysts set in glassy groundmass (a: PPL, b: XPL) (Sample no. N5-2)

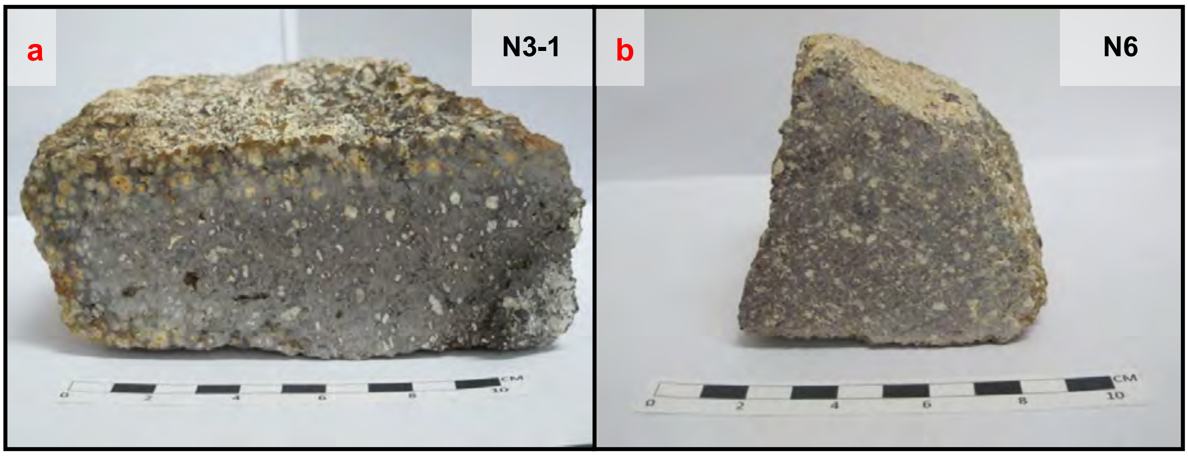


Figure 3.12 Devitrified perlite showing: a) reddish brown specimen with spherulitic texture and feldspar phenocrysts (UTM: 019915); b) reddish brown specimen with feldspar phenocrysts (UTM: 019915)

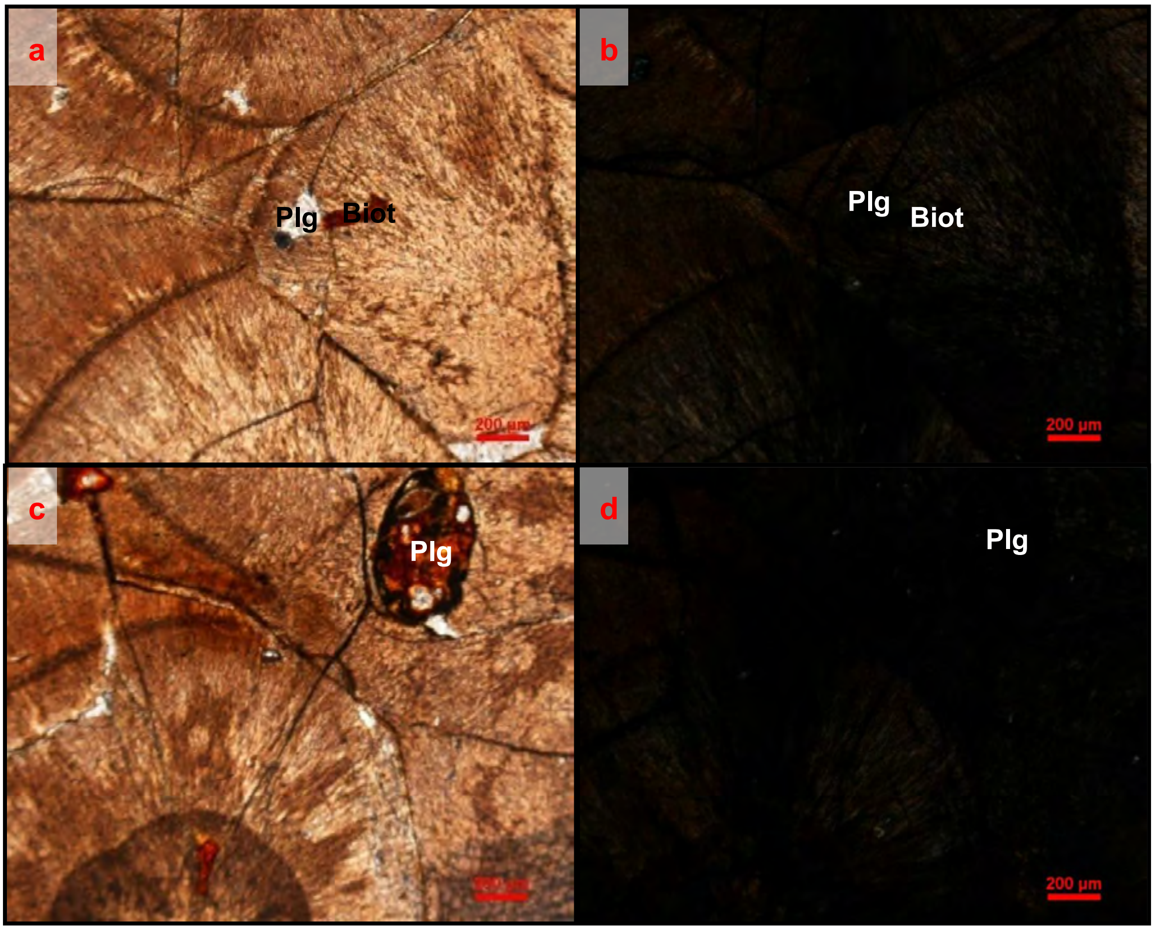


Figure 3.13 Photomicrographs shows biotite and feldspar phenocryst set in spherulitic groundmass (a: PPL, b: XPL); feldspar phenocryst set in spherulitic groundmass (c: PPL, d: XPL) (Sample no. N3-1)

