CHAPTER 3

Occurrence and Petrography

The volcanic and associated rocks in Tak Province, Northern Thailand and peripheral areas have many rock types including volcanic, pyroclastic, and intrusive rocks. There are one hundred and forty samples were collected from both outcrop and float rocks for petrography method. The least-altered thirty volcanic and associated rock samples were carefully selected from petrography data. The rock names used in this chapter are based on their occurrences, textures and/or mineral constituents and geochemistry (in chapter 4). This chapter illustrates the rock samples in terms of occurrences, lithology and petrography of the rock sample. Petrographically, the standard thin section (0.03 mm thick) of all the selected samples were prepared and studied at the Department of Geological Sciences, Faculty of Science, Chiang Mai University. The thin sections were studied to characterize mineral compositions, textures, and alterations. The results of the petrographic study are summarized in Chapter 3 and individually reported in Appendix B.

3.1 The Mae Phrik Area

The samples were collected from both in situ float rocks (Figure 3.1) and outcrops (Figure 3.2 and 3.3) along the road number 1, from Lampang Province to Tak Province via Mae Phrik District, Lampang Province. The Mae Phrik area consists of rhyodacite (sample number BTK25/1-1, BTK25/1-2, and BTK25/7) and basalt (dike) (sample number BTK25/8-1 and BTK25/8-3). The basaltic dike intruded into felsic plutonic rocks has been detected in some outcrops and float rocks (Figure 3.4). The outcrops of these rocks are brown to green in color and some outcrops have pale green to pale gray in color. All of volcanic rocks in the Mae Phrik area have slightly porphyritic and very fine-grained textures.

Figure 3.1 The in situ float rocks of rhyodacite in the Mae Phrik area at grid reference 516181.7 E 1915922.3 N (Mr. Chanakan Boonnawa, 175 cm tall, is to scale).

Figure 3.2 The outcrop of rhyodacite in the Mae Phrik area at grid reference 516138.2 E 1912653.8 N (the hammer 40 cm long).

Figure 3.3 The outcrop of basalt in the Mae Phrik area at grid reference 518005.1 E 1914791.8 N (Dr. Burapha Phajuy, 182 cm tall, is to scale).

Figure 3.4 The outcrop of granitic intrusion (Tak Batholith) at grid reference 518005.1 E 1914791.8 N (Dr. Burapha Phajuy, 182 cm tall, is to scale).

The studied volcanic rocks in the Mae Phrik area are associated with the granitic intrusions that have formed in Triassic period (Mahawat, 1982). This granite named as Tak Batholith, and is made up of biotite granite, tourmaline granite, granodiorite, biotite-muscovite granite, muscovite-tourmaline granite, and biotite-tourmaline granite. Basaltic dikes intruded into granitic rocks are present in this area.

Rhyodacite

Rhyodacite sample is a very fine-grain and shows slightly porphyritic texture. It is a pinkish brown in color with a yellowish brown weathering surface. The phenocrysts are made up of quartz (colorless), feldspars (white), and opaque minerals (black), and are embedded in a very fine-grained groundmass.

Under microscope, rhyolite shows slightly porphyritic texture (Figure 3.5). The phenocrysts/microphenocrysts in the sample are made up largely of quartz and plagioclase, with small amounts of alkali feldspar and opaque minerals. The groundmass phase is made up mainly of quartz-alkali feldspar devitrification with small amounts of quartz, alkali feldspar and chlorite.

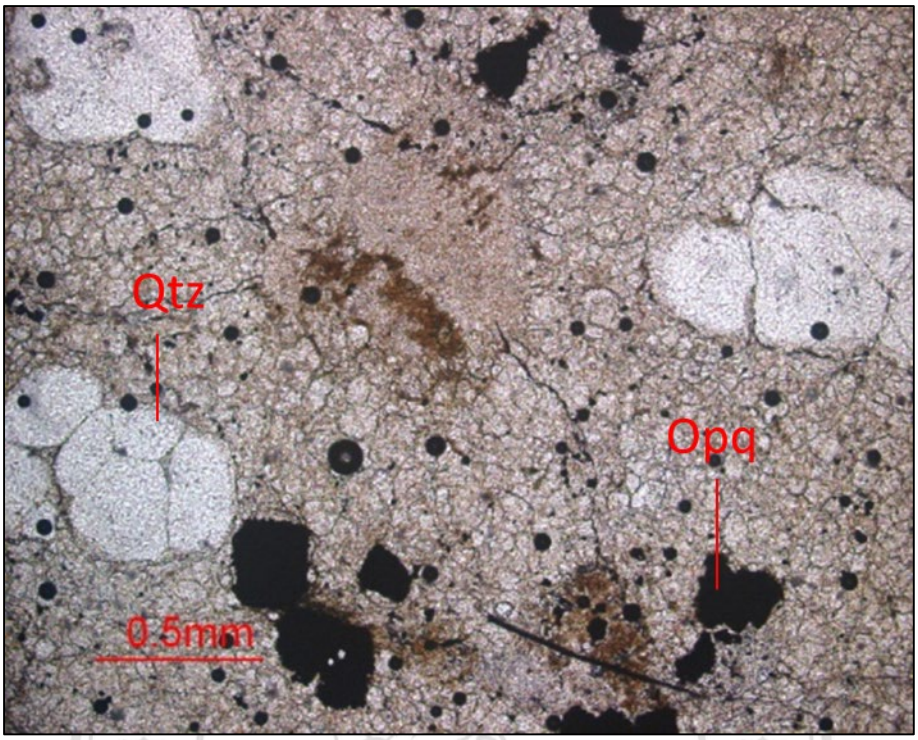
Quartz phenocrysts/microphenocrysts (Figure 3.6) are euhedral to subhedarl (sizes up to 2 mm across). It is commonly shows rounded edges and embayed outlines. Groundmass quartz is anhedral with sizes up to 0.1 mm across.

Plagioclase phenocryst/microphenocrysts (Figure 3.7) are subhedral with sizes up to 1 mm across. These phenocrysts/microphenocrysts may have formed as a cluster of glomerocrysts. Plagioclase crystals show carlsbad twin and albite twin and is moderately replaced by sericite and clay minerals.

Alkali feldspar phenocrysts/microphenocrysts are subhedral to euhedral (sizes up to 1 mm across). They show simple twin and perthitic texture (sanidine type). Groundmass alkali feldspar is anhedral with sizes up to 0.1 mm across. Alkali feldspar is slightly replaced by clay minerals.

Opaque minerals phenocryst/microphenocrysts are subhedral with sizes up to 0.7 mm across. They are moderately altered to leucoxene. Opaque minerals in

a)



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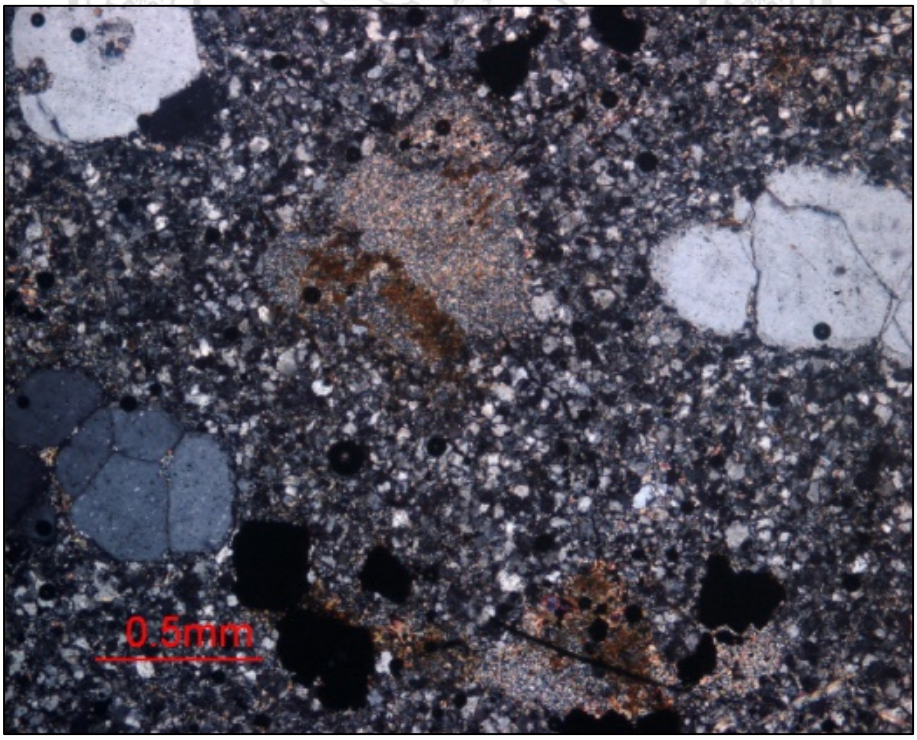
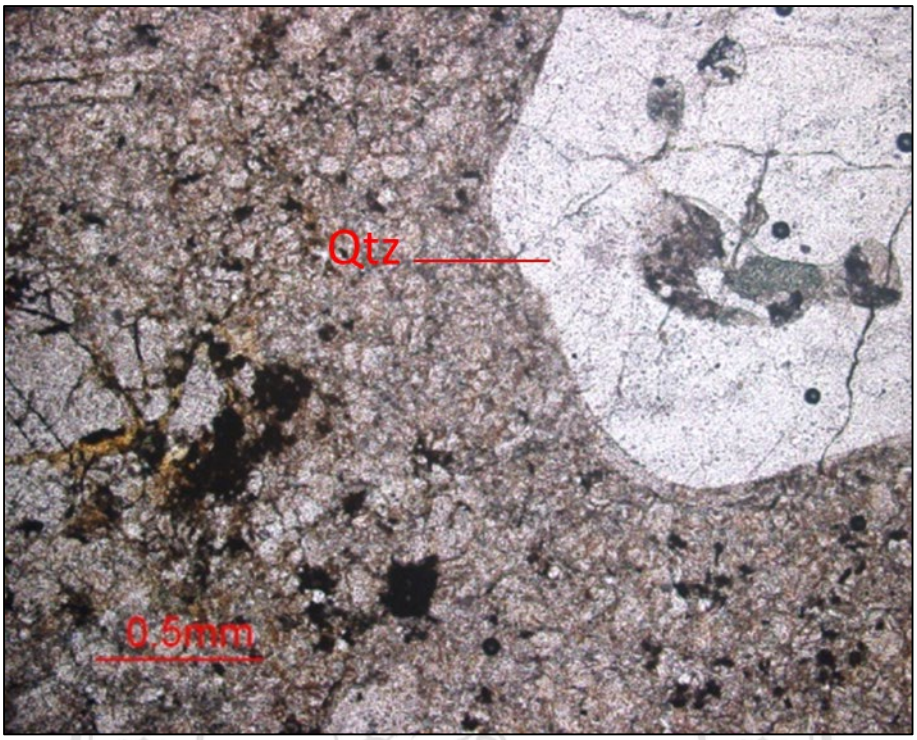


Figure 3.5 Photomicrographs of rhyodacite in the Mae Phrik area (sample number BTK25/1-2) showing a porphyritic texture; quartz (Qtz) (a) Ordinary light (b) Crossed polars.

a)



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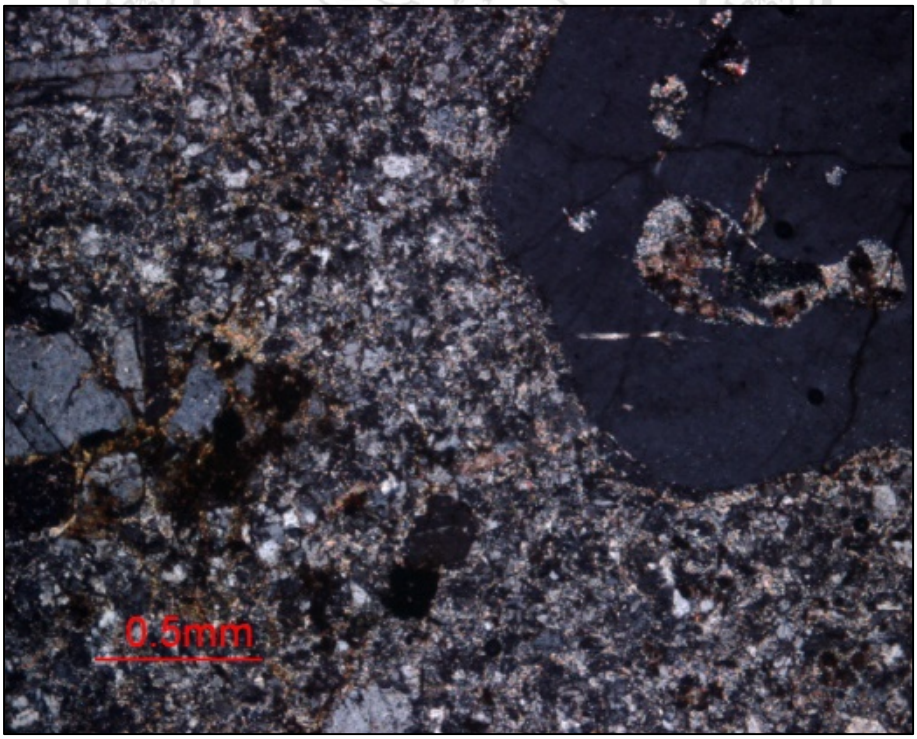
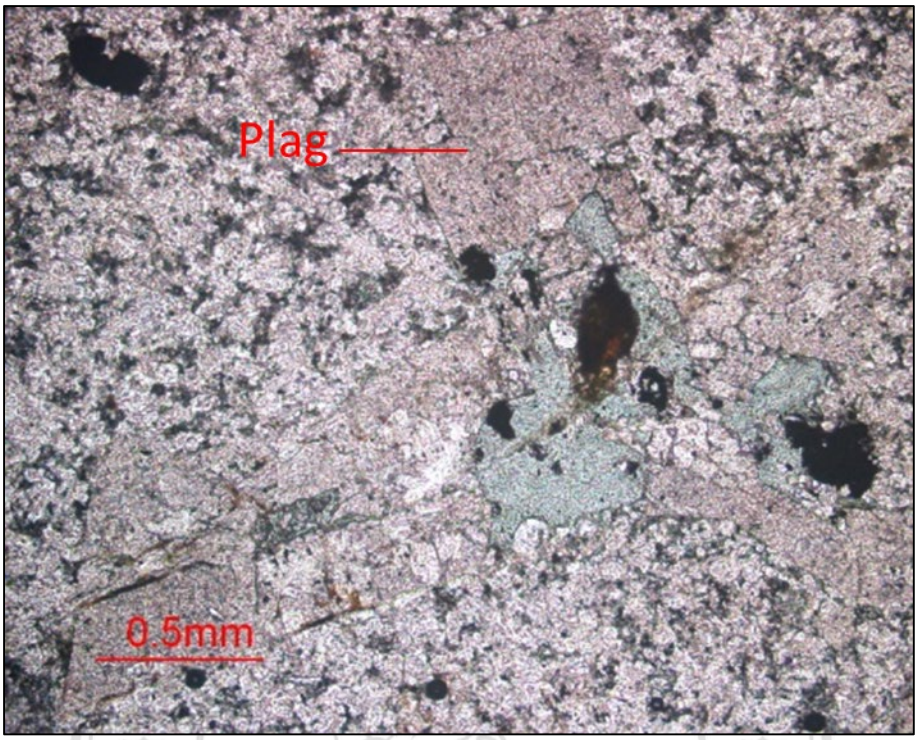


Figure 3.6 Photomicrographs of rhyodacite in the Mae Phrik area (sample number BTK25/1-1) showing quartz phenocrysts (Qtz) (a) Ordinary light (b) Crossed polars.

a)



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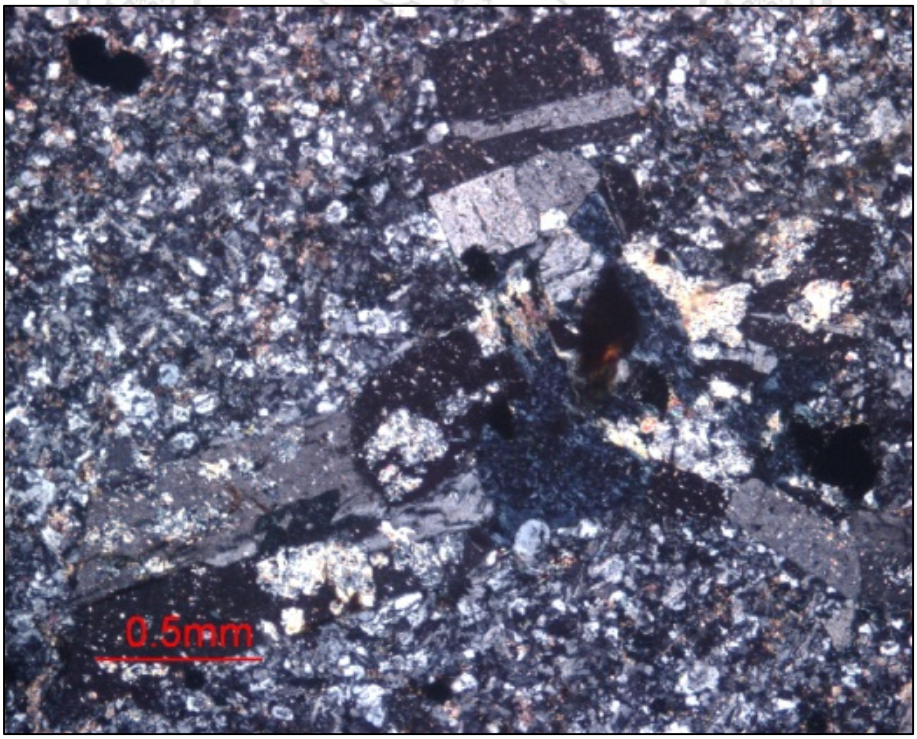


Figure 3.7 Photomicrographs of rhyodacite in the Mae Phrik area (sample number BTK25/7) illustrating plagioclase phenocrysts (Plag) (a) Ordinary light (b) Crossed polars.

groundmass are anhedral and fine-grain with sizes up to 0.2 mm across. Quartz-alkali feldspar intergrowth groundmass is devitrified from grass. Chlorite patches are anhedral and fine-grain with sizes up to 0.1 mm across.

These rhyodacitic volcanic rocks in the Mae Phrik area are associated with rhyolitic tuff. The rhyolitic tuffs are made up mainly of glass shards with subordinate quartz and alkali feldspar with small amounts of rock fragments and show eutaxitic texture (Figure 3.8). Quartz fragments are anhedral (sizes up to 0.75 mm across). Alkali feldspar fragments are anhedral (sizes up to 1.25 mm across). Rock fragments are angular and have a low spherecity shape (sizes up to 1.5 mm across) that consists of basalt, rhyolite, and welded tuff. The groundmass phase is made up mainly of quartz-alkali feldspar devitrification, granophyric and spherulitic intergrowth, with small amounts of quartz, alkali feldspar, muscovite, and zircon. All of these rocks are commonly present leucoxene and clay minerals in the groundmass phase. Based on composition, these pyroclastic rocks can be defined to ash tuff based on grain size.