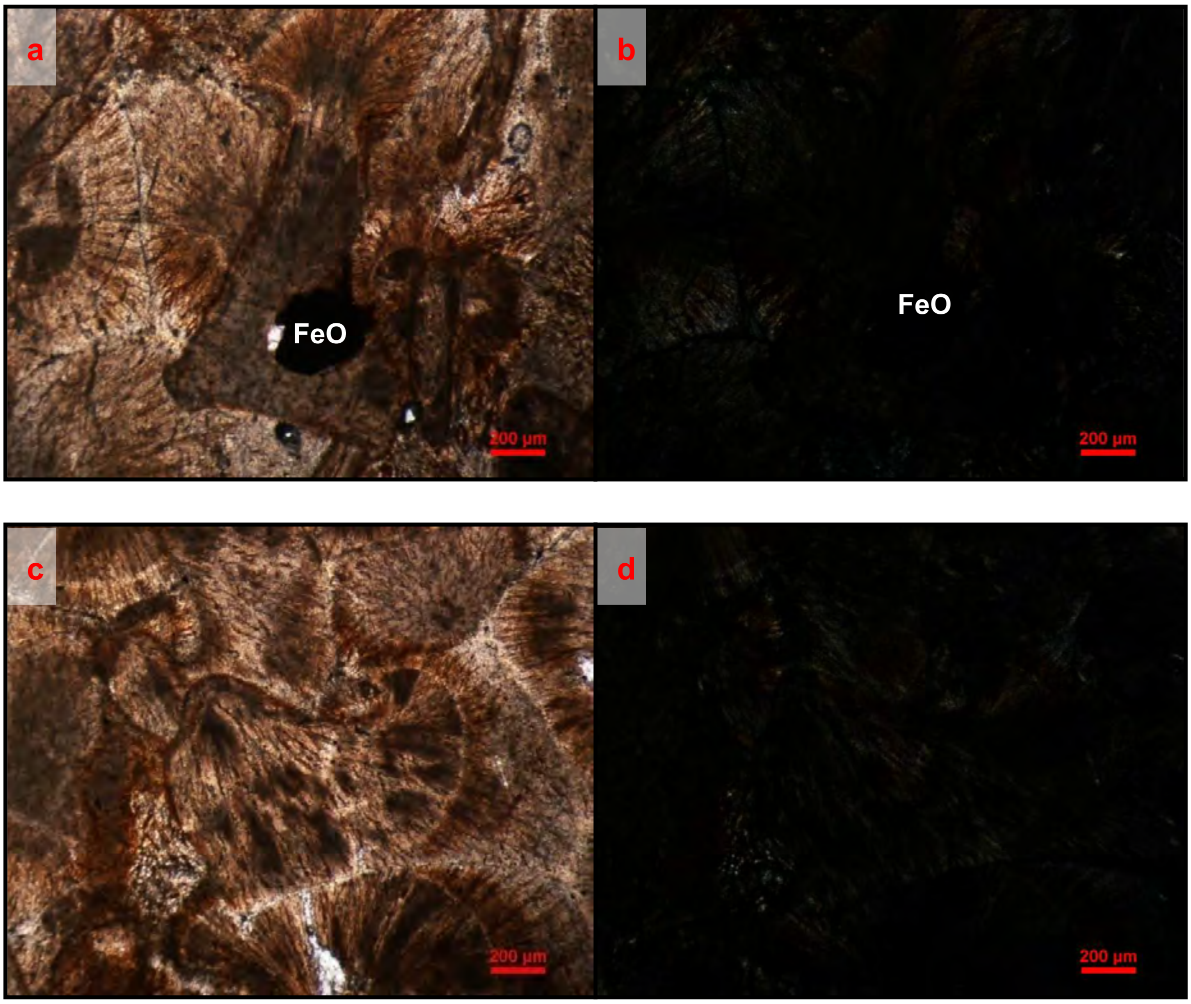


Figure 3.14 Photomicrographs shows iron oxide phenocryst set in spherulitic groundmass (a: PPL, b: XPL); spherulitic texture (c: PPL, d: XPL) (Sample no. N6)

3.2 Whole-Rock Geochemistry

Seventeen representative samples from Khao Falamee, Amphoe Srabot, Changwat Lopburi were chemically analyzed for their major and minor elements using X-ray Fluorescence Spectrometry. The major and minor oxides of these volcanic rocks were calculated for CIPW normative minerals as shown in Table 3.1. Geochemical analyses from this study can lead to understanding the nature of the rock samples. The results show that the major and minor oxides of samples are quite similar to each other, except in pyroclastics which have a wide range of %SiO_2. In general, these volcanics contain 59.08 - 78.61% SiO_2, 0.18 - 0.44% TiO_2, 10.19 - 19.63% Al_2O_3, 0.48 - 1.11% CaO, 0.20 - 1.73% MgO, 0.40 - 1.29% FeO_{total}, 2.37 -5.63% K_2O, 0.18 - 3.89% Na_2O and 0.01 - 0.04% MnO.

Regarding to perlites including lower perlites, upper perlites and devitrified perlites, they consist of 70.05 - 78.61% SiO_2, 0.18 - 0.26 % TiO_2, 10.19 - 13.33% Al_2O_3, 0.48 - 0.77% CaO, 0.20 - 0.52% MgO, 0.40 - 0.98 wt% FeO_{total}, 4.03 - 5.63% K_2O, 0.20 - 3.51% Na_2O and 0.02-0.04% MnO.

Harker variation diagrams (Harker, 1909) plotting between weight percents of major oxides versus weight percent of SiO_2 are shown in Figure 3.14.

Table 3.1 Major element analyses and CIPW Norm (wt%) of 14 rock samples.

Major Oxides	Lower Perlite				Pumiceous Perlite			Pumiceous Tuff						Upper Perlite		Devitrified Perlite	
(wt%)	N1-1	N1-2	N3-2	N3-3	ST1+2	N2-1	N2-2	N4-1	N4-2	N4-3	N4-4	N4-5	ST4	N5-1	N5-2	N3-1	N6
SiO2	78.61	73.42	71.83	70.05	71.66	72.16	71.17	69.46	64.88	66.46	59.08	74.29	67.06	73.77	71.57	72.46	73.22
Al2O3	10.19	12.33	12.12	11.67	12.48	12.04	11.83	13.38	13.58	13.51	19.63	12.18	13.26	13.33	12.91	13.47	13.39
CaO	0.55	0.66	0.71	0.77	0.71	0.65	0.72	0.81	1.07	0.94	1.11	0.49	0.86	0.71	0.71	0.54	0.48
MgO	0.30	0.31	0.41	0.31	0.61	0.30	0.33	1.10	1.46	1.61	1.07	0.30	1.73	0.42	0.52	0.20	0.27
FeOtotal	0.40	0.66	0.67	0.72	0.75	0.64	0.68	0.98	1.29	1.09	2.08	0.63	0.90	0.92	0.88	0.98	0.73
K2O	4.67	5.63	5.16	4.03	5.04	5.51	5.15	5.19	4.18	4.24	2.37	4.50	4.52	5.58	5.44	4.40	4.34
Na2O	1.29	1.85	2.07	3.51	1.70	1.74	2.11	0.73	bdl	0.67	0.18	3.89	bdl	2.24	1.81	0.20	3.22
TiO2	0.18	0.20	0.21	0.21	0.21	0.20	0.21	0.26	0.31	0.27	0.44	0.21	0.23	0.26	0.25	0.23	0.22
MnO	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.03	0.02	0.02	0.04	0.01
LOI	4.35	4.20	4.05	0.55	5.15	4,65	3.95	7.35	8.25	8.80	13.24	0.35	9.85	3.85	4.65	2.10	1.50
Total	100.56	99.28	97.25	91.85	98.33	97.91	96.17	99.27	95.04	97.61	99.21	96.85	98.44	101.10	98.76	94.62	97.38
Quartz	0.86	0.65	0.63	0.53	0.67	0.65	0.62	0.70	0.74	0.70	0.75	0.45	0.75	0.62	0.63	0.31	6.00
Orthoclase	0.50	0.60	0.55	0.43	0.54	0.58	0.55	0.55	0.44	0.45	0.25	0.55	0.48	0.59	0.58	0.88	0.61
Albite	0.21	0.30	0.33	0.57	0.27	0.28	0.34	0.12	-	0.11	0.03	0.48	-	0.36	0.29	0.47	0.46
Anorthite	0.05	0.06	0.06	0.07	0.07	0.06	0.06	0.07	0.10	0.08	0.10	0.63	0.08	0.06	0.06	0.03	0.52
Corundum	0.04	0.04	0.04	-	0.06	0.04	0.03	0.10	0.14	0.12	0.29	0.04	0.13	0.05	0.05	0.05	0.04
Hyperstine	0.01	0.02	0.02	0.02	0.03	0.01	0.02	0.05	0.07	0.08	0.05	0.01	0.09	0.02	0.03	0.15	0.05
Hematite	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.03	0.01	0.01	0.01	0.01	0.01	-
Rutile	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-
Plg is An	19.10	16.50	15.90	10.80	18.80	17.10	16.00	38.00	100.00	43.70	77.30	6.50	100.00	14.90	17.80	59.90	7.60