Basalt

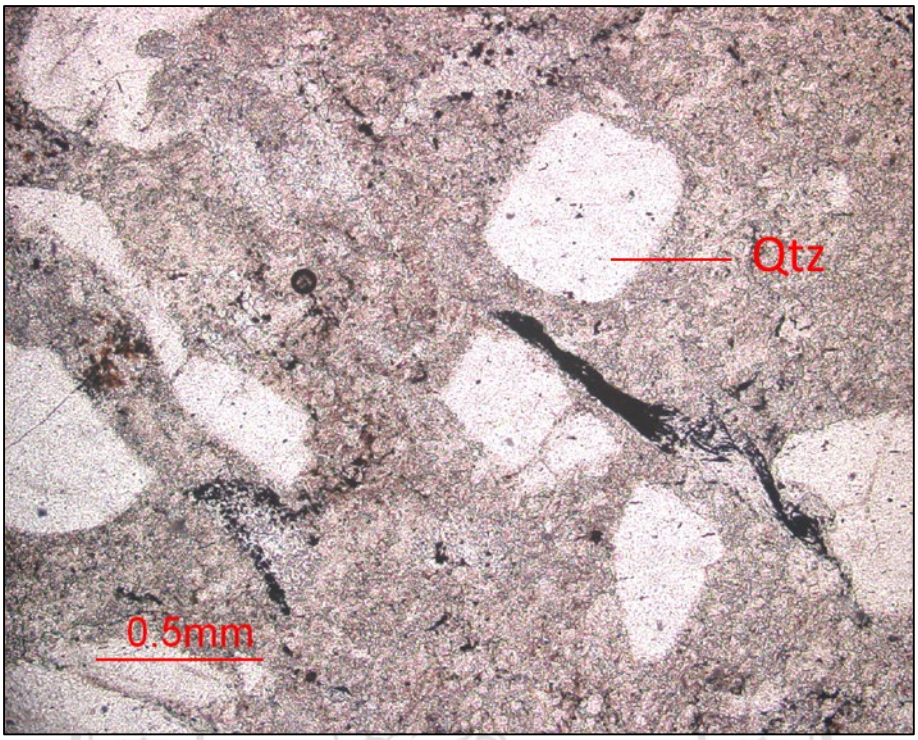
Basalt in the Mae Phrik area has a dark green color and its surface is cover by dark yellowish brown materials. It has a very fine-grained texture.

Under microscope, basalt shows slightly porphyritic texture. The phenocrysts/microphenocrysts in the sample are made up largely of plagioclase with small amount of unidentified mafic mineral. The groundmass phase is made up mainly of plagioclase, with small amounts of unidentified mafic minerals, and opaque minerals. Plagioclase and clinopyroxene in the groundmass phase are ophitic/ subohitic intergrowth.

Plagioclase phenocryst/microphenocrysts (Figure 3.9) are subhedral with sizes up to 1 mm across. Their crystals show polysynthetic twin and are broken. Groundmass plagioclase is anhedral with sizes up to 0.1 mm across. Plagioclase is slightly replaced by sericite and clay minerals.

Unidentified mafic minerals phenocrysts/microphenocrysts (Figure 3.10) are subhedral to euhedral (sizes up to 0.5 mm across). Unidentified mafic in groundmass

a)



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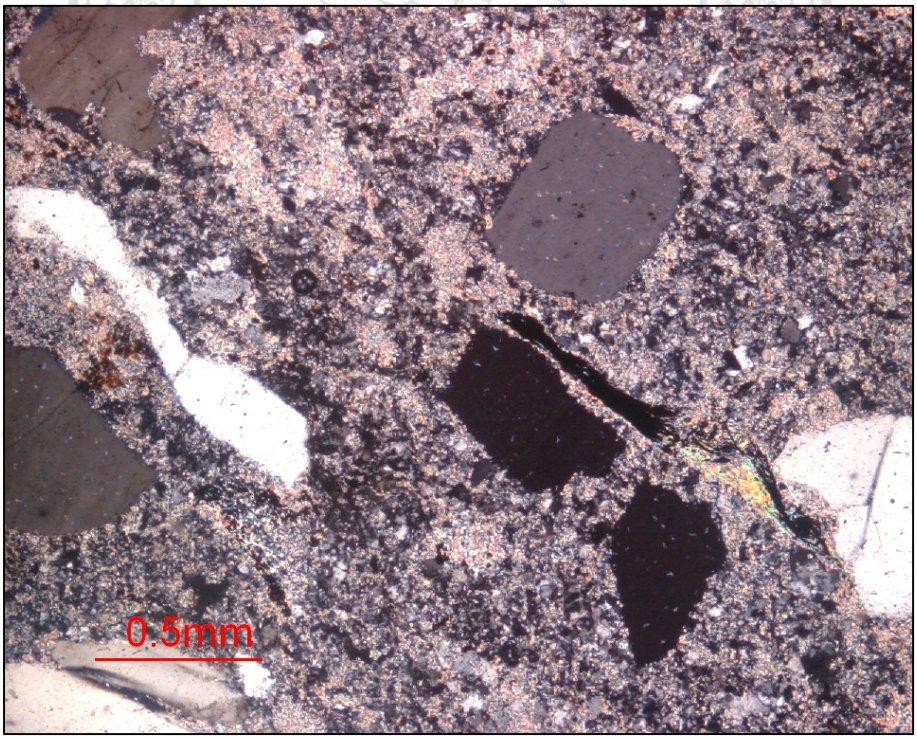
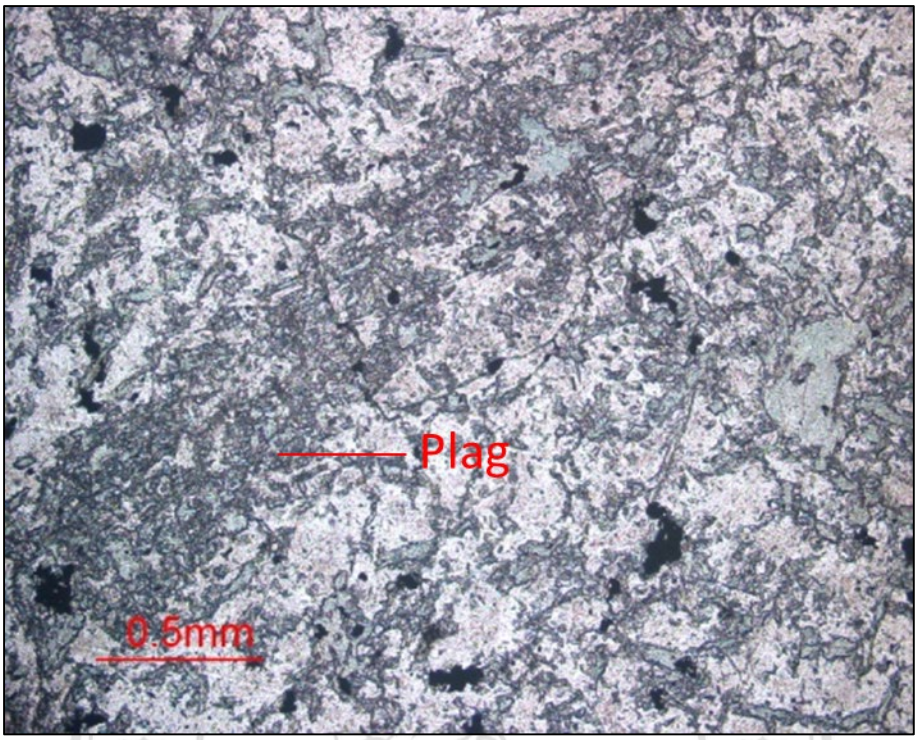


Figure 3.8 Photomicrographs of rhyolitic tuff in the Mae Phrik area (sample number BTK 25/4) showing quartz fragments (Qtz) and eutaxitic texture (a) Ordinary light (b) Crossed polars.

a)



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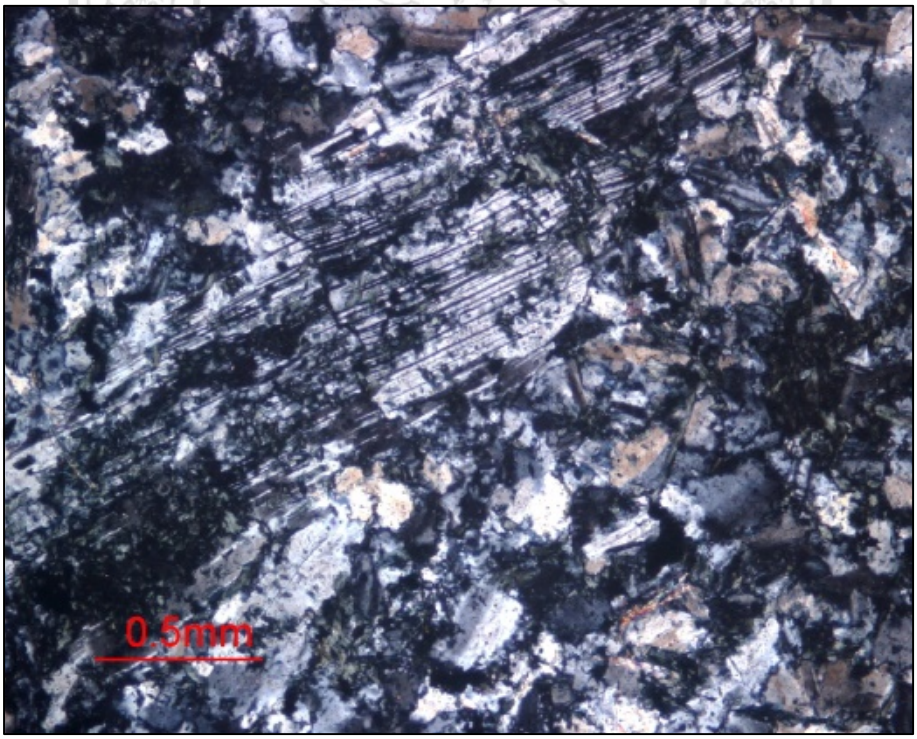
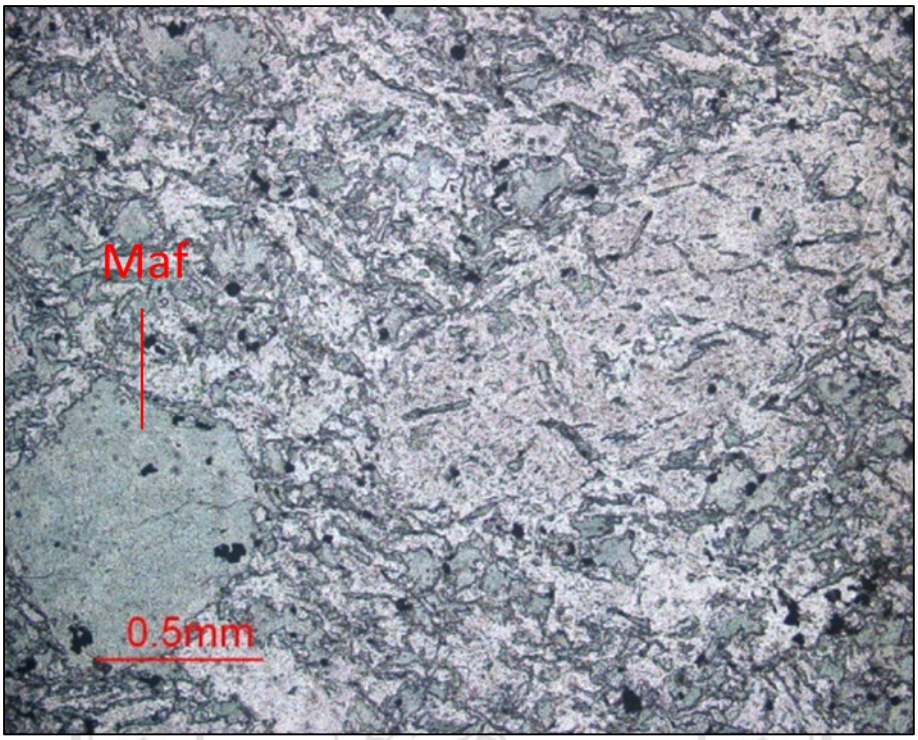


Figure 3.9 Photomicrographs of basalt in the Mae Phrik area (sample number BTK25/8-1) displaying plagioclase phenocrysts (Plag) (a) Ordinary light (b) Crossed polars.

a)



b)

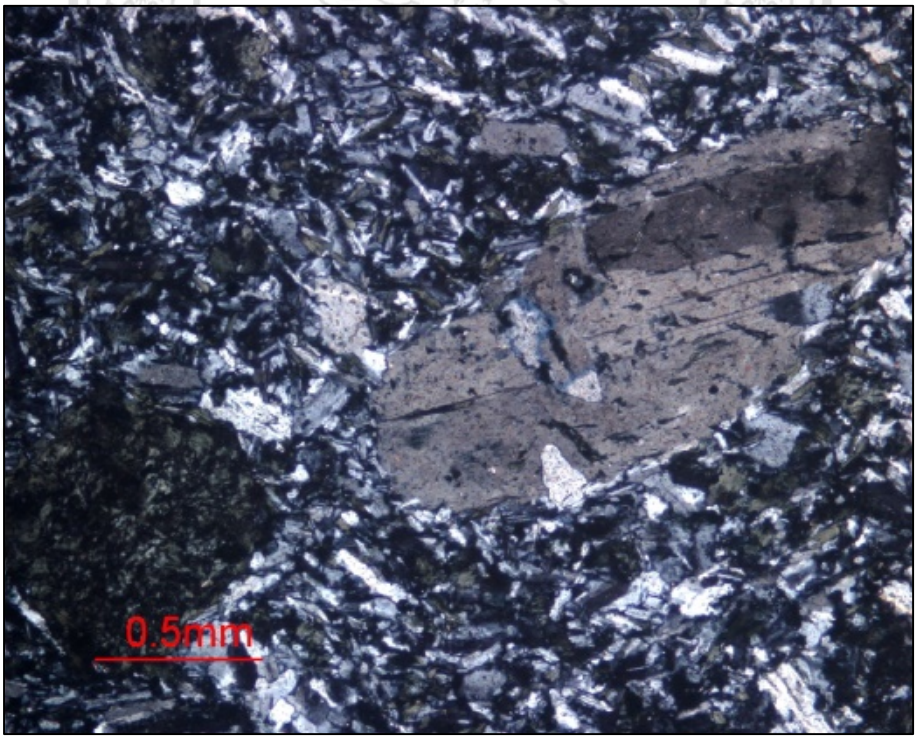


Figure 3.10 Photomicrographs of basalt in the Mae Phrik area (sample number BTK25/8-3) showing unidentified mafic minerals phenocrysts (Maf.) in a very fine-grained groundmass (a) Ordinary light (b) Crossed polars.

minerals are anhedral with sizes up to 0.1 mm across. Unidentified mafic minerals are completely replaced by serpentine/chlorite. Opaque minerals in the groundmass phase are anhedral and fine-grain with sizes up to 0.1 mm across**.**

These basaltic rocks in the Mae Phrik area are associated with granite. They have formed by cut along the Triassic granitic intrusion. Granite is made up mainly of quartz, alkali feldspar and palgioclase, with a small amount of muscovite (Figure 3.11). Trace minerals, zircon/monazite and apatite, can be detected in this sample. This rock has an equigranular texture, with grain sizes averaging less than 1 mm across. Very small amounts of secondary opaque minerals, epidotes, and chlorite are present in this sample. Plagioclase crystals are broken and folded by deformation.

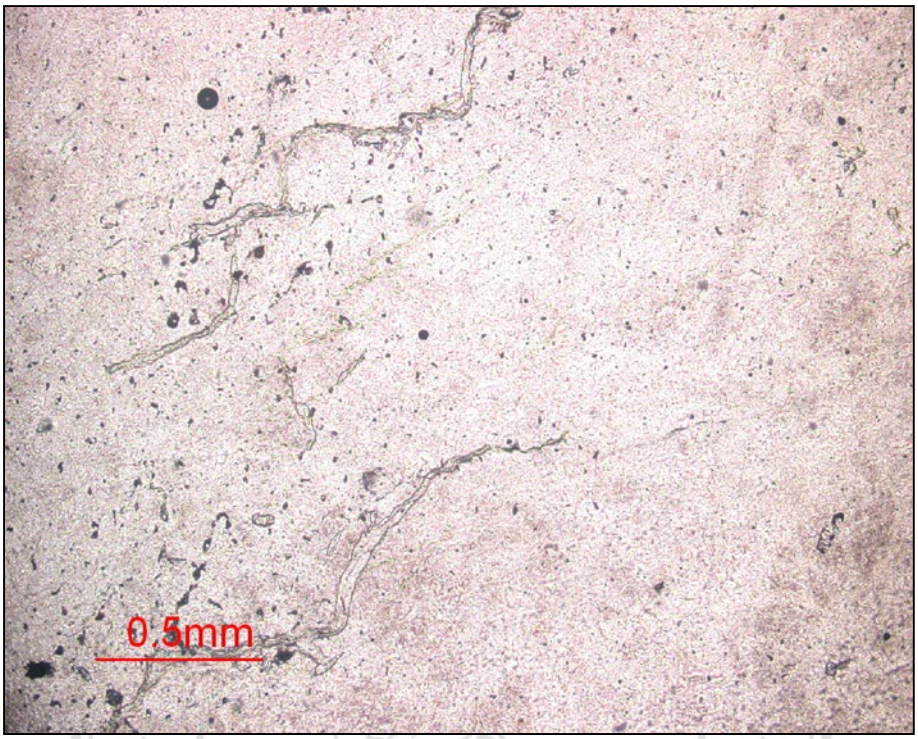
3.2 The Mae Salaem Area

The sample was collected from outcrop (Figure 3.12) along the local highway which runs from Thoen District to Ban Mae Salaem in Mae Salaem area. The volcanic rocks in the Mae Salaem area consists of rhyolite (sample number MSL25/1-1) and tuff. The outcrop of this rock is pale pink to reddish in color. The volcanic rock has porphyritic and very fine-grained textures. All of studied rocks in the Mae Salaem area are associated with the granitic intrusions that have formed in the Triassic period.

Rhyolite in the Mae Salaem area is a very fine-grained and shows slightly porphyritic in texture, and is pale pink to reddish in color with a yellowish brown weathering on their surfaces. The phenocrysts are made up of quartz (colorless), feldspars (white), and opaque minerals (black), which are embedded in a very fine-grained groundmass.

Under microscope, rhyolite shows a porphyritic texture. The phenocrysts/microphenocrysts are made up largely of quartz and plagioclase, with a small amount of alkali feldspar. The groundmass phase is made up mainly of quartz-alkali feldspar (granophyric and spherulitic) intergrowth with small amounts of quartz, alkali feldspar, muscovite, and opaque minerals.

a)



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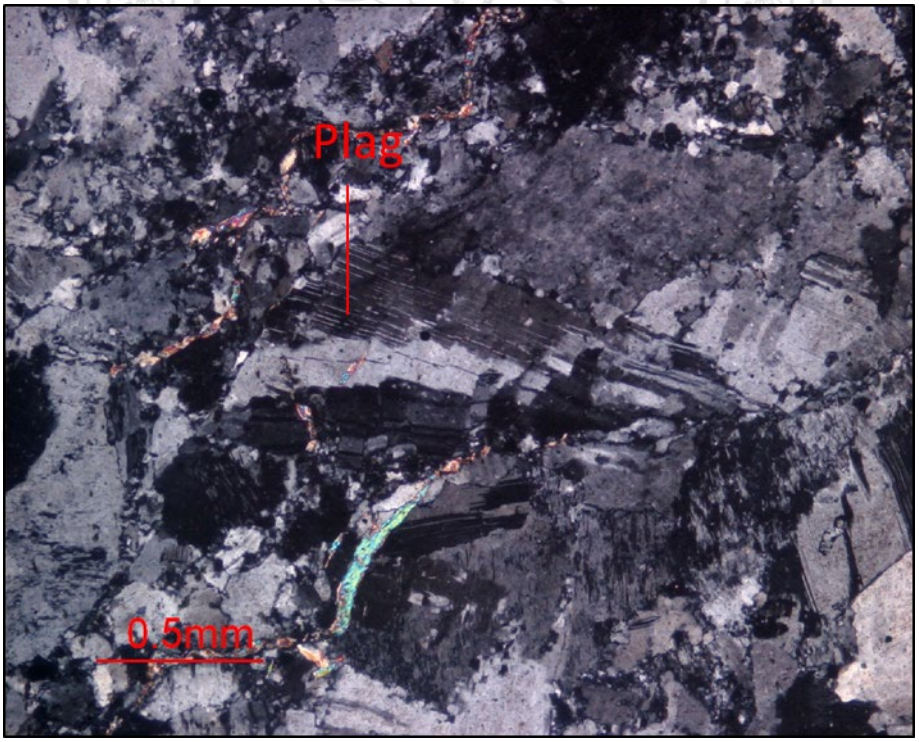


Figure 3.11 Photomicrographs of granite in the Mae Phrik area (sample number BTK25/8-2) showing kink and fold of plagioclase (Plag) (a) Ordinary light (b) Crossed polars.

Figure 3.12 The outcrop of rhyolite in the Mae Salaem area at grid reference 533774.0 E 1922471.7 N (Dr. Burapha Phajuy, 182 cm tall, is to scale).

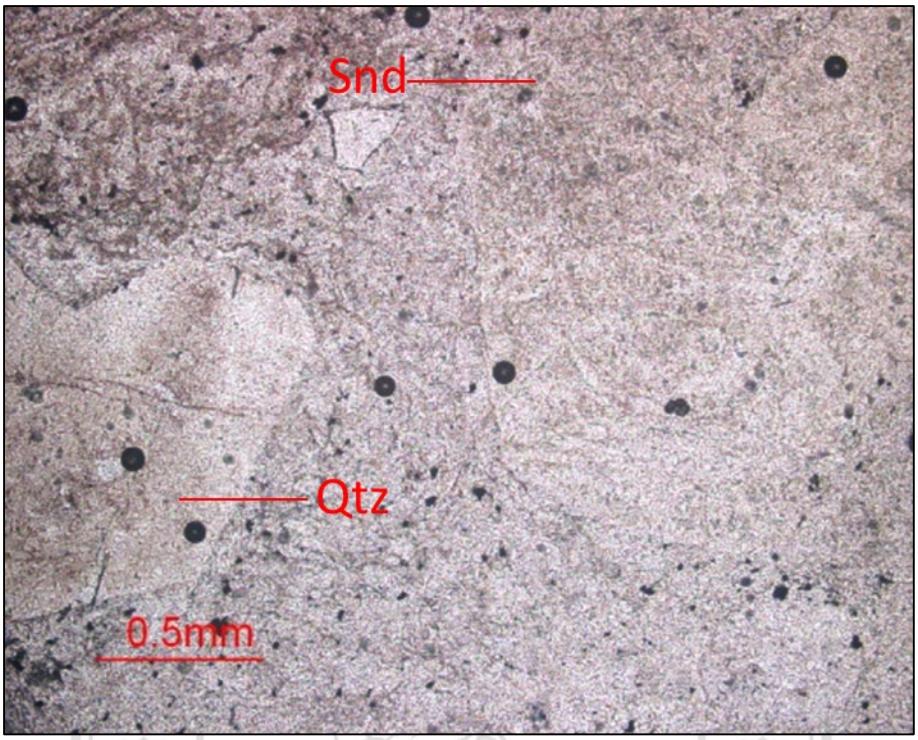
Quartz phenocrysts/microphenocrysts are euhedral to subhedarl (sizes up to 0.75 mm across). They commonly show rounded edges and embayed outlines. Groundmass quartz is anhedral with sizes up to 0.1 mm across (Figure 3.13).

Plagioclase phenocryst/microphenocrysts are subhedral with sizes up to 1.5 mm across. Their crystals show carlsbad twins and albite twins and is slightly to moderately replaced by sericite and clay minerals.

Alkali feldspar phenocrysts/microphenocrysts are subhedral to euhedral (sizes up to 1 mm across). They show simple twin and perthitic texture (sanidine type). Groundmass alkali feldspar is anhedral with sizes up to 0.1 mm across. Alkali feldspar is slightly replaced by clay minerals.

Quartz-alkali feldspar intergrowth groundmass is composed of microgranophyric intergrowth and spherulite (sizes up to 1.5 mm across). Granophyric intergrowth is made up of radial quartz embedded in alkali feldspar. Spherulite is radial aggregate of

a)



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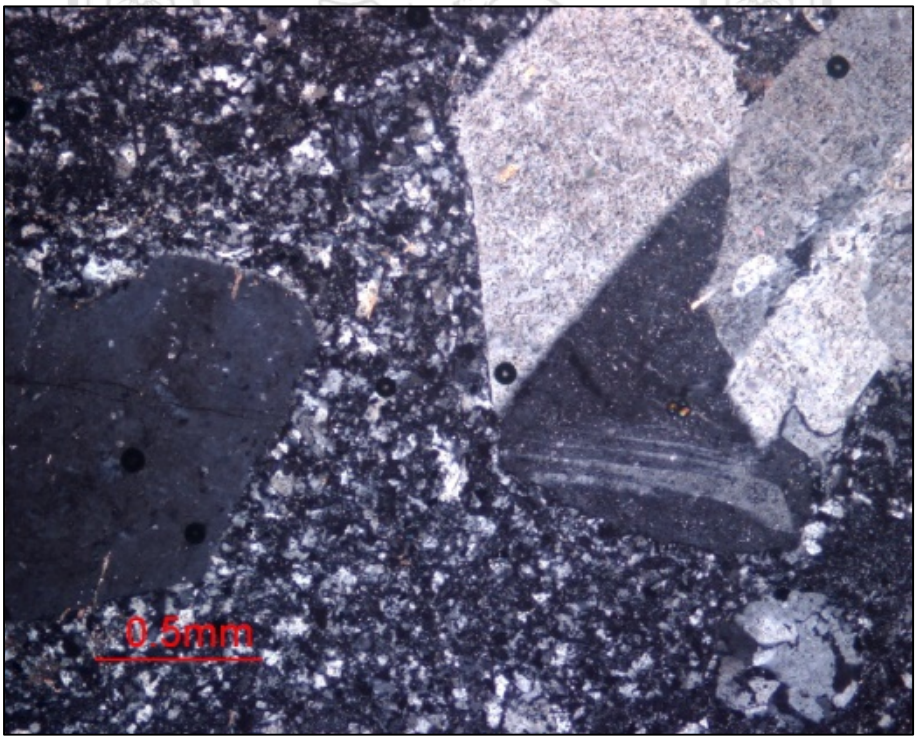


Figure 3.13 Photomicrographs of rhyolite in the Mae Salaem area (sample number MSL25/1-1) showing porphyritic texture and quartz (Qtz) and sanidine (Snd) phenocrysts (a) Ordinary light (b) Crossed polars.

quartz and feldspar. Muscovite is anhedral and fine-grain with sizes up to 0.2 mm across. Opaque minerals in the groundmass phase are anhedral and fine-grain with sizes up to 0.2 mm across.

This rhyolite is associated with rhyolitic tuff. The rhyolitic tuffs are made up mainly of glass shards with subordinate quartz and alkali feldspar with small amounts of rock fragments and show eutaxitic texture (Figure 3.14). Quartz fragments are anhedral (sizes up to 0.75 mm across). Alkali feldspar fragments are anhedral (sizes up to 1.25 mm across). Rock fragments are angular and low spherecity in shape (sizes up to 1.5 mm across) and consist of basalt, rhyolite, and welded tuff. The groundmass phase is made up mainly of quartz-alkali feldspar devitrification, granophyric and spherulitic intergrowth, with small amounts of quartz, alkali feldspar, muscovite, and zircon. All of these rocks are commonly present leucoxene and clay minerals in the groundmass phase. Based on composition, these pyroclastic rocks can be defined to ash tuff based on grain size.

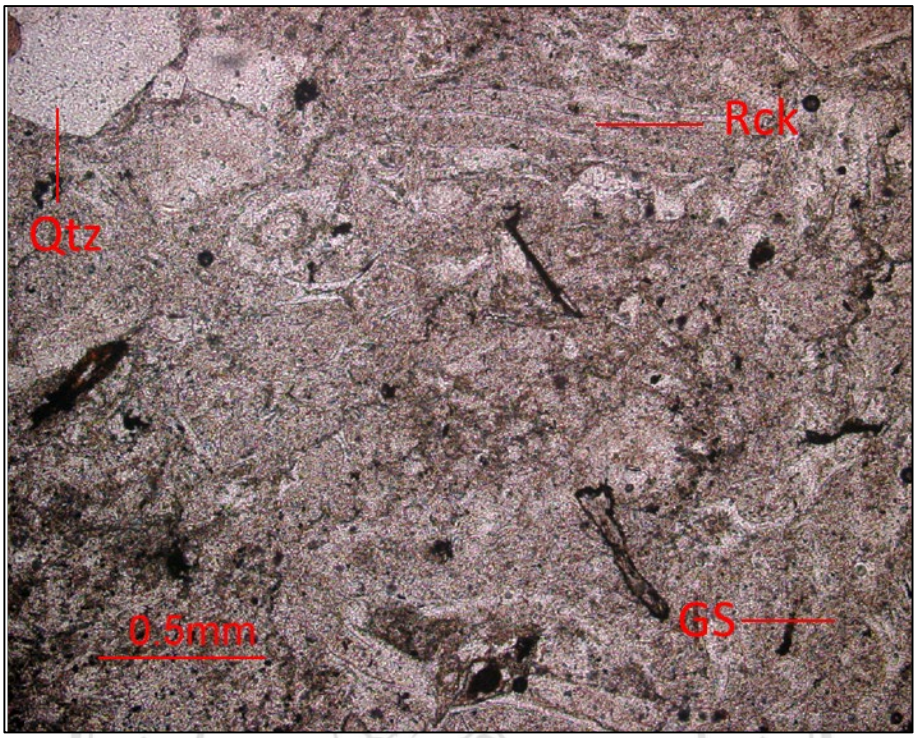
3.3 The Pong Daeng Area

The sample was collected from in situ float rocks (Figure 3.15) and outcrop in the eastern part of Ban Pong Daeng, Mueang Tak District in Tak Province. The Pong Daeng area consists of basalt porphyry (sample number PDNG30/4) and tuff. The in situ float rock is dark gray to dark green in color. The basalt of the Pong Daeng area has porphyritic and very fine-grained textures. All of the studied rock in the Pong Daeng area is associated with the granitic intrusions that have formed in Triassic period. This association is similar to basalt and granite in the Mae Phrik area.

Basalt in the Pong Daeng area has a dark green color and its surface is cover by dark yellowish brown materials. It has very fine-grained texture.

Under microscope, basalt shows a porphyritic texture. The phenocrysts/microphenocrysts are made up of plagioclase with small amount of unidentified mafic minerals. The groundmass phase is made up mainly of plagioclase, with small amounts of unidentified mafic minerals, and opaque minerals.

a)



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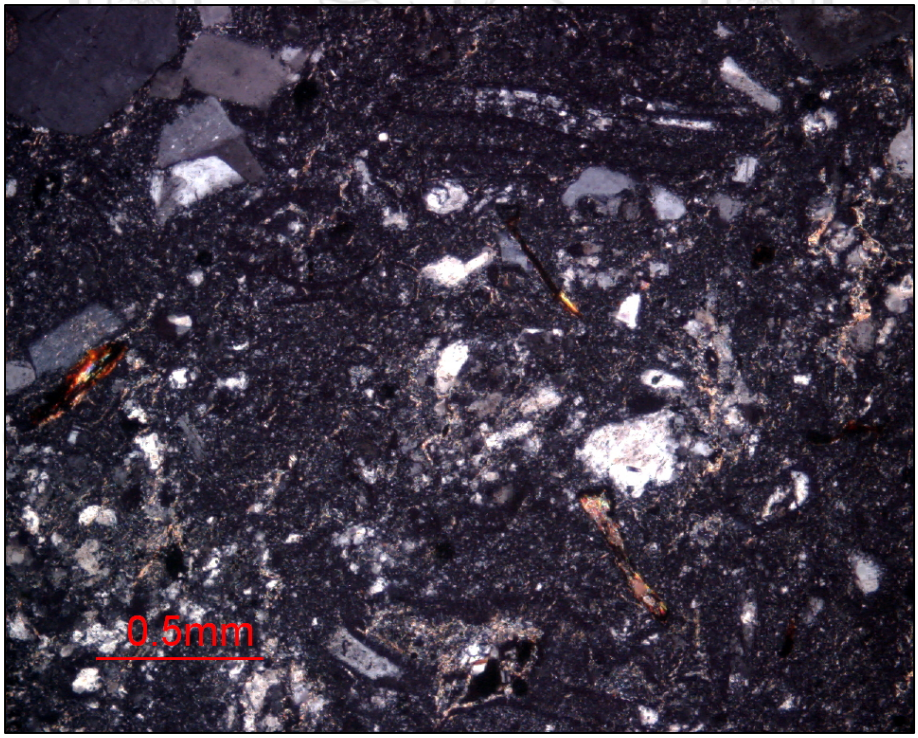


Figure 3.14 Photomicrographs of rhyolitic tuff in the Mae Salaem area (sample number MSL29/6) showing quartz (Qtz), glass shard (Gs) and rock fragment (Rck) (a) Ordinary light (b) Crossed polars.

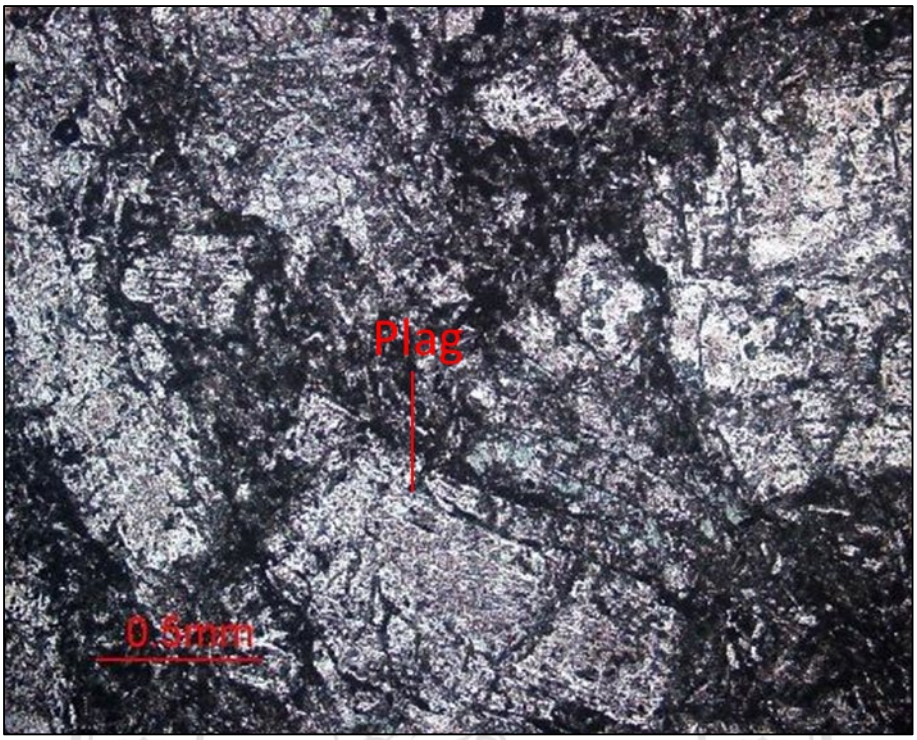
Figure 3.15 The outcrop and in situ floats of basalt porphyry in the Pong Daeng area at grid reference 538438.4 E 1886969.4 N (Dr. Burapha Phajuy, 182 cm tall, is to scale).

Felted plagioclase grains have two grain sizes, plagioclase phenocryst/microphenocrysts are subhedral with sizes up to 1 mm across. Their crystals show carlsbad twin. Groundmass plagioclase is anhedral with sizes up to 0.1 mm across. Plagioclase is slightly replaced by sericite and clay minerals. Plagioclase crystals are broken and fold by deformation (Figure 3.16).

Unidentified mafic minerals phenocrysts/microphenocrysts are subhedral to euhedral (sizes up to 1.5 mm across). Groundmass unidentified mafic minerals are anhedral with sizes up to 0.1 mm across. Unidentified mafic minerals are completely replaced by serpentine/chlorite and epidote. Opaque minerals in the groundmass phase are anhedral and fine-grained with sizes up to 0.1 mm across**.**

This basalt is associated with granodiorite and basaltic tuff. Granodiorite is the part of Triassic granitic intrusion (Tak Batolith) and is made up principally of quartz, plagioclase and alkali feldspar, with small amounts of biotite and hornblende and trace amounts of titanite, zircon/monazite and apatite. The granodiorite show medium-

a)



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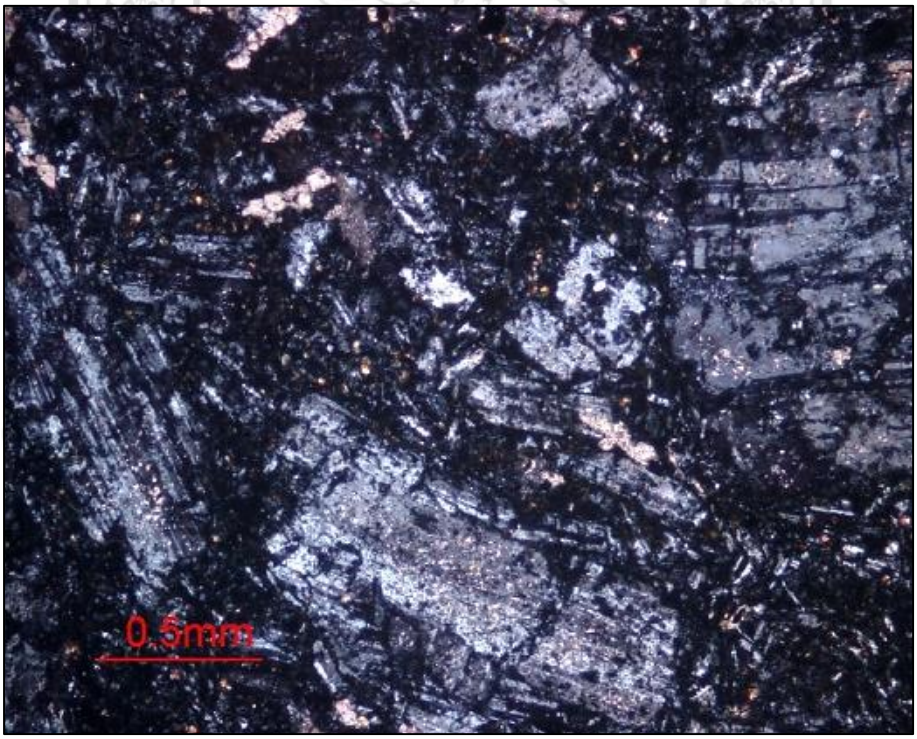


Figure 3.16 Photomicrographs of basalt porphyry in the Pong Daeng area (sample number PDNG30/4) showing folded plagioclase (Plag) phenocrysts (a) Ordinary light (b) Crossed polars.

grained groundmass (grain sizes average less than 3 mm across). Foliation in the hand specimen can be observed under microscope, parallel of long axes in biotite. Patches of epidotes is slightly present in the sample. Plagioclase crystals are broken and folded by deformation. Zircon inclusion in biotite crystal has been found in some samples (Figure 3.17). Basaltic tuff is made up mainly of slightly felted plagioclase, with small amounts of epidote, hornblende, chlorite, quartz and glass (Figure 3.18). Plagioclase is euhedral (sizes up to 1.25 mm across). Quartz fragments are anhedral (sizes up to 0.75 mm across). Epidote, hornblende, chlorite, and glass are very fine-grained. Based on composition, these pyroclastic rocks can be defined to fine tuff based on grain size.