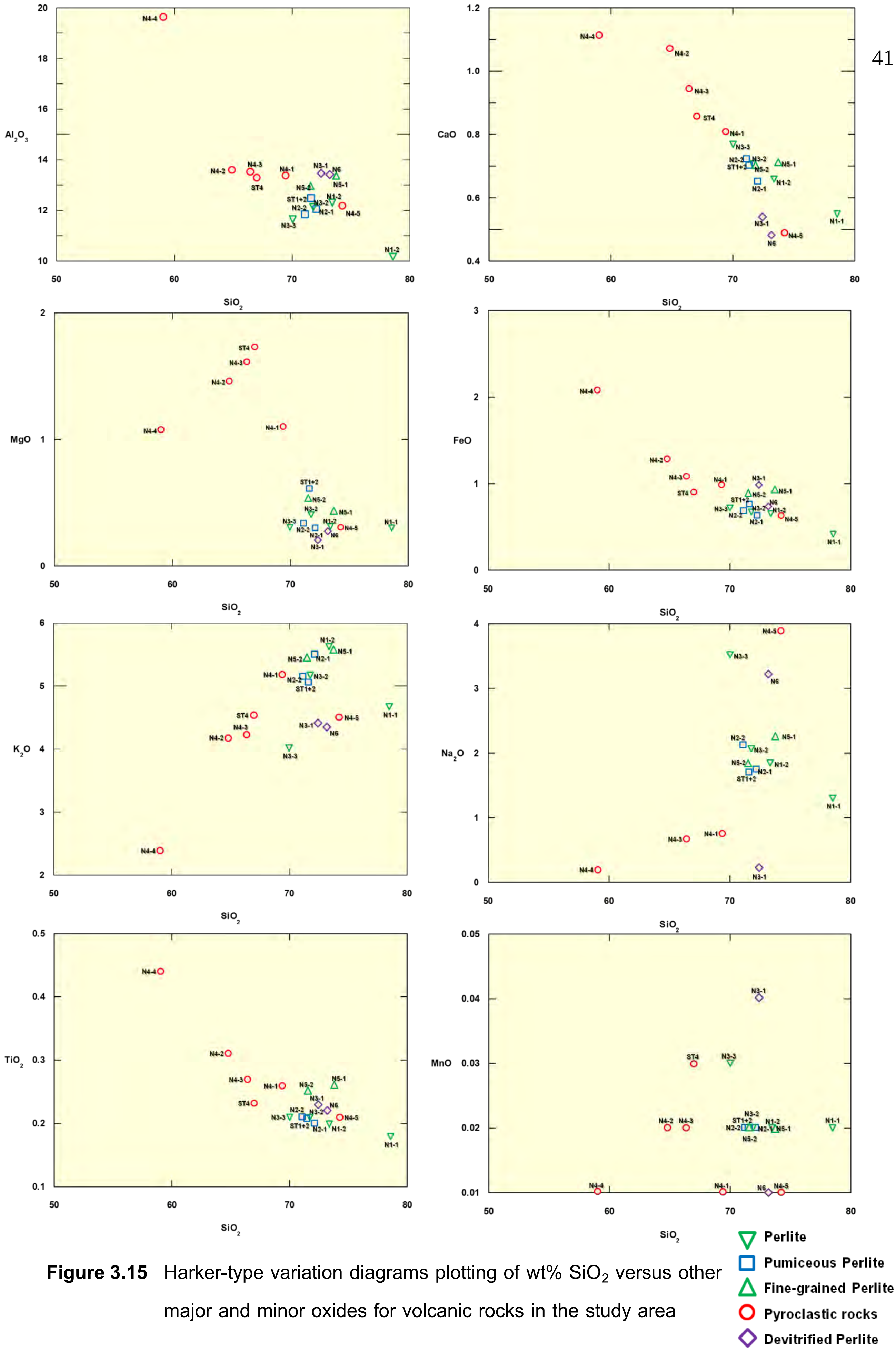


Figure 3.15 Harker-type variation diagrams plotting of wt% SiO_2 versus other major and minor oxides for volcanic rocks in the study area

3.3 Mineral Assemblages

Mineral assemblages were additionally identified using X-ray Diffractrometer (XRD). The results were used to support petrographic description. In summary, mineral compositions contained in each volcanic rock are reported as follow: lower perlite mainly contains plagioclase (albite) and cristobalite (Fig. 3.15); pumiceous perlite contains mainly plagioclase (albite) and montmorillonite (Fig. 3.16); pyroclastics contain plagioclase (anorthite) and montmorillonite (Fig. 3.17); upper perlite contains plagioclase (albite) and cristobalite (Fig. 3.18); devitrified perlite contains plagioclase (albite) and cristobalite (Fig. 3.19).

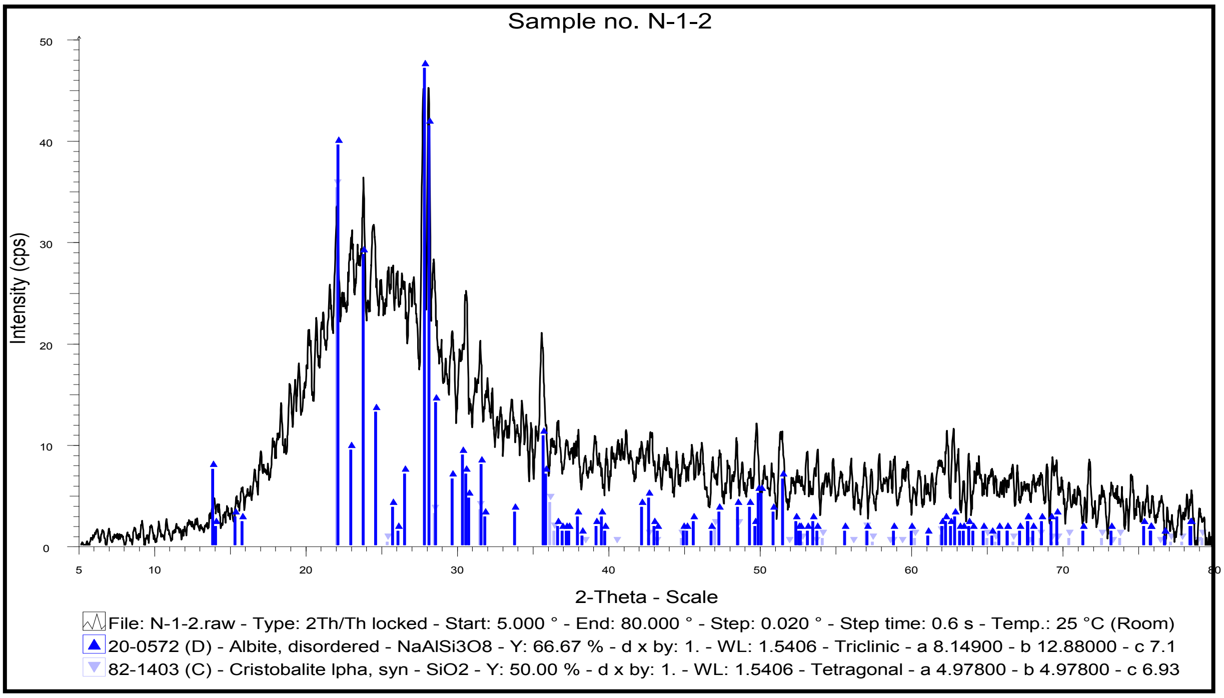


Figure 3.16 Mineral assemblages identified using XRD pattern of lower perlite indicating albite and cristobalite (Sample no. N1-2); hump background appears to be amorphous (glassy groundmass) presented as major amount

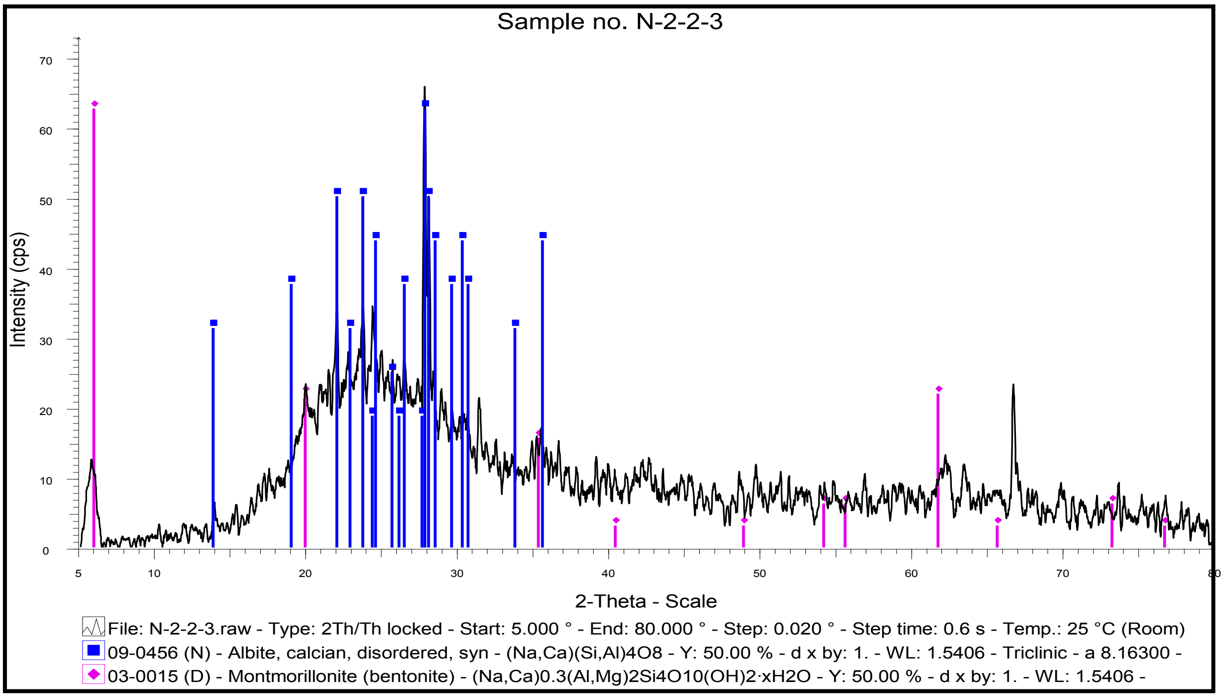


Figure 3.17 Mineral assemblages identified using XRD pattern of pumiceous perlite indicating albite and montmorillonite (Sample no. N2-2); the hump background appears to be amorphous (glassy groundmass) presented as moderate amount