3.4 The Wang Luek Area

The samples were collected from both in situ float rocks (Figure 3.19) and outcrops (Figure 3.20) near the Wang Luek, Ban Dan Lan Hoi District in Sukhothai Province. The Wang Luek area consists of gabbro, including sample number WL29/2-2 and WL29/3, and cumulus gabbro including WL29/1-1, WL29/1-2, WL29/1-3, and WL29/2-1. The outcrops of these rocks are dark gray to dark green in color and some outcrops are pale green to pale gray in color. The gabbroic rocks of the Wang Luek area have fine to medium-grained texture.

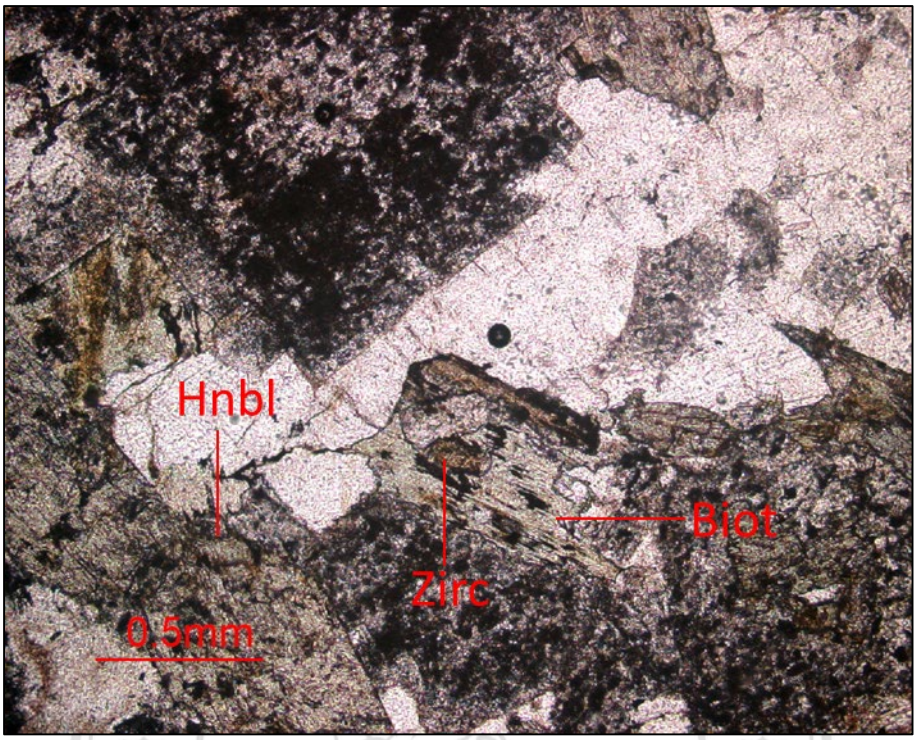
Gabbro

Gabbro in the Wang Luek area has a greenish, gray color and the surface is covered by dark, yellowish brown materials. It is equigranular and has a medium-grain (grain sizes less than 1 mm across). The gabbro contains white, lath shape crystals (plagioclase) and green crystals (pyroxene).

Under microscope, gabbro is made up largely of plagioclase and clinopyroxene, with subordinate unidentified mafic minerals and opaque mineral (magnetite?). Plagioclase and clinopyroxene in the groundmass phase are ophitic/subohitic intergrowth (Figure 3.21).

Plagioclase is euhedral and short prismatic (sizes up to 0.75 mm across). Plagioclase is completely replaced by epidotes, clay minerals, and sericite.

a)



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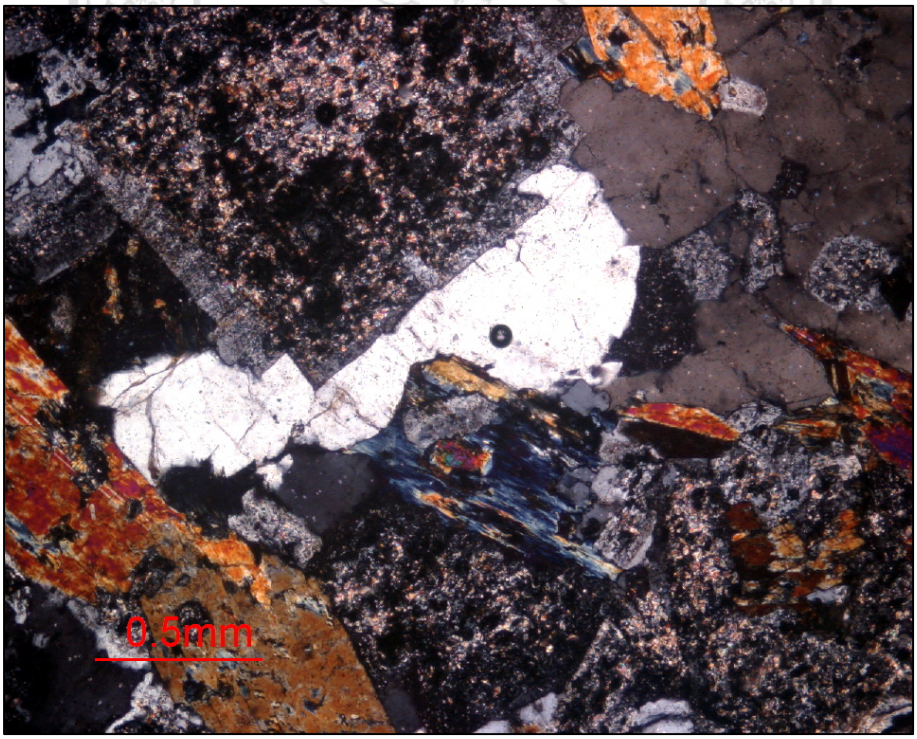
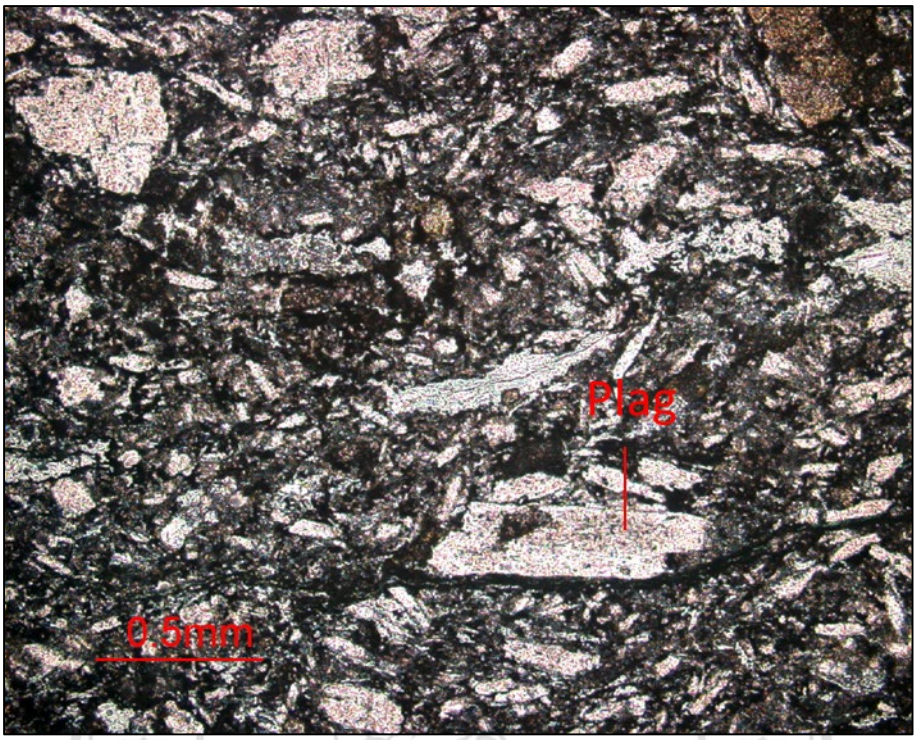


Figure 3.17 Photomicrographs of granodiorite in the Pong Daeng area (sample number PDNG 30/11) showing hornblende (Hnbl) and zircon (Zirc) inclusion in biotite crystal (Biot) (a) Ordinary light (b) Crossed polars.

a)



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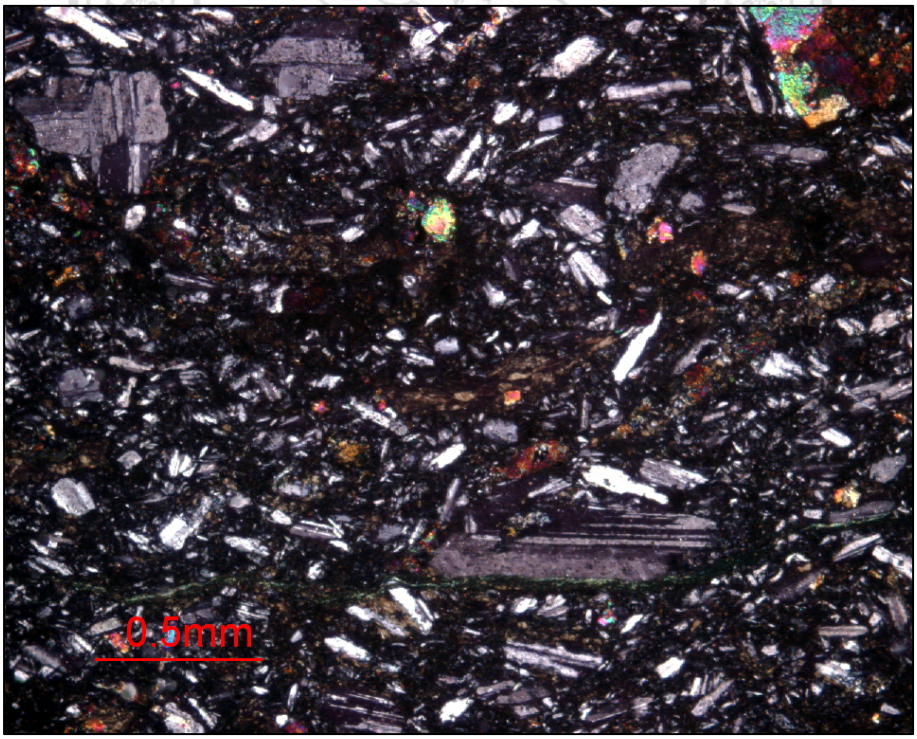
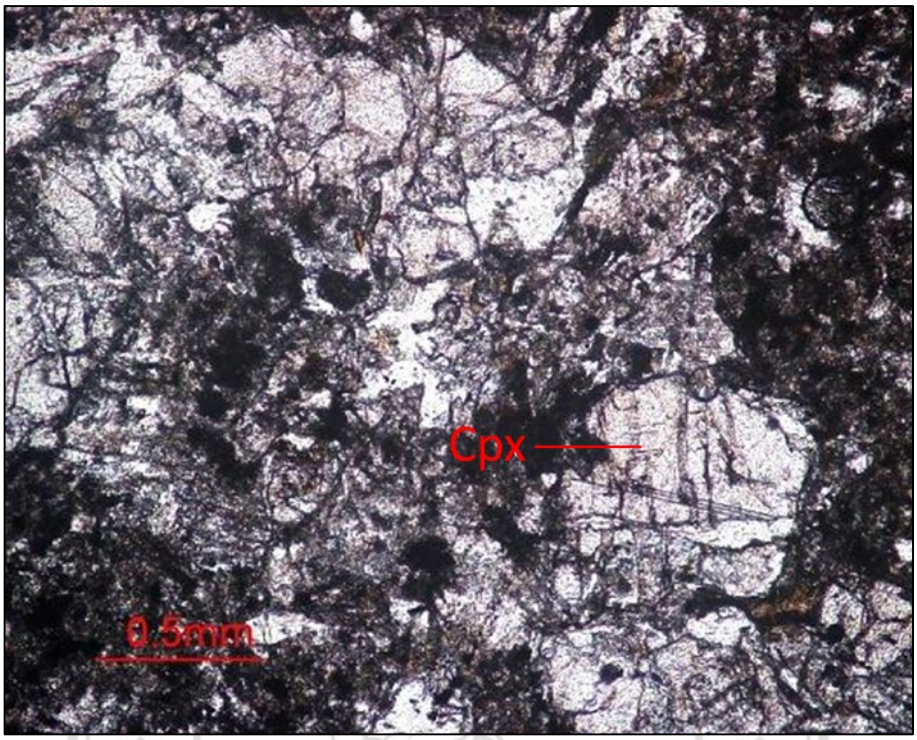


Figure 3.18 Photomicrographs of basaltic tuff in the Pong Daeng area (sample number PDNG 30/6-1) showing felted plagioclase (Plag) (a) Ordinary light (b) Crossed polars.

Figure 3.19 The in situ float rocks of gabbro in the Wang Luek area at grid reference 544569.5 E 1888131.8 N (Dr. Burapha Phajuy, 182 cm tall, is to scale).

Figure 3.20 The outcrops of gabbro in the Wang Luek area at grid reference 544951.1 E 1888567.7 N (Dr. Burapha Phajuy, 182 cm tall, is to scale) .

a)



b)

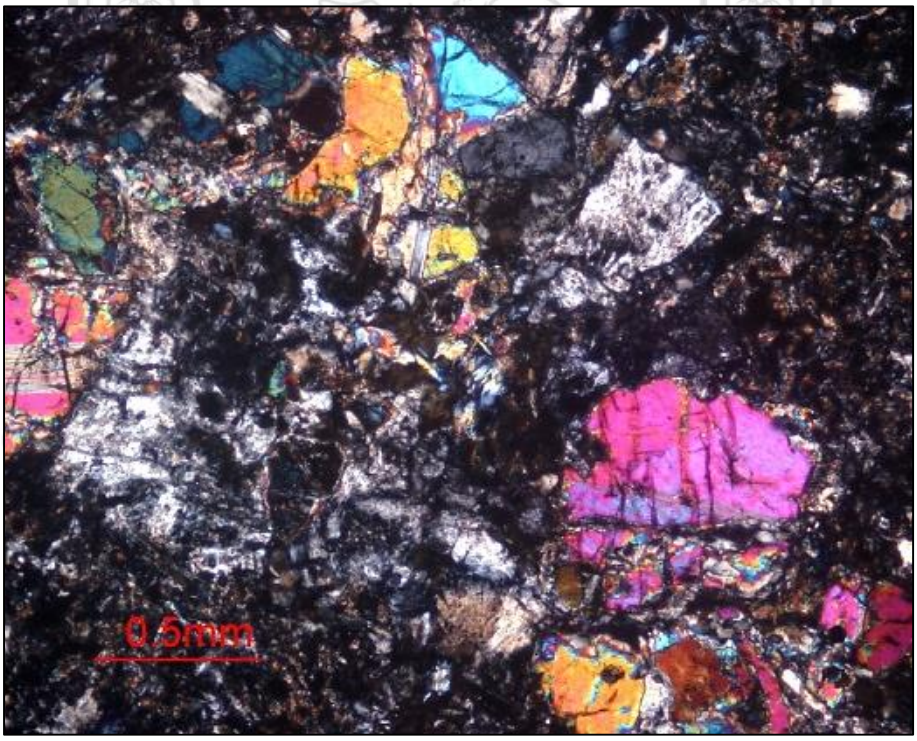


Figure 3.21 Photomicrographs of gabbro in the Wang Luek area (sample number WL29/2-2) showing ophitic/subohitic intergrowth; clinopyroxene (Cpx) (a) Ordinary light (b) Crossed polars.

Clinopyroxene is subhedarl (sizes up to 1.5 mm across) and colorless. It is moderately replaced by epidote and chlorite/ serpentine. Plagioclase inclusion has been observed in clinopyroxene crystals.

Unidentified mafic mineral is euhedral and has short-primaic/prismatic shapes (sizes up to 0.5 mm across). It is completely replaced by serpentine/chlorite and has small amounts of pale brown, amphibole and opaque minerals.

Opaque mineral (magnetite ?) is subhedral; equant (sizes up to 0.2 mm across) and intergranular with plagioclase laths.

Cumulus Gabbro

Cumulus gabbro in the Wang Luak area has a greenish gray in color and is fine-grained (grain size average less than 0.1 mm across). The tarnished surface is pale - moderate yellowish brown. It is made up of dark and white minerals. Tiny veins of light gray materials are rarely present in the hand specimen.

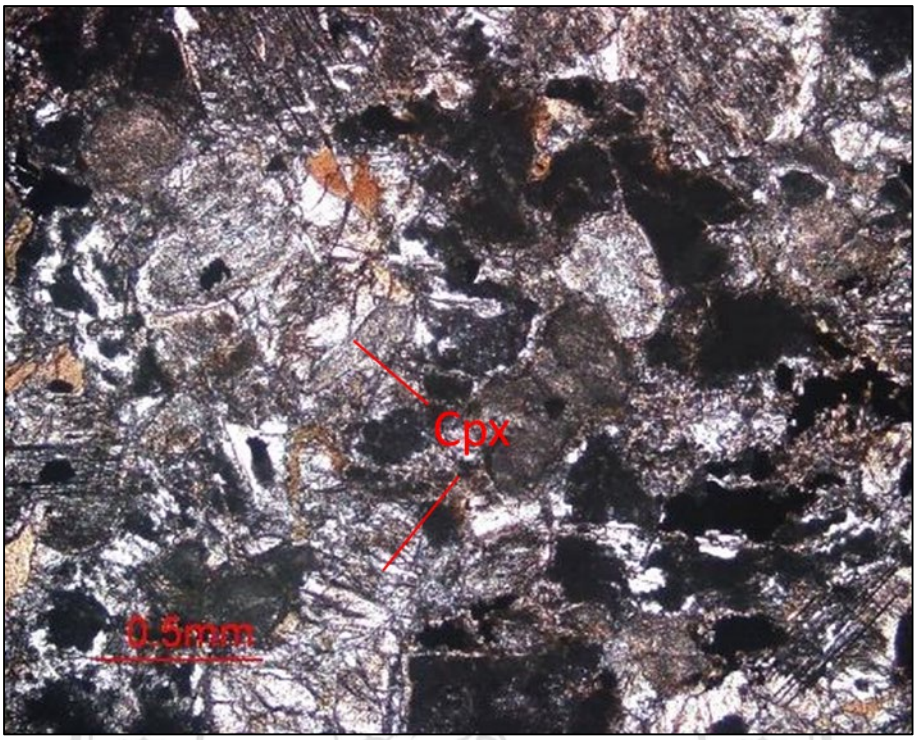
Under microscope, gabbro is equigranular (grain size in the range of 0.2 - 1 mm across) and shows cumulus texture (Figure 3.22). The cumulus crystals are made up mainly of plagioclase with subordinate clinopyroxene and unidentified mafic mineral and small amount of apatite. The intercumulus crystals comprise hornblende and opaque minerals (magnetite?). Patches of calcite, chlorite, epidotes and clay minerals are slightly replaced in this rock.