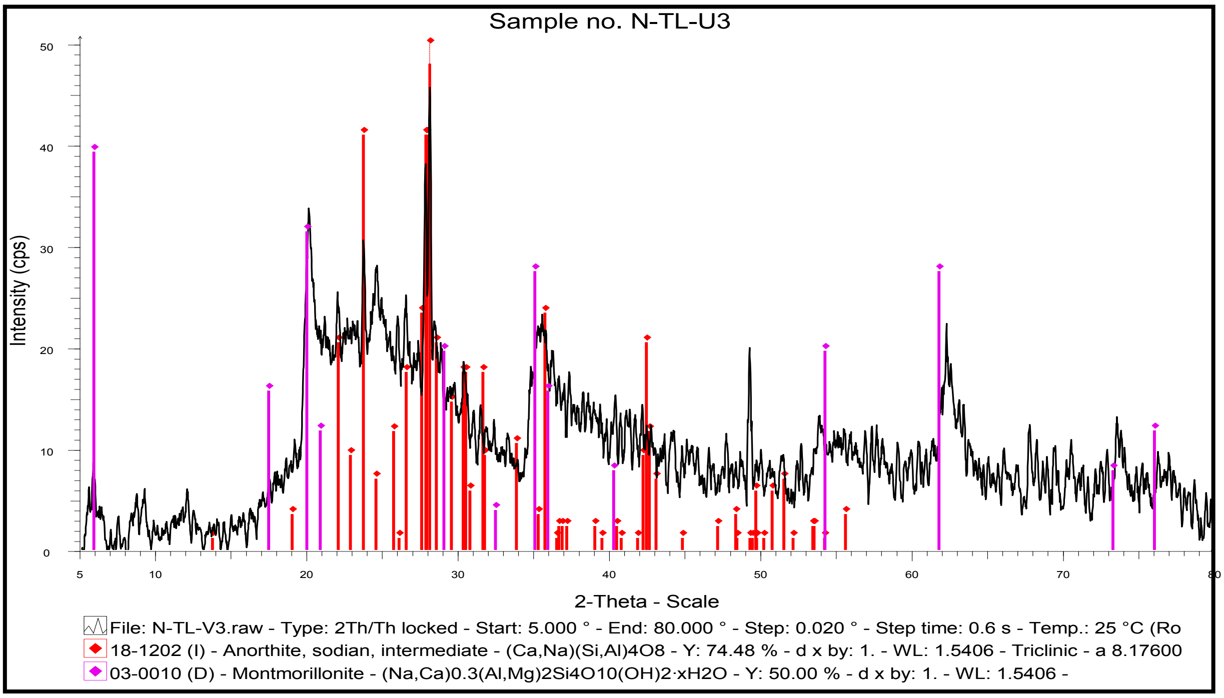


Figure 3.18 Mineral assemblages identified using XRD pattern of pyroclastics indicating anorthite and montmorillonite (Sample no. N4-4); the hump background appears to be amorphous (glassy groundmass) presented as major amount

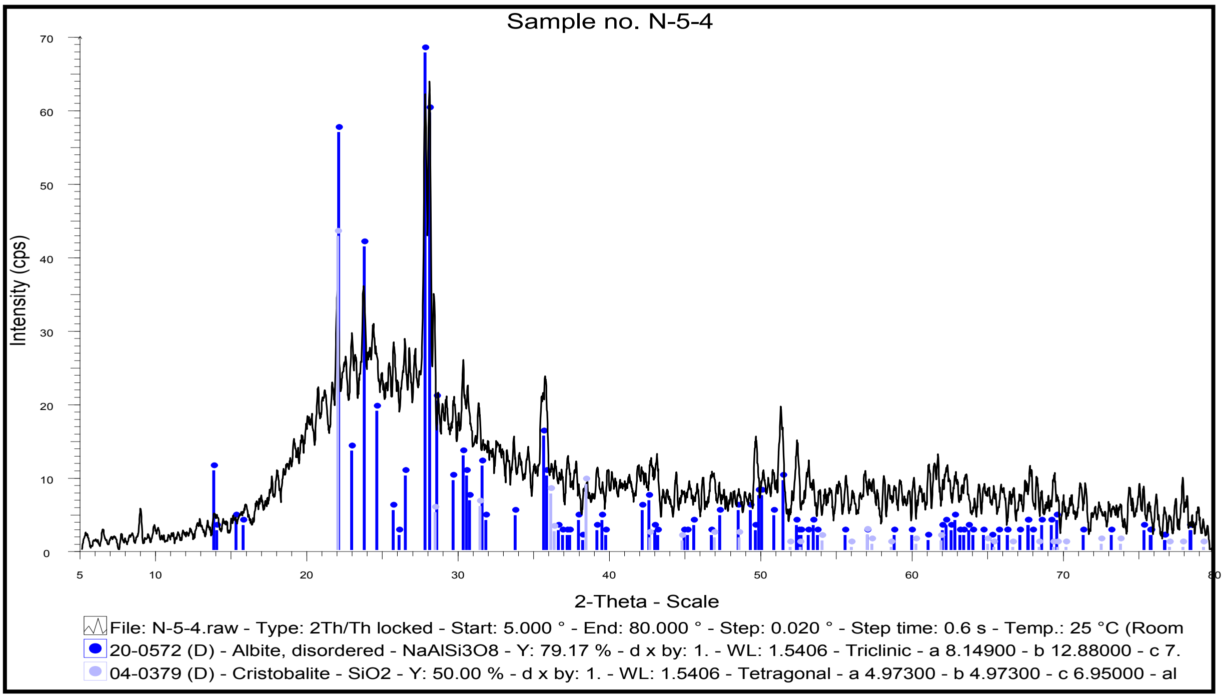


Figure 3.19 Mineral assemblages identified using XRD pattern of upper perlite indicating albite and cristobalite (Sample no. N5-1); the hump background appears to be amorphous (glassy groundmass) presented as moderate amount

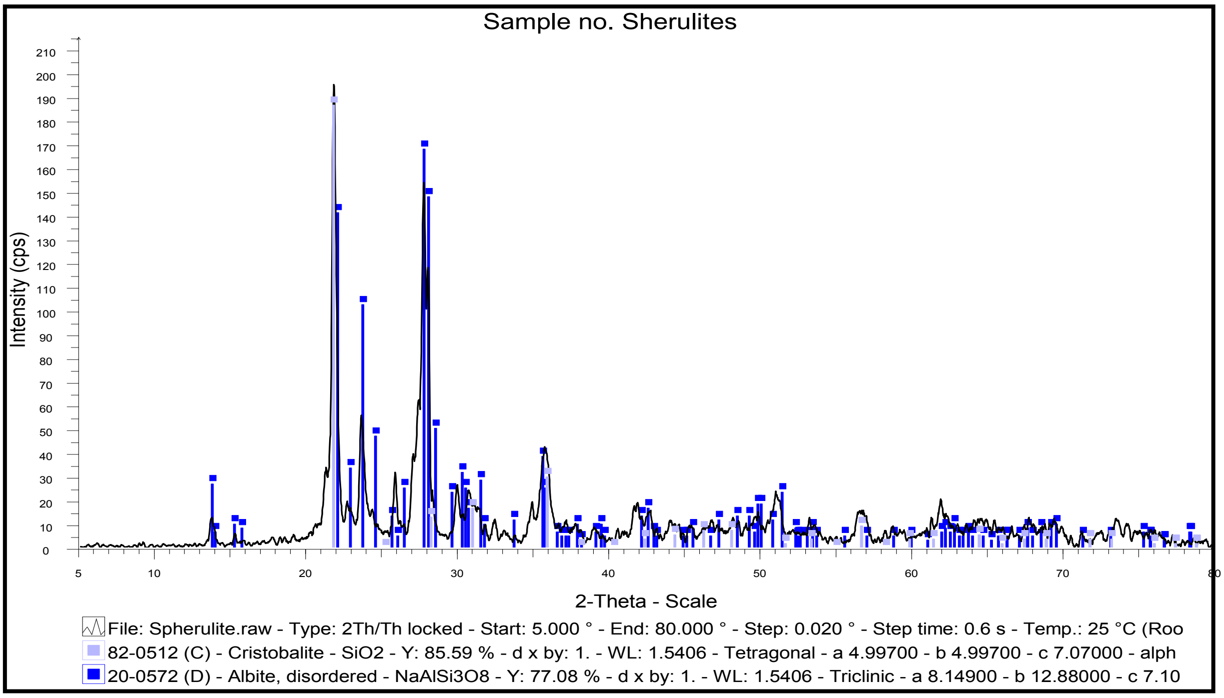


Figure 3.20 Mineral assemblages identified using XRD pattern of upper perlite indicating albite and cristobalite (Sample no. N6); the hump background appears to be amorphous (glassy groundmass) presented as minor amount

3.4 Mineral Chemistry

Electron Probe Micro-Analyzer (EPMA) was engaged to analyze chemical composition of mineral (mineral chemistry) of a few crucial minerals including ilmenite and feldspar. Their analyses are summarized in Tables 3.2 and 3.3. Feldspar generally yields composition of alkali feldspar although some samples fall within plagioclase range as shown in Figures 3.20 and 3.21.