Plagioclase is euhedral to subhedral, long prismatic (sizes up to 0.8 mm across) and completely replaced by epidotes, sericite, and clay minerals. Plagioclase crystals line parallel along long axis.

Clinopyroxene is subhedarl (sizes up to 1 mm across) and colorless. It is slightly replaced by epidote and chlorite/ serpentine. Plagioclase inclusion has been observed in clinopyroxene crystals.

Unidentified mafic mineral is euhedral and has short-primaic/prismatic shapes (sizes up to 1 mm across). It is completely replaced by serpentine/chlorite and small amounts of pale brown amphibole and opaque minerals.

a)



b)

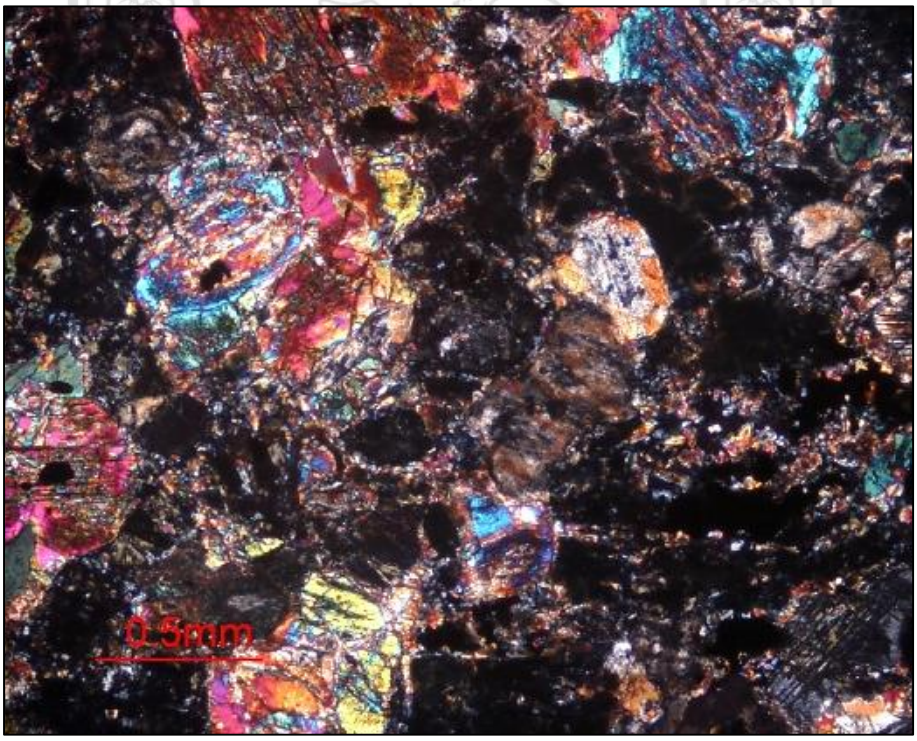


Figure 3.22 Photomicrographs of cumulus gabbro in the Wang Luek area (sample number WL29/1-3) showing cumulus texture; clinopyroxene (Cpx) (a) Ordinary light (b) Crossed polars.

Hornblende is anhedral (sizes up to 1 mm across) and shows an intercumulus crystalization. It has a pleochroic formula as X = pale yellow, Y = yellowish brown and Z = greenish brow. Inclusions of unidentified mafic mineral, clinopyroxene and plagioclase are commonly present in this amphibole crystal.

Opaque mineral (magnetite?) is anhedral with sizes up to 0.5 mm across and slightly replaced by titanite/leucoxene. It formed as intercumulus crystallization. Plagioclase inclusion can be observed in the opaque mineral.

Apatite is euhedral and has a short-primaic/prismatic shape (sizes up to 0.15 mm across). Apatite inclusion has been observed in plagioclase and clinopyroxene crystals (Figure 3.23).

3.5 The Wang Prachop Area

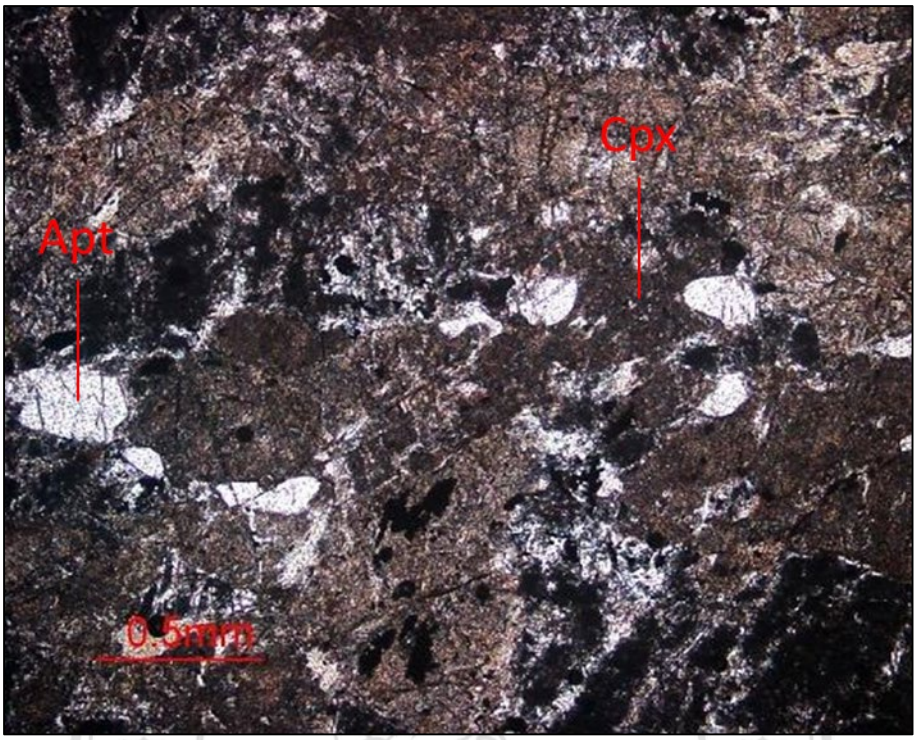
The samples were collected from both in situ float rocks (Figure 3.24 and 3.25) and outcrops (Figure 3.26 and 3.27) along highway number 12 which runs from Tak to Sukhothai Provinces. The Wang Prachop area consists of rhyolite (sample number WPC26/3-1) and andesite porphyry including sample number WPC26/4, WPC26/7, WPC26/10, WPC26/11, WPC26/12, WPC27/2, and WPC27/3. The outcrop of rhyolite is a pale pink in color and it shows porphyritic and very fine-grained textures. The outcrops of andesite porphyry are gray to dark green in color and some outcrops have pale green to pale gray in color. These volcanic rocks have porphyritic and very fine-grained textures.

Rhyolite

Rhyolite in the Wang Prachop area is very fine-grain and porphyritic textures. It has a pale pink to reddish in color with a yellowish brown weathering surface. The phenocrysts are made up of quartz (colorless), feldspars (white), and opaque minerals (black) and are embedded in a very fine-grained groundmass.

Under microscope, rhyolite shows slightly porphyritic texture (Figure 3.28). The phenocrysts/microphenocrysts in the sample are made up largely of quartz and plagioclase with small amount of alkali feldspar. The groundmass phase is made up mainly of quartz-alkali feldspar granophyric and spherulitic intergrowth, with small

a)



b)

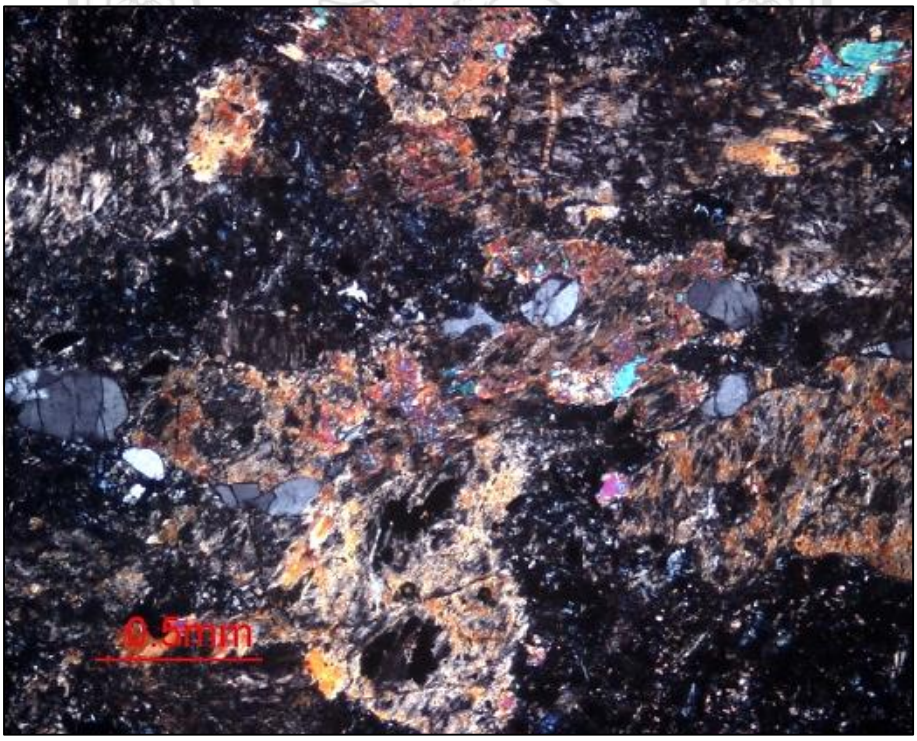


Figure 3.23 Photomicrographs of cumulus gabbro in the Wang Luek area (sample number WL29/1-2) showing apatite (Apt) inclusion in clinopyroxene (Cpx) crystals (a) Ordinary light (b) Crossed polars.

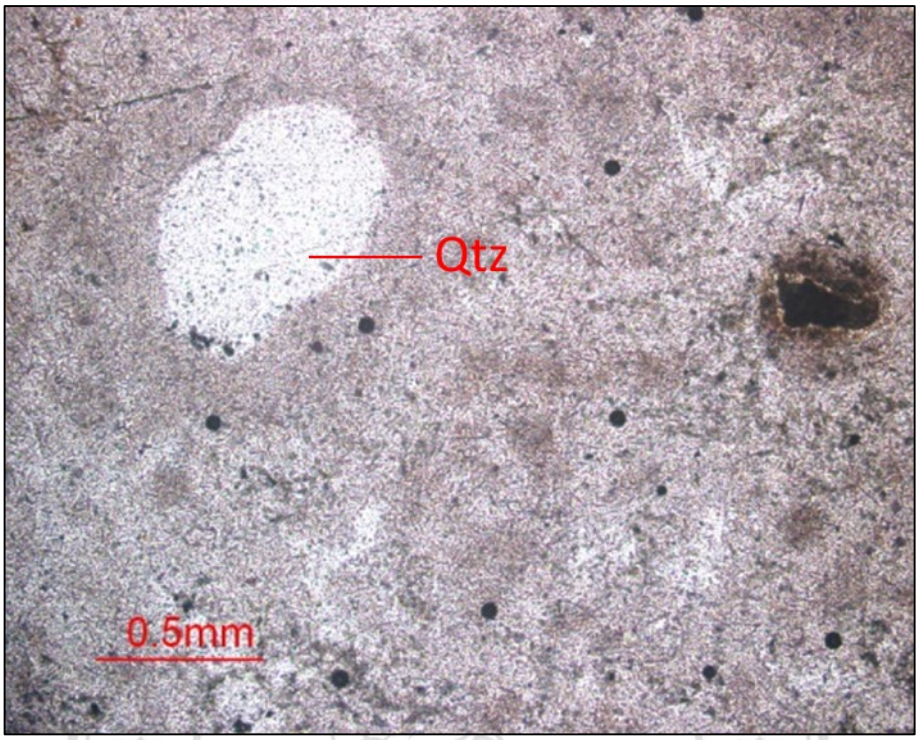
Figure 3.24 The in situ float rocks of rhyolite in the Wang Prachop area at grid reference 531983.0 E 1870780.5 N (Dr. Burapha Phajuy, 182 cm tall, is to scale).

Figure 3.25 The in situ float rocks of andesite porphyry in the Wang Prachop area at grid reference 534396.8 E 1876070.2 N (the hammer 40 cm long).

Figure 3.26 The outcrops of andesite porphyry in the Wang Prachop area at grid reference 534800.2 E 1873573.5 N (Mr. Chanakan. Boonnawa, 175 cm tall, is to scale).

Figure 3.27 The outcrops of andesite porphyry in the Wang Prachop area at grid reference 533142.6 E 1869515.6 N (Dr. Burapha Phajuy, 182 cm tall, is to scale).

a)



b)

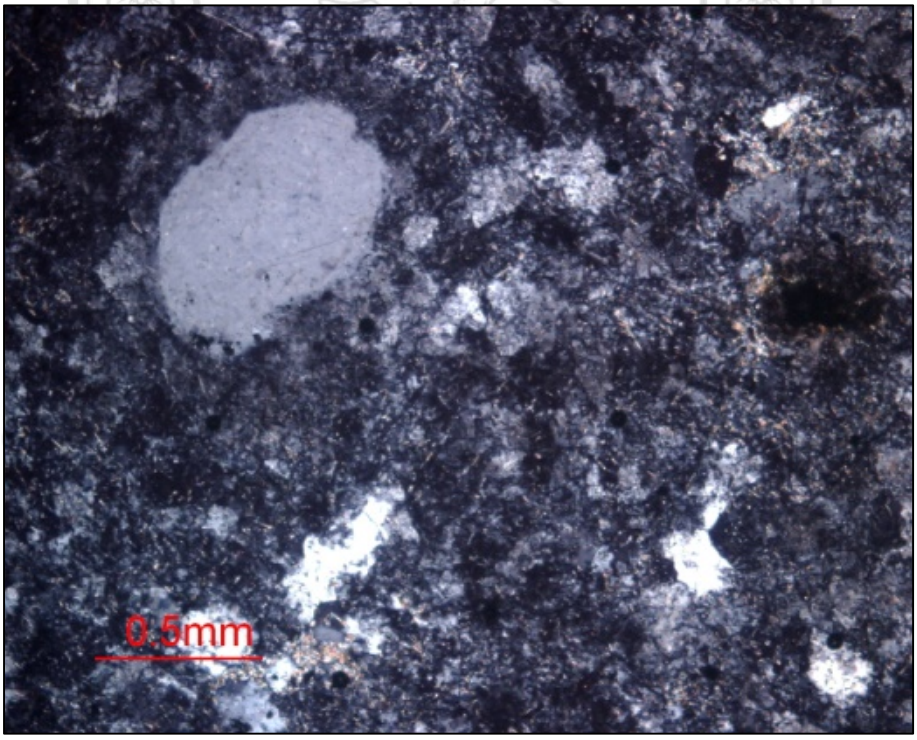


Figure 3.28 Photomicrographs of rhyolite in the Wang Prachop area (sample number WPC26/3-1) showing quartz (Qtz) phenocrysts (a) Ordinary light (b) Crossed polars.

amounts of quartz, alkali feldspar, muscovite, and opaque minerals.

Quartz phenocrysts/microphenocrysts are euhedral to subhedarl (sizes up to 0.75 mm across). They commonly show rounded edges and embayed outlines. Groundmass quartz is anhedral with sizes up to 0.1 mm across.

Plagioclase phenocryst/microphenocrysts are subhedral with sizes up to 1.5 mm across. Their crystals show carlsbad twin and albite twin and are slightly to moderately replaced by sericite and clay minerals.

Alkali feldspar phenocrysts/microphenocrysts are subhedral to euhedral (sizes up to 1 mm across). They show simple twin and a perthitic texture (sanidine type). Groundmass alkali feldspar is anhedral with sizes up to 0.1 mm across. Alkali feldspar is slightly replaced by clay minerals.

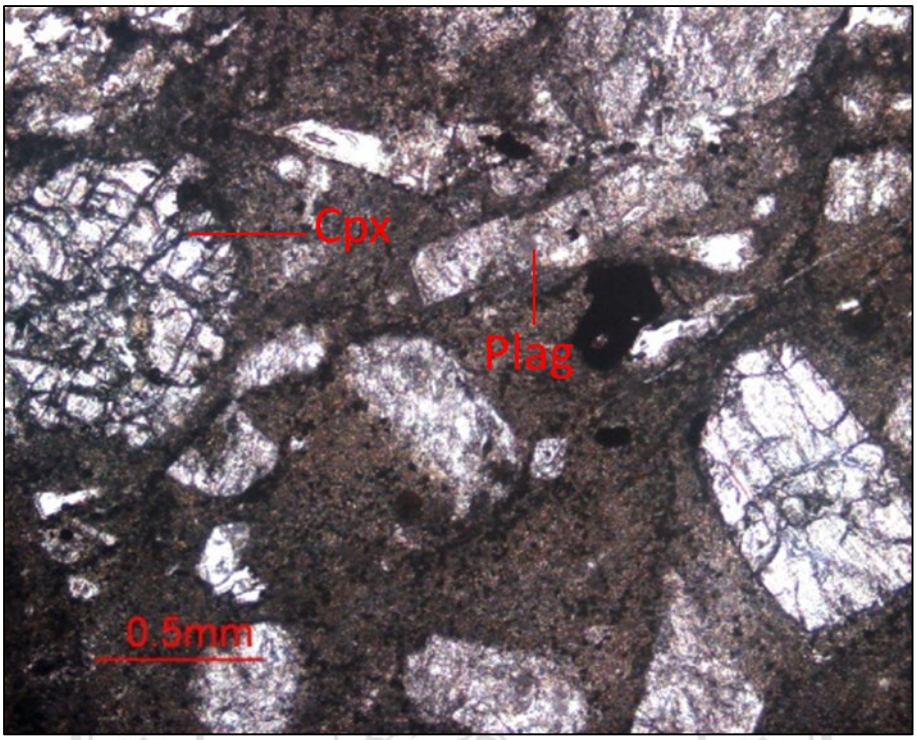
Quartz-alkali feldspar intergrowth groundmass is composed of micropoikilitic intergrowth and spherulite (sizes up to 1.5 mm across). Granophyric intergrowth is made up of radial quartz, embedded in alkali feldspar. Spherulite is a radial aggregate of quartz and feldspar. Muscovite in the groundmass phase is anhedral and fine-grained with sizes up to 0.2 mm across. Opaque minerals in the groundmass phase are anhedral and fine-grained with sizes up to 0.2 mm across.

Andesite porphyry

Andesite in the Wang Prachop area has a dark green color and its surface is covered by dark, yellowish brown materials. It has a very fine-grained texture. The rock does not react with cold diluted hydrochloric acid and is non magnetic.