Table 3.2 Representative EPMA analyses of ilmenite in volcanic rock samples.

	Lower Perlite	Pumiceous Perlite	Pyroclastics	Upper Perlite	Devitrified Perlite
	N1-2	**ST1+2**	**N4-5**	**N5-2**	**N3-1**
SiO2	0.005	0.018	0.329	1.028	0.013
TiO2	45.598	43.457	44.554	35.739	44.610
Al2O3	0.279	0.317	1.154	0.320	0.215
FeOtotal	52.590	54.319	51.485	56.582	53.353
MnO	0.400	0.335	0.640	1.469	0.452
MgO	1.390	1.249	0.619	2.103	1.378
CaO	0.000	0.000	0.000	0.000	0.000
Na2O	0.000	0.006	0.013	0.010	0.000
K2O	0.003	0.006	0.000	0.058	0.001
P2O5	0.003	0.007	0.025	0.008	0.007
Cl	0.005	0.002	0.004	0.010	0.009
Total	100.273	99.715	98.823	97.328	100.038
Base on 3O					
Si	0.000	0.000	0.009	0.029	0.000
Ti	0.891	0.863	0.879	0.746	0.878
Al	0.009	0.010	0.036	0.010	0.007
Fe	1.142	1.200	1.130	1.313	1.168
Mn	0.009	0.007	0.014	0.035	0.010
Mg	0.054	0.049	0.024	0.087	0.054
Ca	0.000	0.000	0.000	0.000	0.000
Na	0.000	0.000	0.001	0.001	0.000
K	0.000	0.000	0.000	0.002	0.000
P	0.000	0.000	0.001	0.000	0.000
Cl	0.000	0.000	0.000	0.000	0.000
Total	2.105	2.131	2.094	2.222	2.118

Table 3.3 Representative EPMA analyses of feldspar in volcanic rock samples.

	Lower Perlite		Pyroclastics	Upper Perlite					Devitrified Perlite			
	N1-2	N3-4	N4-5	N5-1(1)	N5-1(2)	N5-1(3)	N5-2(1)	N5-2(2)	N3-1(1)	N3-1(2)	N6(1)	N6(2)
SiO2	59.48	60.36	55.43	64.16	63.54	63.92	63.47	62.40	60.00	59.55	62.74	63.53
TiO2	0.03	0.00	0.07	0.17	0.16	0.14	0.18	0.17	0.02	0.02	0.12	0.08
Al2O3	26.40	20.38	27.47	18.20	18.70	18.56	18.75	18.71	24.43	24.49	20.12	19.40
FeOtotal	0.11	0.23	0.61	0.72	0.68	0.70	0.89	1.21	0.24	0.19	0.28	0.29
MnO	0.01	0.01	0.01	0.04	0.02	0.03	0.03	0.26	0.01	0.01	0.01	0.00
MgO	0.00	0.01	0.00	0.07	0.06	0.05	0.05	0.15	0.01	0.00	0.00	0.01
CaO	7.42	0.52	12.31	0.34	0.35	0.31	0.33	0.40	7.39	7.43	0.25	0.27
Na2O	6.71	0.53	2.52	0.03	0.09	0.06	0.06	0.29	6.41	6.43	0.63	0.91
K2O	0.41	15.57	0.28	15.47	15.58	15.56	15.64	15.59	1.57	1.06	15.21	15.43
P2O5	0.00	0.00	0.02	0.01	0.01	0.02	0.00	0.02	0.01	0.00	0.01	0.01
Cl	0.00	0.02	0.01	0.14	0.12	0.12	0.13	0.11	0.01	0.00	0.07	0.06
Total	100.58	97.63	98.73	99.35	99.31	99.49	99.54	99.30	100.10	99.19	99.44	99.99
Base on 8O												
Si	2.636	2.875	2.521	2.988	2.964	2.974	2.959	2.521	2.687	2.684	2.917	2.941
Ti	0.001	0.000	0.002	0.006	0.006	0.005	0.006	0.002	0.001	0.001	0.004	0.003
Al	1.379	1.144	1.473	0.999	1.028	1.018	1.031	1.473	1.290	1.301	1.103	1.059
Fe	0.004	0.009	0.023	0.028	0.027	0.027	0.035	0.023	0.009	0.007	0.011	0.011
Mn	0.000	0.001	0.000	0.002	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Mg	0.000	0.001	0.000	0.005	0.004	0.004	0.004	0.000	0.001	0.000	0.000	0.001
Ca	0.353	0.026	0.600	0.017	0.018	0.015	0.016	0.600	0.355	0.359	0.013	0.014
Na	0.576	0.049	0.222	0.003	0.008	0.005	0.006	0.222	0.557	0.562	0.057	0.082
K	0.023	0.946	0.016	0.919	0.927	0.924	0.930	0.016	0.090	0.061	0.902	0.911
P	0.000	0.000	0.001	0.000	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000
Cl	0.000	0.000	0.000	0.004	0.003	0.003	0.004	0.000	0.000	0.000	0.002	0.002
Total	4.973	5.051	4.859	4.971	4.986	4.978	4.991	4.859	4.990	4.976	5.009	5.024
%Ca	37.035	2.583	71.578	1.821	1.849	1.619	1.721	71.578	35.426	36.584	1.292	1.352
%Na	60.520	4.767	26.477	0.317	0.807	0.528	0.608	26.477	55.621	57.234	5.872	8.135
%K	2.445	92.650	1.945	97.862	97.344	97.852	97.671	1.945	8.953	6.182	92.836	90.514