Under microscope, andesite shows a porphyritic texture (Figure 3.29). The phenocrysts/microphenocrysts are made up of plagioclase with small amount of unidentified mafic minerals, clinopyroxene, and opaque minerals. The phenocrysts/microphenocrysts may form as glomerocrysts and cumulocrysts. The groundmass phase is made up mainly of plagioclase, with small amounts of unidentified mafic minerals, opaque minerals, and apatite.

a)



b)

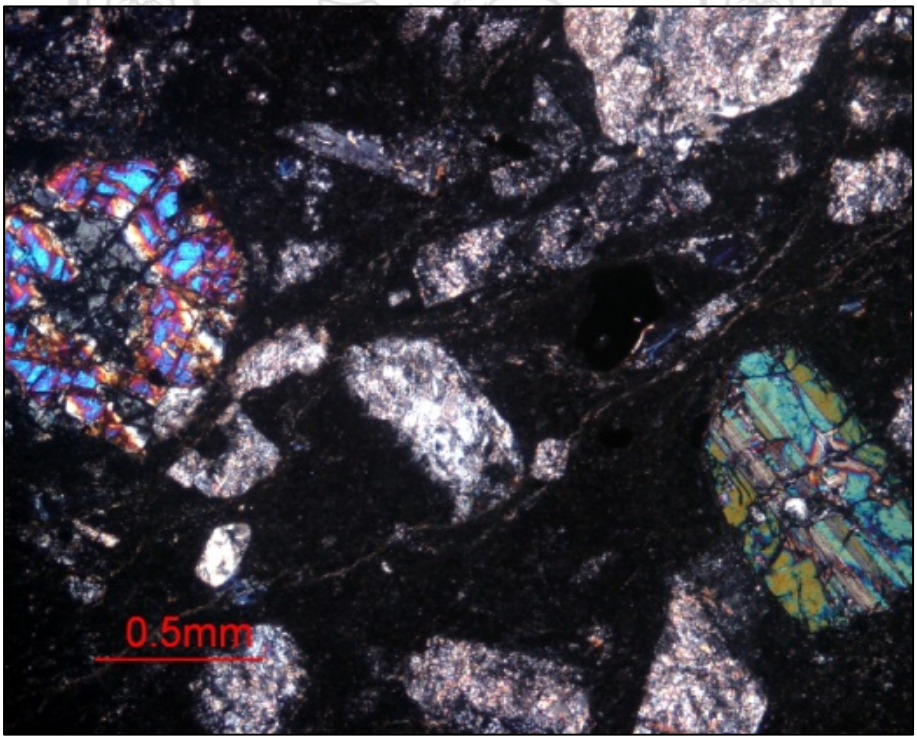


Figure 3.29 Photomicrographs of andesite porphyry in the Wang Prachop area (sample number WPC26/11) showing highly porphyritic texture; clinopyroxene (Cpx) and plagioclase (Plag) (a) Ordinary light (b) Crossed polars.

Felted plagioclase grains have bimodal grain sizes, plagioclase phenocryst/microphenocrysts are subhedral with sizes up to 2 mm across. Their crystals show Carlsbad twin, the groundmass plagioclase is anhedral with sizes up to 0.1 mm across. Plagioclase is highly replaced by sericite and clay minerals. Inclusion of apatite is present in some grains.

Unidentified mafic minerals phenocrysts/microphenocrysts (Figure 3.30) are subhedral to euhedral (sizes up to 1 mm across). Groundmass unidentified mafic mineral are anhedral with sizes up to 0.1 mm across. Unidentified mafic mineral are completely replaced by serpentine/chlorite. Inclusion of apatite is present in some grains.

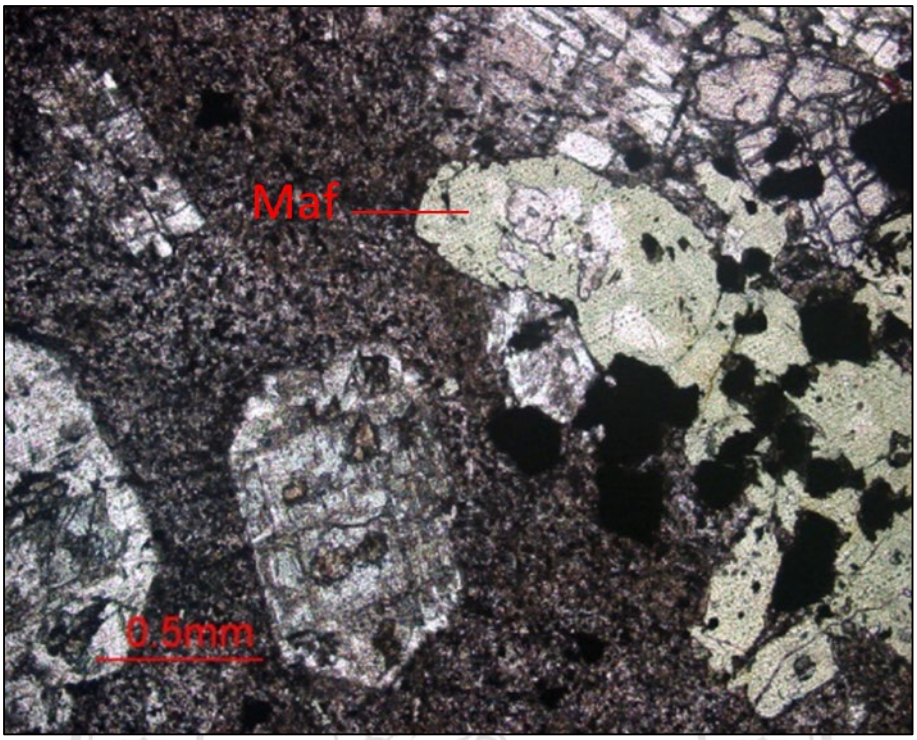
Clinopyroxene is colorless and anhedral (averaged size 1 mm across). Some crystals show characteristics of the exsolution structure that is made up of lamellae clinopyroxene in orthopyroxene host. It is moderately altered to serpentine/chlorite. Fractures filled with serpentine/chlorite are commonly present in the clinopyroxene crystals. Inclusion of apatite and opaque minerals are present in some grains (Figure 3.31).

Opaque minerals phenocrysts/microphenocrysts are subhedral to anhedral (sizes up to 0.5 mm across). Groundmass opaque minerals are anhedral with sizes up to 0.1 mm across.

Apatite is euhedral and has a short-primaic/prismatic shapes (sizes up to 0.15 mm across). Apatite inclusion has been observed in plagioclase, unidentified mafic minerals, and clinopyroxene crystals.

The volcanic rocks in the Wang Prachop area are associated with rhyolitic and basaltic tuffs. The rhyolitic tuffs are made up mainly of glass shard with subordinate quartz and alkali feldspar with small amount of rock fragments and show eutaxitic texture (Figure 3.32). Quartz fragments are anhedral (sizes up to 0.75 mm across). Alkali feldspar fragments are anhedral (sizes up to 1.25 mm across). Rock fragments are angular and low spherecity shape (sizes up to 1.5 mm across) that consist of basalt, rhyolite, and welded tuff. The groundmass phase is made up mainly of quartz-alkali feldspar devitrification, granophyric and spherulitic intergrowth, with small amounts of

a)



b)

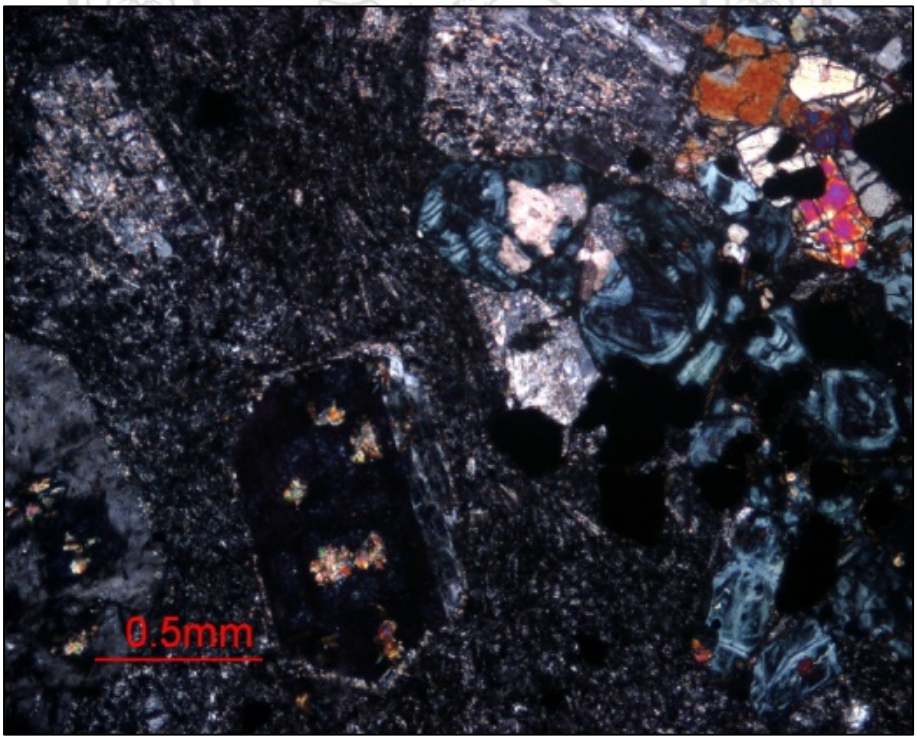
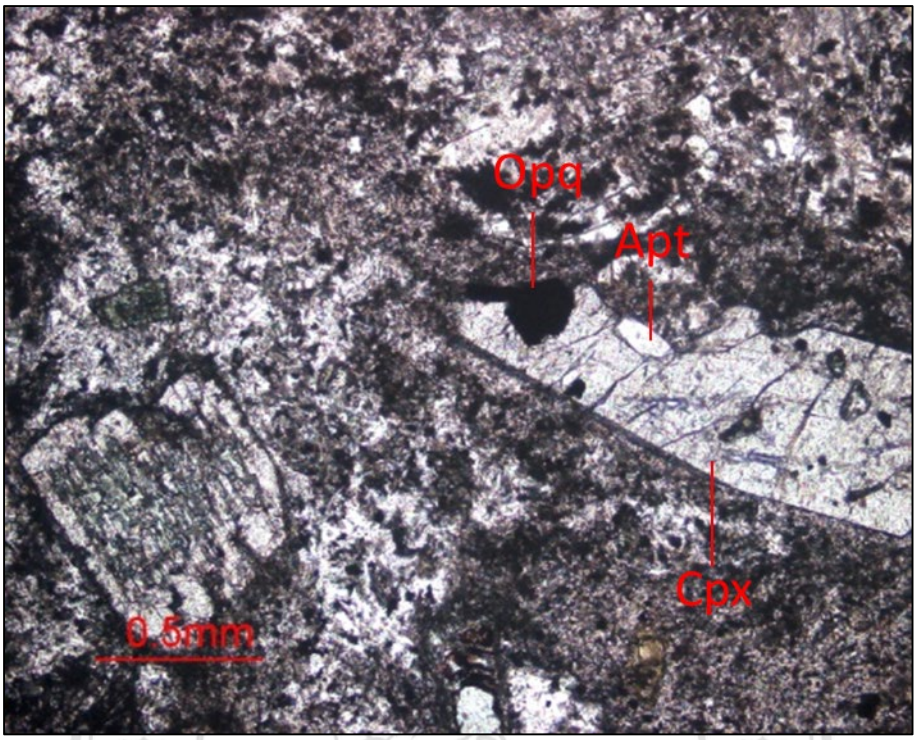


Figure 3.30 Photomicrographs of andesite porphyry in the Wang Prachop area (sample number WPC26/4) showing unidentified mafic minerals (Maf) phenocrysts/ microphenocrysts (a) Ordinary light (b) Crossed polars.

a)



b)

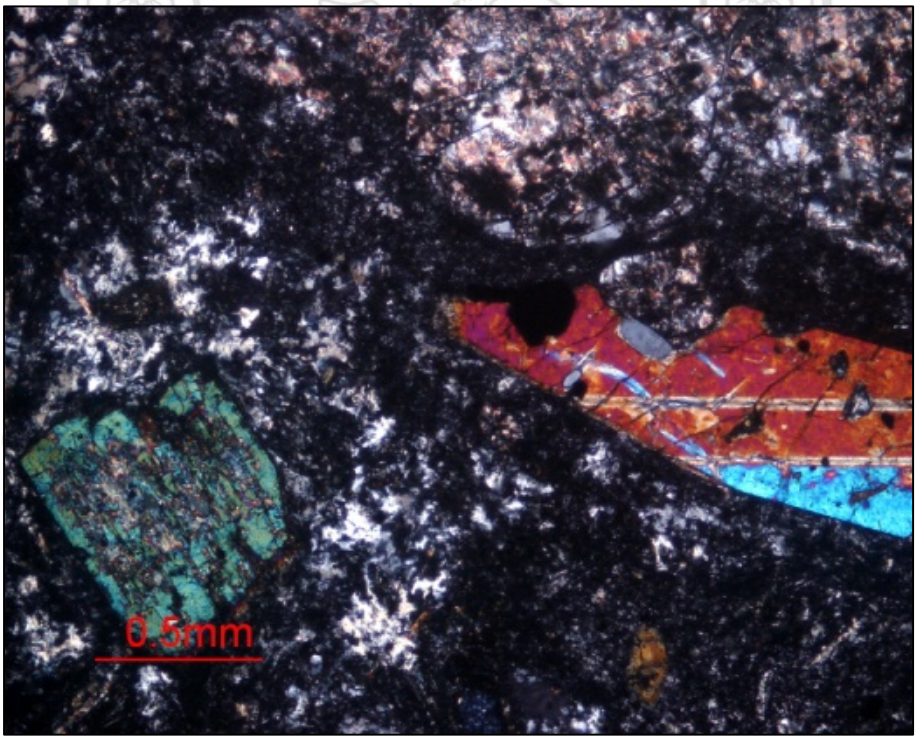
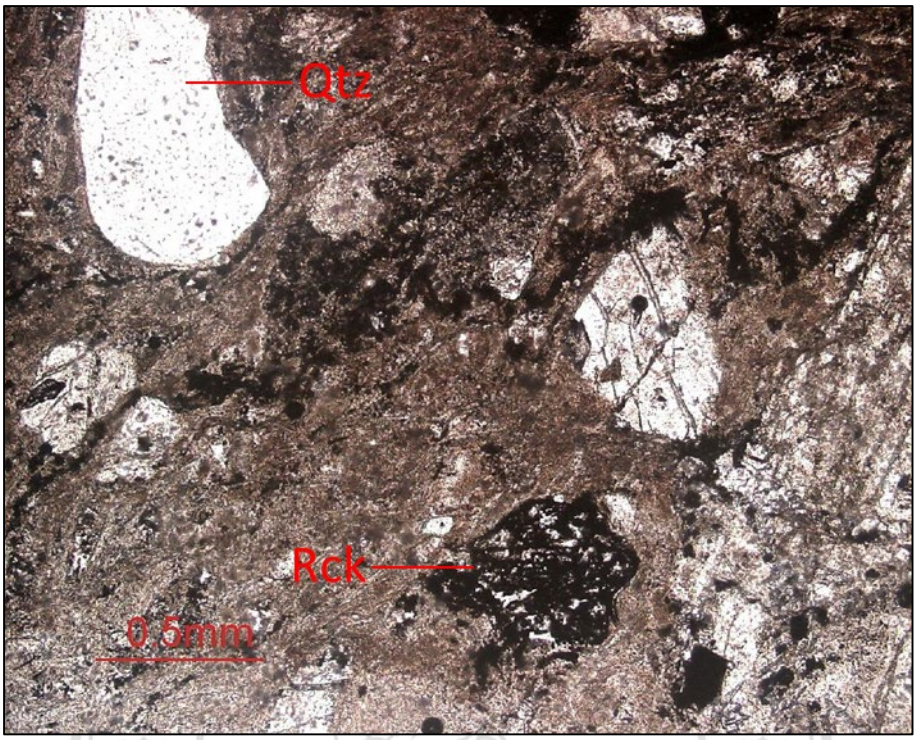


Figure 3.31 Photomicrographs of andesite porphyry in the Wang Prachop area (sample number WPC26/7) showing inclusion of apatite (Apt) and opaque minerals (Opq) in clinopyroxene (Cpx) (a) Ordinary light (b) Crossed polars.

a)



b)

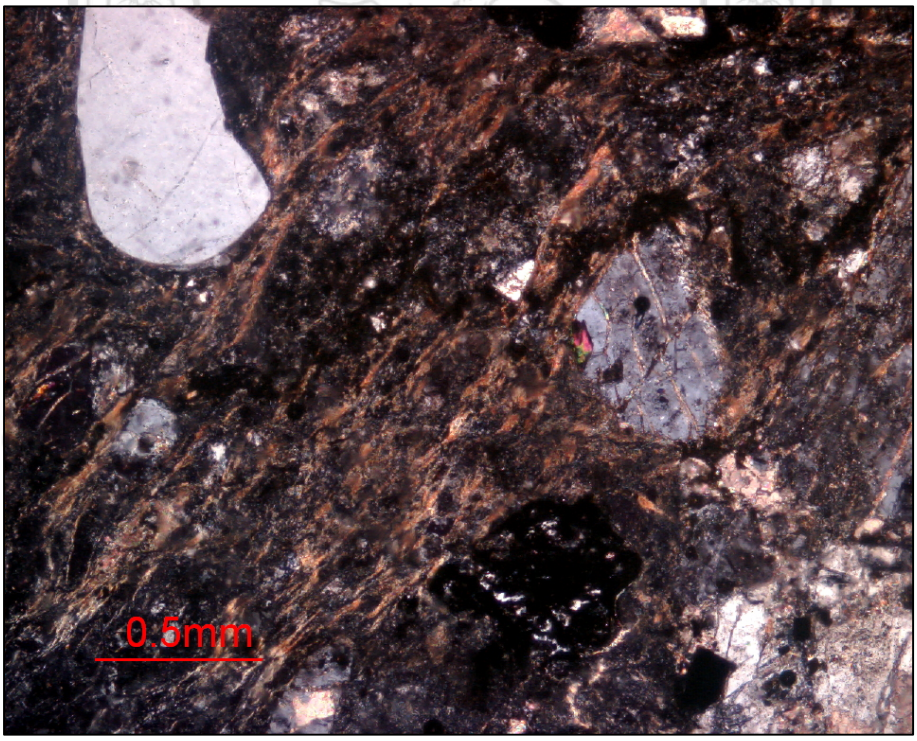


Figure 3.32 Photomicrographs of rhyolitic tuff in the Wang Prachop area (sample number WPC26/9-1) showing quartz (Qtz) and rock fragments (Rck) and eutaxitic texture (a) Ordinary light (b) Crossed polars.

quartz, alkali feldspar, muscovite, and zircon. All of these rocks are commonly present leucoxene and clay minerals in the groundmass phase. These rhyolitic tuffs can define to fine tuff based on grain size. Basaltic tuff is made up mainly of slightly felted plagioclase, with small amounts of epidote, hornblende, chlorite, and glass (Figure 3.33). Plagioclase is euhedral (sizes up to 1.25 mm across). Quartz fragments are anhedral (sizes up to 0.75 mm across). Epidote, hornblende, chlorite, and glass are very fine-grain. These basaltic tuffs can define to fine tuff based on grain size.