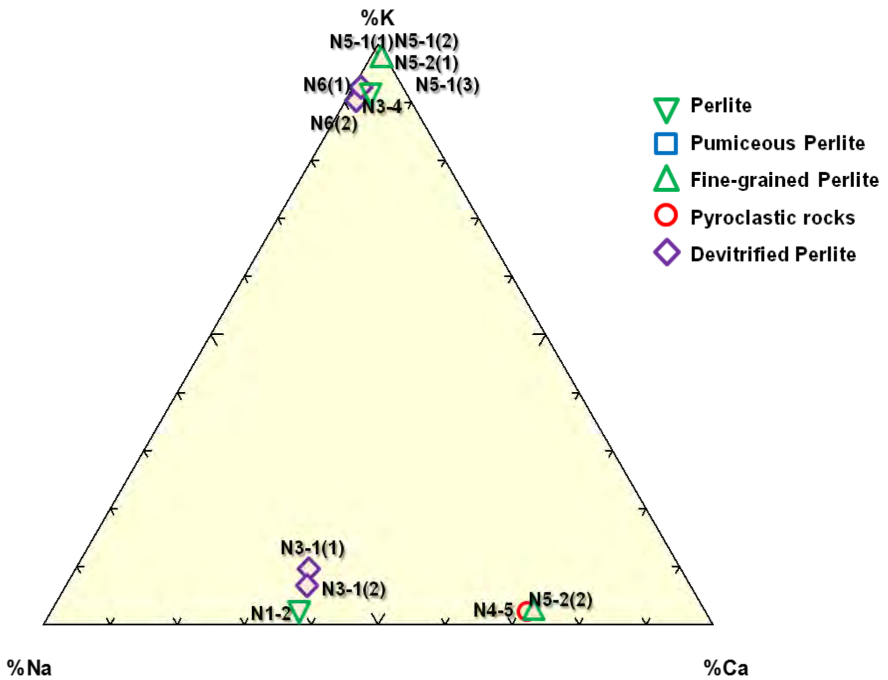


Figure 3.21 Atomic Ca-Na-K plots of feldspar in volcanic rocks of the study area

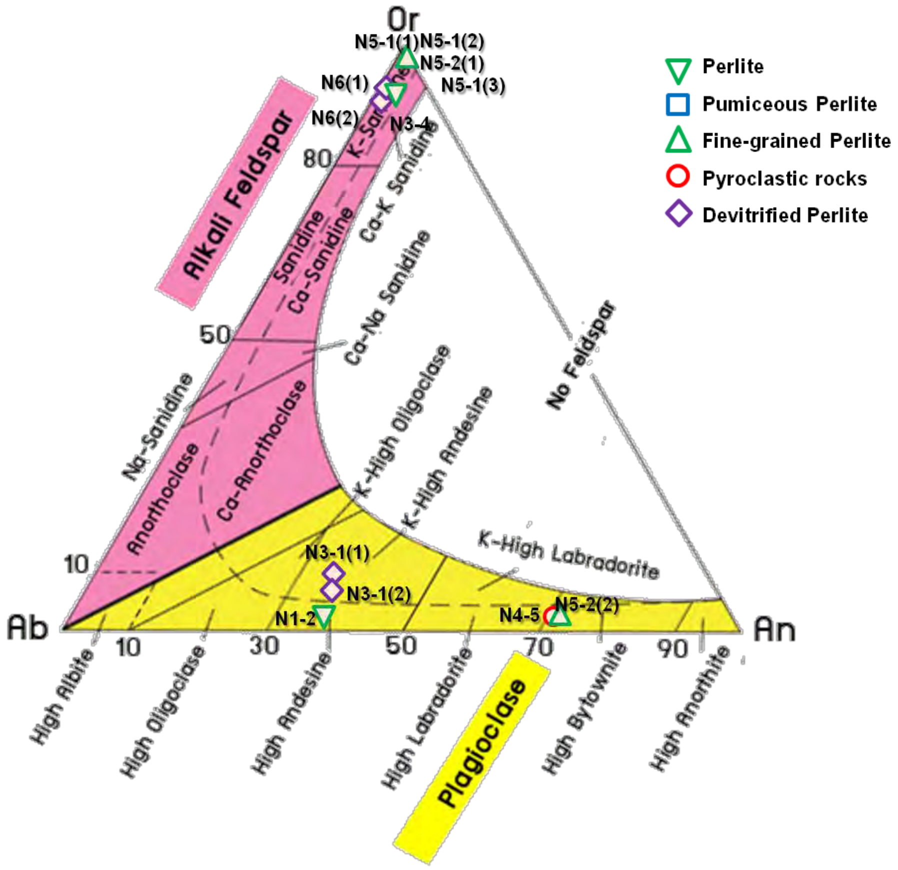


Figure 3.22 Atomic plots of feldspars in the ternary Or-Ab-An diagram (Modified from Parsons, 2009)

CHAPTER IV

DISCUSSION AND CONCLUSIONS

4.1 Discussion

Based on geologic setting, volcanic rocks in the study area can be divided into five categories, including *Lower Perlite*, *Pumiceous Perlite*, *Pyroclastics*, *Upper Perlite* and *Devitrified Perlite* which their succession is shown in Figure 2.6. However, they all are similar in mineral assemblage, mineral chemistry and whole-rock composition, except pyroclastics group has wide range of %SiO_2. Petrographic investigation of the perlites including lower perlite and upper perlite usually shows perlitic texture (onion-skin like fractures) which is an important characteristic and clearly recognized. Bound meteoric water and perlitic texture may cause expansion after heating which this property makes it suitable for industrial uses. Spherulitic texture and alkali feldspar nucleuses are generally found in the studied perlites; this appears to be significant characteristic of devitrified perlite.

Geochemically, the studied perlites mostly have composition similar to rhyolite as indicated by plotting between total alkalis versus SiO_2 (TAS) diagram (LeBas *et al.*, 1986) as shown in Figure 4.1. They have similar chemical composition likely rhyolite but pyroclastics (sample no. N4-1, N4-2, N4-3, N4-4, N4-5 and ST4) range in compositions between andesite and rhyolite. It may be caused by the xenolithic clasts like basalt which are found in these pyroclastics. Their compositions may influence the whole-rock composition.

Based on mineral assemblages, the studied perlites including lower perlite, pumiceous perlite, upper perlite and devitrified perlite, are composed mainly of albite and cristobalite. Moreover, the hump backgrounds in XRD patterns indicate amorphous (glassy) material which generally occurs as groundmass in these perlites. Less amount of this gassy material is recognized in devitrified perlite. Thus, it is supported that devitrified perlite has altered from glass then forming mineral within spherulites (see Fig. 3.15).

Mineral chemistry of feldspars falls mainly within sanidine composition although a few samples contain bytownite and andesine composition. The sanidine composition clearly indicates high temperature which agrees well with volcanic occurrences. However, bytownite and andesine compositions (plagioclase) may be occurred as xenocrystic feldspar in the rock samples which may have been picked up by magma from lower parts. Classification of feldspars in rock samples is shown in Figure 3.21.

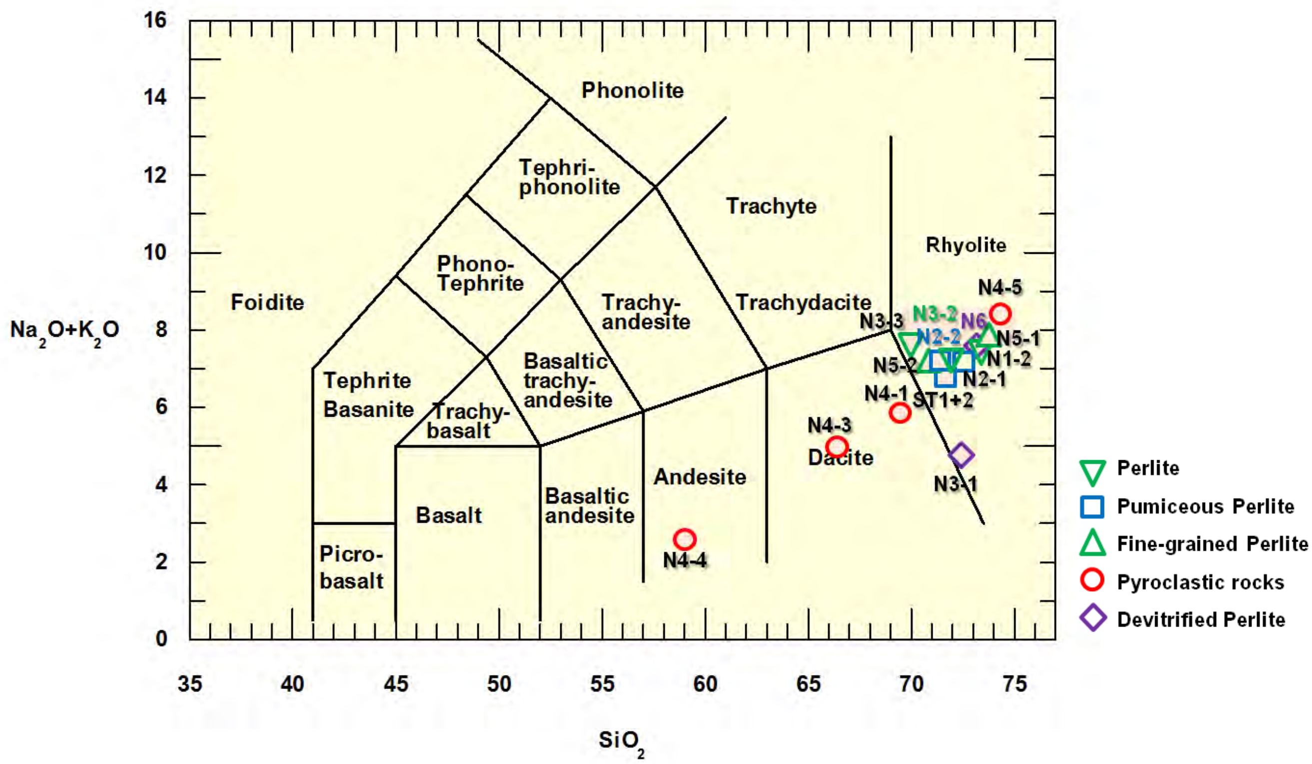


Figure 4.1 Total alkalis versus SiO_2 (TAS) diagram showing compositions of volcanic rock samples in the study area (LeBas *et al.*, 1986)

4.2 Conclusions

1. The studied perlites are composed mainly of more than 70% silica-glass groundmass with microcrystalline lath-shaped feldspars and alkaline feldspar phenocrysts, biotite and iron oxides. Perlitic cracks are clearly observed in these rocks. Spherulitic texture is clearly found in devitrified perlite.

2. Geochemical analyses show that majority of the studied perlites similarly comprise major and minor oxides which contain about 70-79% SiO_2, 0.2% TiO_2, 10-13% Al_2O_3, 0.5-0.8% CaO, 0.2-0.6% MgO, 0.4-1 wt% FeO_{total}, 4-6% K_2O, 0.2-4% Na_2O and 0.01-0.04% MnO. Consequently, Falamee perlites are mostly named as rhyolitic perlites.

3. The studied perlites including lower perlite, pumiceous perlite, upper perlite and devitrified perlite, are composed mainly of albite and cristobalite as the main mineral assemblages.

4. Based on mineral chemistry, ilmenite and feldspar commonly contain in the studied perlites which feldspars are mainly characterized by sanidine with a few samples contain bytownite and andesine composition.

5. Alteration of perlites is called “devitrification”, forming of minerals i.e. cristobalite, alkali feldspar etc. Spherulite is a crucial texture that shows alteration of perlites.

6. Based on volcanic succession at Khao Falamee, the following rock units from bottom to top are lower perlite, pumiceous perlite, pyroclastics, upper perlite and devitrified perlite. Pyroclastic rocks associated with these perlites are also composed of rhyolitic components with a wider range of dacitic to andesitic pyroclastic rocks. However, these pyroclastics should occur from the same magma chamber.

REFERENCES

Bunopas, S. 1992. Geotectonics and geologic evolution of Thailand, Proceedings of a National Conference on Geologic Resources of Thailand: Potentail for Future Development, Bangkok, Thailand, P 209 – 228

Dalakishvili, A.I. 2005. Glass Formation in Perlite and Obsidian-Containing Batches. *Glass Physics and Chemistry*, Vol. 31, No. 6: P 820 - 822

Fink, J.H. and Manley, C.R. 1987. Origin of Pumiceous and Glassy Textures in Rhyolite flows and domes. *In* Fink, J.H.(ed.) The Emplacement of Silicic domes and lava flows. Boulder, CO, P 77 – 88. *Geological Society of America Special*, No. 212

Heide, K. and Heide, G. 2011. Vitreous State in Nature - Origin and Properties. *Chemie Der Erde*, Vol. 71: P 305 - 335

Intasopa, SB. 1993. Petrology and Geochronology of the Volcanic Rocks of the Central Thailand Volcanic Belt, Unpublished PhD Thesis, University of New Brunswick, Canada, P 242

Jungyusuk, N. and Suriyachai, P. 1987. Geological survey report: Map sheet Baan Mahaphot (5139 I), King Amphoe Sritep (5239 IV), Baan Phenyid (Amphoe Srabot, 5139 II) and Amphoe Chaibadan (5239 III): Department of Mineral Resources, Bangkok (in Thai)

Jungyusuk, N. 1995. Perlite and Volcanic rocks in Lam Narai Volcanic Field, Changwat Lopburi: Department of Mineral Resources, Bangkok

Jungyusuk, N. 2010. Geology of Khao Falamee (Phanomchat) report: Klongyang co-orperation, 68p (in Thai)

Morley, C.K., Woganan, N., Sankumarn, N., Hoon, T. B., Alief, A. and Simmons, M. 2001. Late Oligocene – Recent Stress Evolution in Rift basins for Northern and Central Thailand: Implications for escape tectonics. *Tectonophysics*, Vol. 334: P 115 – 150

Premmanee, J. and Wijitchareampong, A. 2540/1997. Mineral exploration in Lam Narai area . Department of Mineral Resources, Thailand, 191p (in Thai)

Remus, D., Webster, M. and Keawkan, K. 1993. Rift Architecture and Sedimentology of the Phetchabun Intermontane Basin, Central Thailand. *Southeast Asian Earth Science*, Vol. 8: P 421 – 432

Saisuttichai, D. and Manning, D.A.C. 2007. Geochemical Characteristics and Expansion properties of a Highly Potassic Perlitic Rhyolite from Lopburi, Thailand. *Resource Geology,* Vol. 57, No. 3: P 301 - 312