3.6 The Wang Chao Area

The samples were collected from both in situ float rocks (Figure 3.34) and outcrops (Figure 3.35) along highway number 104 and highway number 1 which run from Tak to Kamphaeng Phet Provinces. The Wang Chao area consists of rhyolite including sample number WCH26/2-1, WCH26/2-2, WCH26/3-1, WCH26/3-2, WCH26/4, WCH26/5, and WCH27/5-2, andesite (sample number WCH28/4) and basalt (sample number WCH28/8-1). The outcrops of rhyolite are pale pink in color and it shows porphyritic and very fine-grained textures. The outcrops of andesite and basalt are gray to dark green in color and some outcrops have pale green to pale gray in color. All of these rocks have porphyritic and very fine-grained textures.

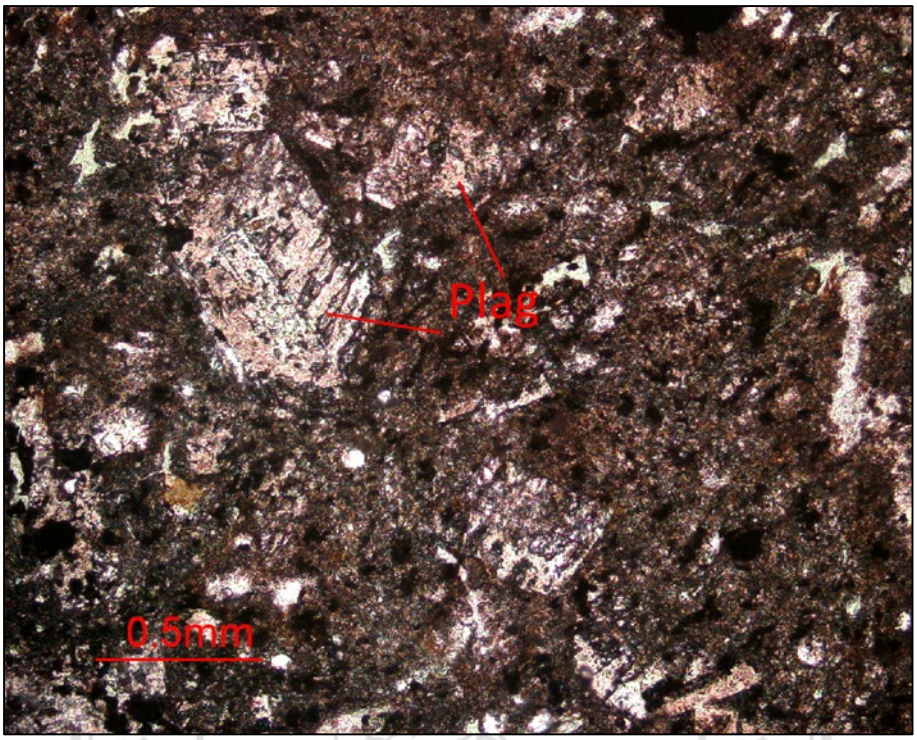
Rhyolite

Rhyolite in the Wang Chao area is very fine-grain and porphyritic textures. It has a pale pink to reddish in color with a yellowish brown weathering surface. The phenocrysts are made up of quartz (colorless), feldspars (white), and opaque minerals (black) and are embedded in a very fine-grained groundmass.

Under microscope, rhyolite shows slightly porphyritic texture (Figure 3.36). The phenocrysts/microphenocrysts are made up largely of quartz and plagioclase with small amount of alkali feldspar. The groundmass phase is made up mainly of quartz-alkali feldspar granophyric and spherulitic intergrowth with small amounts of quartz, alkali feldspar, muscovite, and opaque minerals.

Quartz phenocrysts/microphenocrysts are euhedral to subhedarl (sizes up to 0.75 mm across). They commonly show rounded edges and embayed outlines. Groundmass

a)



b)

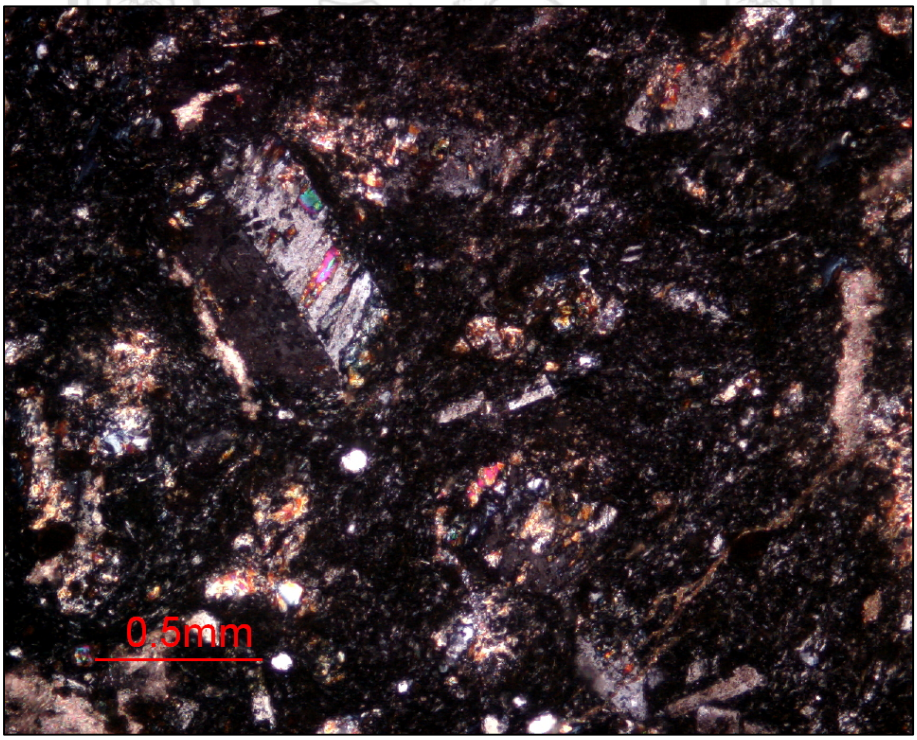
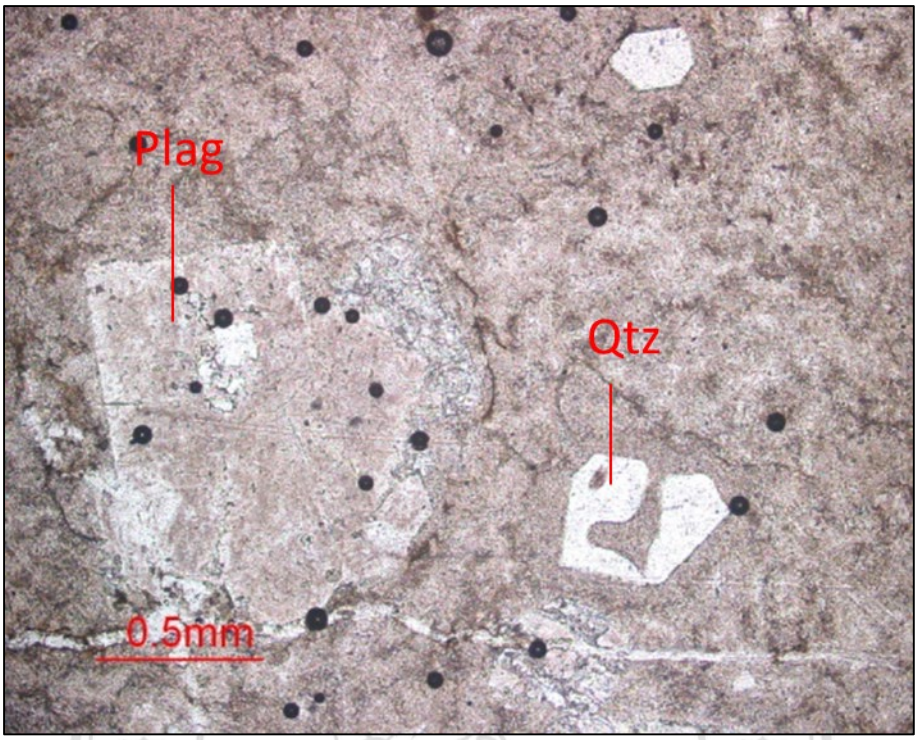


Figure 3.33 Photomicrographs of basaltic tuff in the Wang Prachop area (sample number WPC27/7-2) showing plagioclase (Plag) fragments (a) Ordinary light (b) Crossed polars.

Figure 3.34 The in situ float rocks of rhyolite in the Wang Chao area at grid reference 523553.5 E 1853142.5 N (Dr. Burapha Phajuy, 182 cm tall, is to scale).

Figure 3.35 The outcrop of rhyolite in the Wang Chao area at grid reference 522885.9 E 1857829.1 N (Dr. Burapha Phajuy, 182 cm tall, is to scale).

a)



b)

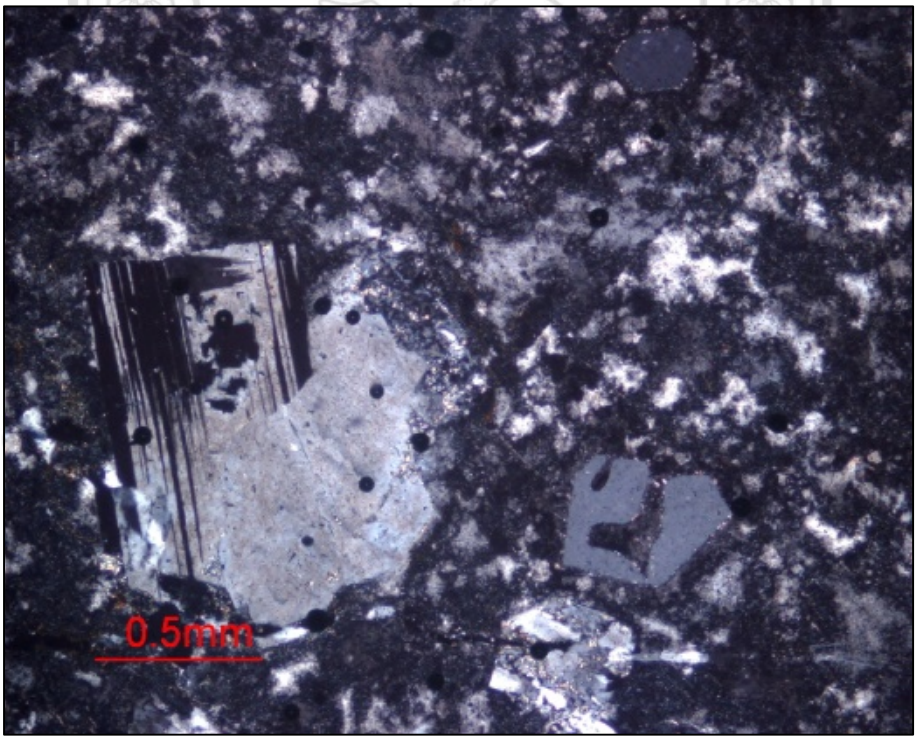


Figure 3.36 Photomicrographs of rhyolite in the Wang Chao area (sample number WCH26/3-1) showing porphyritic texture; quartz (Qtz) and plagioclase (Plag) (a) Ordinary light (b) Crossed polars.

quartz is anhedral with sizes up to 0.1 mm across.

Plagioclase phenocryst/microphenocrysts (Figure 3.37) are subhedral with sizes up to 1.5 mm across. Their crystals show carlsbad twin and albite twin and are slightly to moderately replaced by sericite and clay minerals.

Alkali feldspar phenocrysts/microphenocrysts are subhedral to euhedral (sizes up to 1 mm across). It shows simple twin and perthitic texture (sanidine type). Groundmass alkali feldspar is anhedral with sizes up to 0.1 mm across. Alkali feldspar is slightly replaced by clay minerals.

Quartz-alkali feldspar intergrowth groundmass is composed of microgranophyric intergrowth and spherulite (sizes up to 1.5 mm across). Granophyric intergrowth is made up of radial quartz embedded in alkali feldspar. Spherulite is radial aggregate of quartz and feldspar. Muscovite in the groundmass phase is anhedral and fine-grained with sizes up to 0.2 mm across. Opaque minerals in the groundmass phase are anhedral and fine-grained with sizes up to 0.2 mm across.

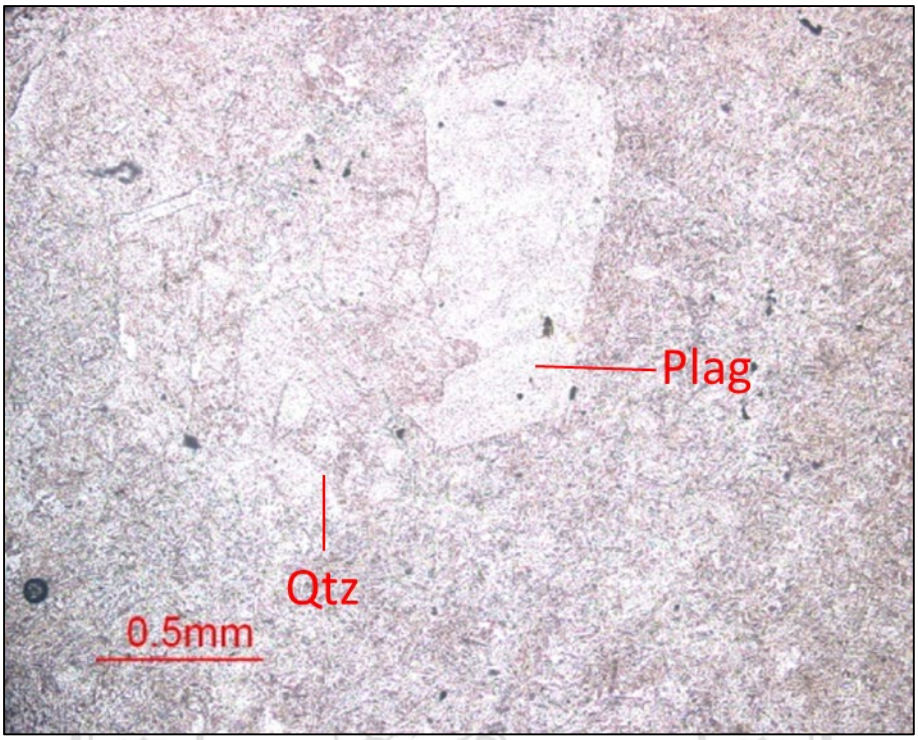
Andesite

Andesite in the Wang Chao area has a dark green color and the surface is covered by dark, yellowish brown materials. . It has very fine-grained and shows slightly porphyritic textures.

Under microscope, andesite shows slightly porphyritic texture. The phenocrysts/ microphenocrysts are made up largely of plagioclase with small amount of unidentified mafic minerals. The groundmass phase is made up mainly of plagioclase with small amounts of clinopyroxene, unidentified mafic minerals, opaque minerals, and quartz. Plagioclase and clinopyroxene in the groundmass phase are ophitic/subophitic intergrowth.

Felted plagioclase grains have bimodal grain sizes (Figure 3.38), plagioclase phenocryst/microphenocrysts are subhedral with sizes up to 1 mm across. Their crystals show carlsbad twin. Groundmass plagioclase is anhedral with sizes up to 0.1 mm across. Plagioclase is slightly replaced by sericite and clay minerals.

a)



b)

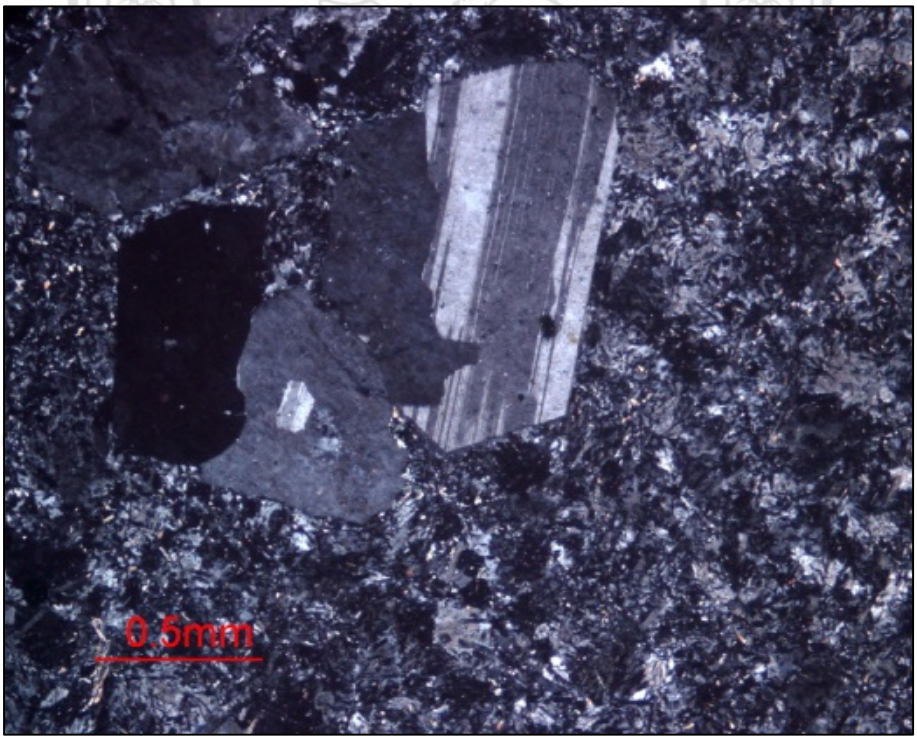
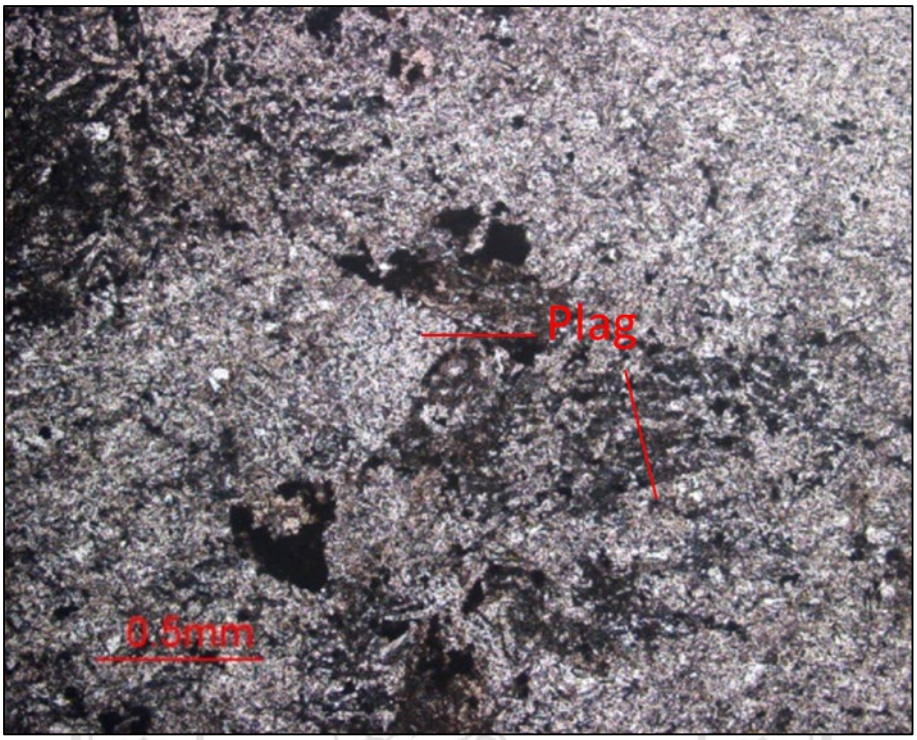


Figure 3.37 Photomicrographs of rhyolite in the Wang Chao area (sample number WCH26/2-1) showing quartz (Qtz) and plagioclase (Plag) phenocrysts (a) Ordinary light (b) Crossed polars.

a)



b)

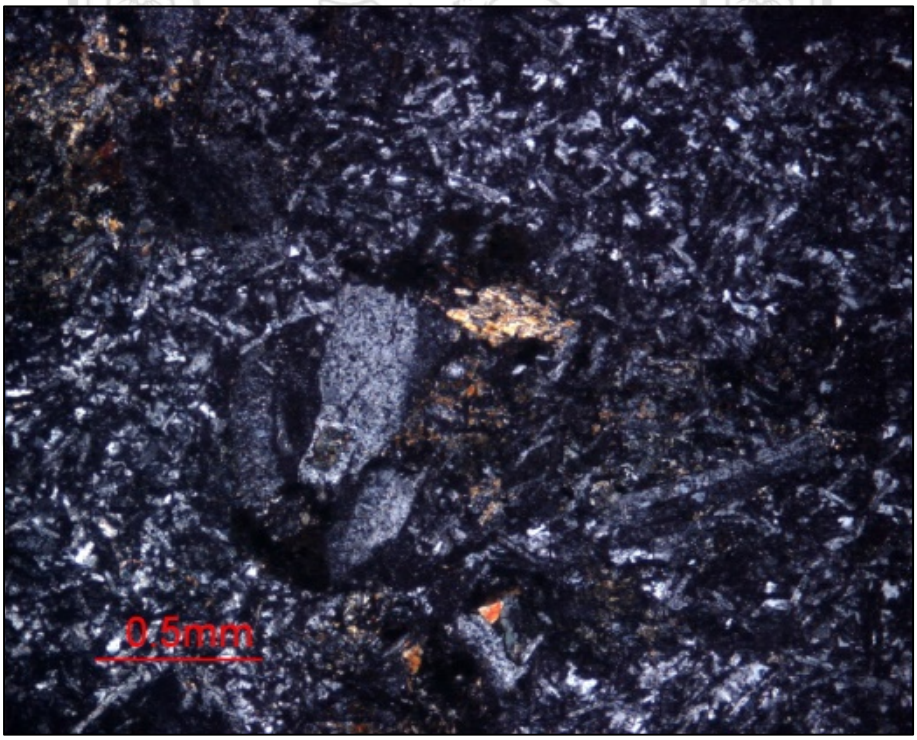


Figure 3.38 Photomicrographs of andesite in the Wang Chao area (sample number WCH28/4) showing felted plagioclase (Plag) (a) Ordinary light (b) Crossed polars.

Unidentified mafic mineral phenocrysts/microphenocrysts are subhedral to euhedral (sizes up to 0.5 mm across). Groundmass unidentified mafic minerals are anhedral with sizes up to 0.1 mm across. Unidentified mafic minerals are completely replaced by serpentine/chlorite.

Opaque minerals in the groundmass phase are anhedral and fine-grained with sizes up to 0.1 mm across**.** Quartz in the groundmass phase is anhedral and fine-grained with sizes up to 0.1 mm across.

Basalt

Basalt in the Wang Chao area has a dark green color and its surface is covered by dark, yellowish brown materials. It has very fine-grained and shows slightly porphyritic textures.

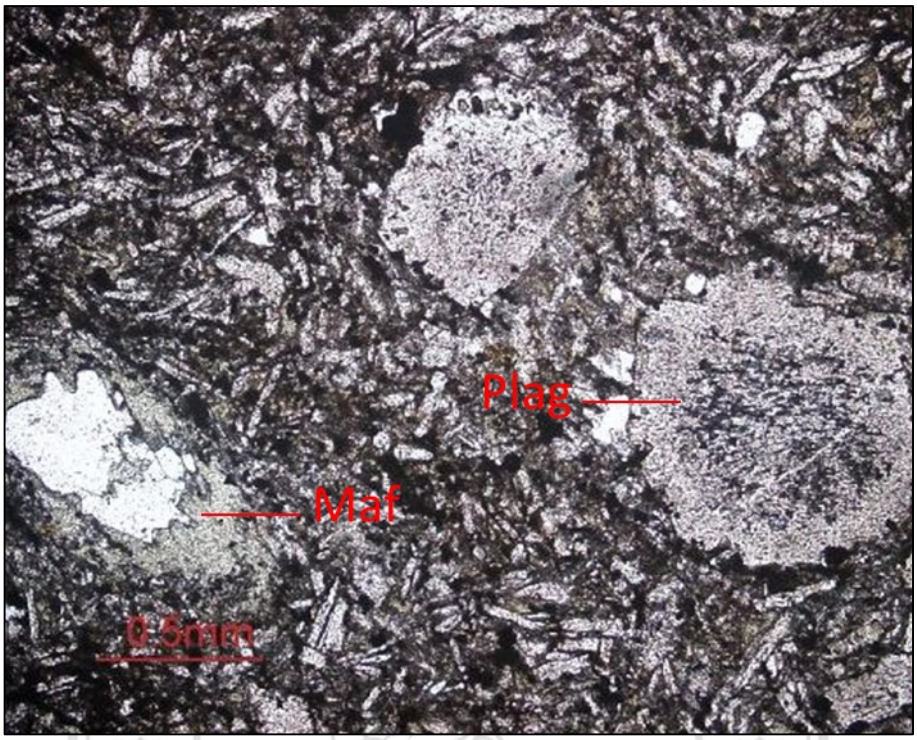
Under microscope, basalt shows slightly porphyritic texture. The phenocrysts/microphenocrysts are made up of plagioclase with small amount of unidentified mafic minerals. The groundmass phase is made up mainly of plagioclase, with small amounts of unidentified mafic minerals, and opaque minerals. Calcite and Fe-oxide are commonly present in the groundmass phase.

Felted plagioclase grains have two grain sizes, plagioclase phenocryst/microphenocrysts are subhedral with sizes up to 1.2 mm across. Their crystals show carlsbad twin. Groundmass plagioclase is anhedral with sizes up to 0.1 mm across. Plagioclase is slightly replaced by sericite and clay minerals.

Unidentified mafic mineral phenocrysts/microphenocrysts are subhedral to euhedral (sizes up to 1.5 mm across). Unidentified mafic minerals in groundmass are anhedral with sizes up to 0.1 mm across. Unidentified mafic minerals are completely replaced by serpentine/chlorite and epidote (Figure 3.39). Opaque minerals in the groundmass phase are anhedral and fine-grain with sizes up to 0.1 mm across**.**

The volcanic rocks in the Wang Chao area are associated with rhyolitic and basaltic tuffs. The rhyolitic tuffs are made up mainly of glass shard with subordinate quartz and alkali feldspar with small amount of rock fragments and show eutaxitic texture (Figure 3.40). Quartz fragments are anhedral (sizes up to 0.75 mm across).

a)



b)

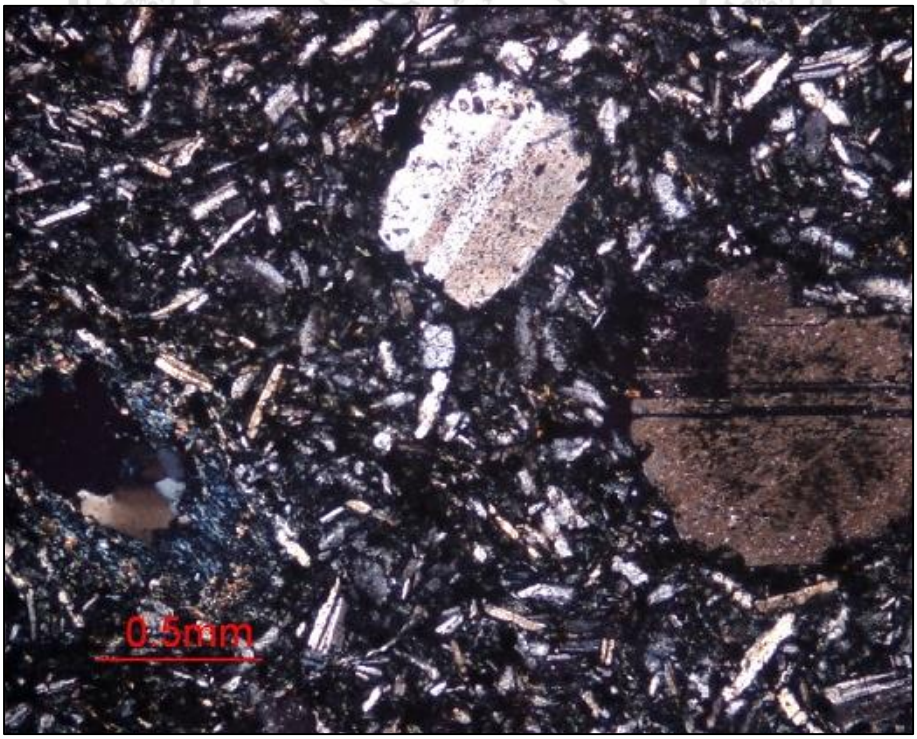
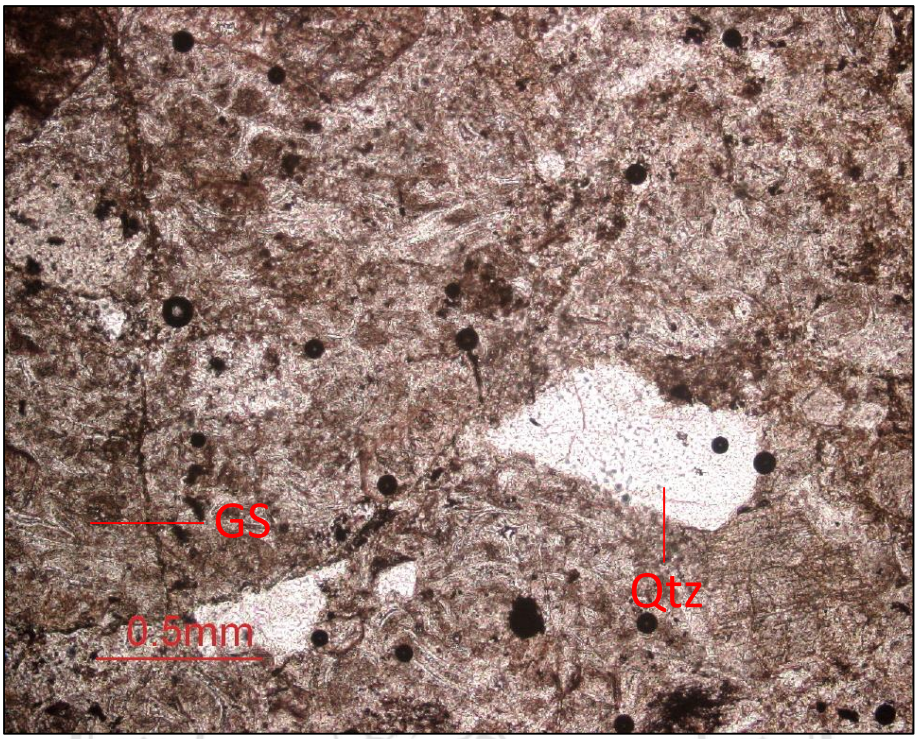


Figure 3.39 Photomicrographs of basalt in the Wang Chao area (sample number WCH28/8-1) showing plagioclase (Plag) and unidentified mafic minerals (Maf) phenocrysts/microphenocrysts (a) Ordinary light (b) Crossed polars.

a)



b)

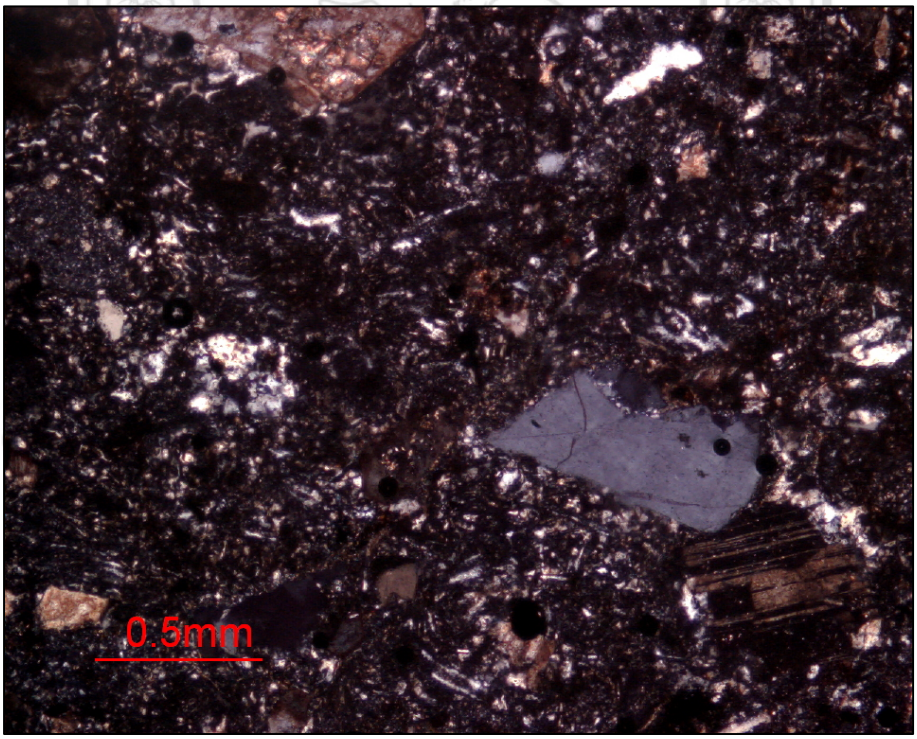
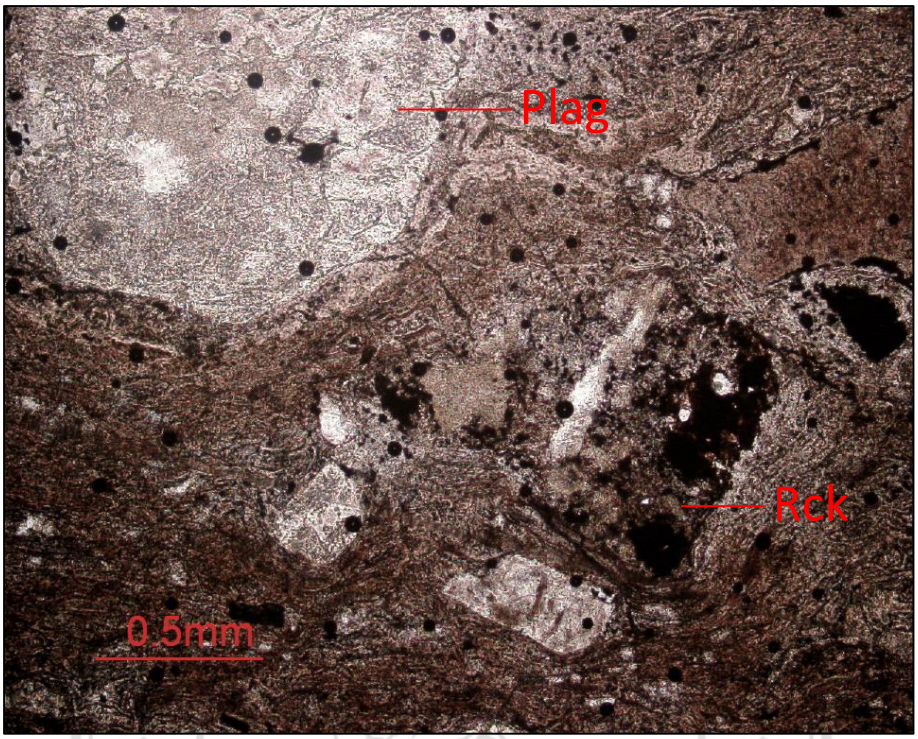


Figure 3.40 Photomicrographs of rhyolitic tuff in the Wang Chao area (sample number WCH27/3) showing quartz (Qtz) and glass shard (GS) and eutaxitic texture (a) Ordinary light (b) Crossed polars.

Alkali feldspar fragments are anhedral (sizes up to 1.25 mm across). Rock fragments are angular and low spherecity shape (sizes up to 1.5 mm across) and consist of basalt, rhyolite, and welded tuff. The groundmass phase is made up mainly of quartz-alkali feldspar devitrification, granophyric and spherulitic intergrowth, with small amounts of quartz, alkali feldspar, muscovite, and zircon. All of these rocks are commonly present leucoxene and clay minerals in the groundmass phase. These rhyolitic tuffs can be defined to fine tuff based on grain size. Basaltic tuff is made up mainly of slightly felted plagioclase, with small amounts of epidote, hornblende, chlorite, and glass (Figure 3.41). Plagioclase is euhedral (sizes up to 1.25 mm across). Epidote, hornblende, chlorite, and glass are very fine-grain. These basaltic tuffs can be defined to fine tuff based on grain size.

a)



b)

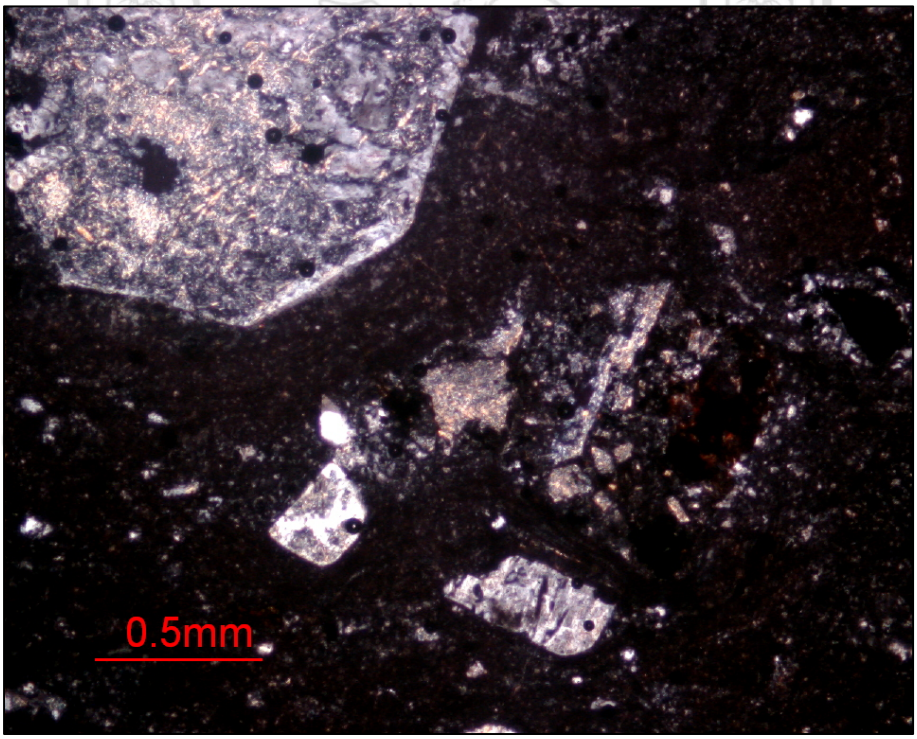


Figure 3.41 Photomicrographs of basaltic tuff in the Wang Chao area (sample number WCH26/5-2) showing plagioclase (Plag) and rock fragments (Rck) and eutaxitic texture (a) Ordinary light (b) Crossed polars.