CHAPTER 3

OCCURRENCE, LITHOLOGY AND PETROGRAPHY

The mafic igneous rocks in the Mae Sai and Mae Chan areas, Chiang Rai Province cover area of approximately 110 Km^2 (Fig 2.1 and 2.2). The thirty-three selected mafic rock samples were collected from both outcrop and float rocks. These studied samples can be separated into two magmatic main groups by lithology, petrography and chemistry (see Chapter 4). The rock names used in this chapter based on their occurrences, textures and/or mineral constituents and geochemistry.

This chapter illustrates the rock samples in terms of occurrences, lithology and petrography of the rock sample. Petrographically, the standard thin section of all the selected samples (0.03 mm thick) were prepared and studied at the Department of Geological Sciences, Faculty of Science, Chiang Mai University. The thin sections were studied to characterize primary mineral compositions, alterations and textures. Rock names are applied, on the basis of both geochemical and textural characteristics. The results of petrographic study are summarized in Chapter 3 and individually reported in Appendix.

3.1 Group I Rocks

3.1.1 Occurrence

The Group I rocks are distributed in the Mae Sai area (Fig 2.1), Chiang Rai Province. The samples were collected from both outcrop (Fig 3.1 and 3.2) and float rocks (Fig 3.3 and 3.4) along the road number 1149, from Ban Huai Rai Samakkhi, Doi Tung Royal Palace Area, Ban Pa Kluai La Hu, Ban Musoe La Ba, Ban I-ko Pha Hi, Ban Musoe Pha Hi and Ban Pha Mi, Mae Sai District, Chiang Rai Province. The Group I rocks include gabbro (sample number MS10B4, MS6.2B5), diorite (sample numbers MS9B4, MS5B6(13), MS5B6(14)), monzodiorite (sample number MS14B3, MS6.3B5(D)), microgabbro (sample number MS16B1, MS12B3, MS68B5), microdiorite (sample numbers MS15B2, MS8B4, MS56B5) and andesite/basalt (dike)

Figure 3.1 The outcrop of Group I Microdiorite at grid reference 849435 (Mr. Jaturapan Boonsa, 172 cm tall, is to scale)

Figure 3.2 The outcrop of Group I Microdiorite at grid reference 854463 (Mr. Jaturapan Boonsa, 172 cm tall, is to scale)

Figure 3.3 The float rocks of Group I Diorite at grid reference 846425 (the hammer 28 cm long)

Figure 3.4 The float rocks of Group I Diorite at grid reference 845473 (the hammer 28 cm long)

(sample number MS6.3B5(B)). The outcrops of these rocks are green to dark green in color and some outcrops have pale green to pale gray in color. The rocks of the Group I have a medium-coarse grained texture, some of them are very fine grained. The gabbro/diorite breccias (partly show jigsaw fit style) injected by felsic plutonic rock have been detected in some outcrops and float rocks (Fig 3.5).

The studied mafic igneous rocks in the Mae Sai area are associated with associated with the Permian-Carboniferous rocks and the Carboniferous sedimentary rocks. The Permian-Carboniferous rocks are made up of gray to dark gray limestone and marble (Fig 3.6). The Carboniferous sedimentary rocks include dark gray shale interbedded with gray siltstone, fine grained sandstone and greywacke. They are juxtaposed by thrust fault between Permian-Carboniferous limestone and mafic igneous rocks. Some outcrops present aplite and pegmatite dyke that cut along the mafic igneous rocks.

3.1.2 Lithology and Petrography

Gabbro

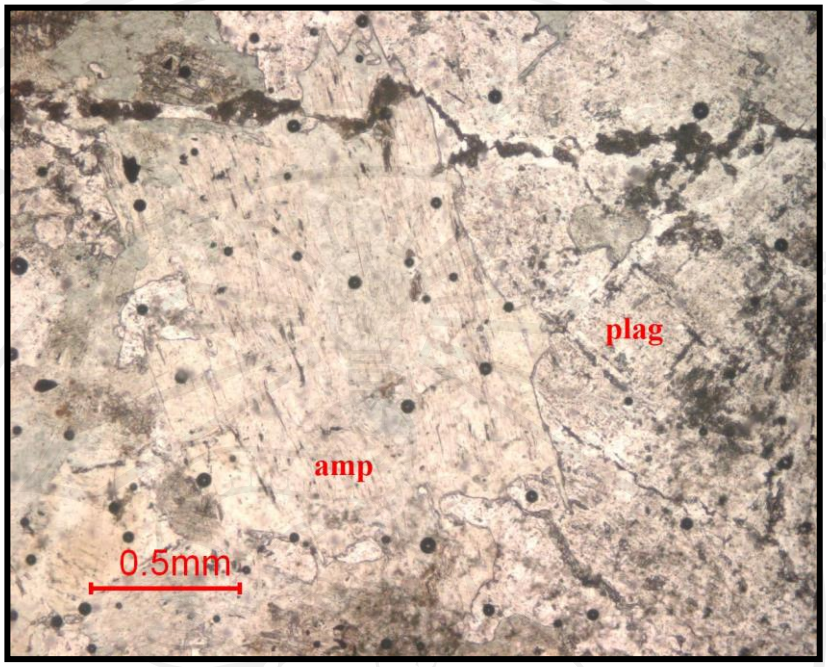
Gabbro of the Group I rocks is non-foliated, has green and white color, green minerals are mafic minerals and white minerals are felsic minerals. Weathering surfaces are brownish yellow color. It is coarse grained texture. Tiny white veins (up to 10 mm across) are present in this rock. They do not react with diluted hydrochloric acid and non-magnetic to slightly magnetic properties.

Under the microscope (Fig 3.7), gabbro is corase grained and seriate texture. Its constituents are made up of amphibole and plagioclase. Secondary patches of chlorite/serpentine, titanite are present in the sample. Tiny veins (up to 0.6 mm across) and voids of epidote, chlorite/pumpellyite, titanite/leucoxene, quartz are infilled in this sample.

Amphibole (averaged size 6.0 mm across) is subhedral-anhedral outline, short prismatic and subequant. The amphibole crystals have a plechroic formula as follows:

Figure 3.5 Gabbro/diorite breccias of group I rocks injected by felsic plutonic rock at grid reference 885513 (the hammer 33 cm long)

Figure 3.6 The outcrop of the Permian gray-limestones at grid reference 909546 (the hammer 33 cm long)



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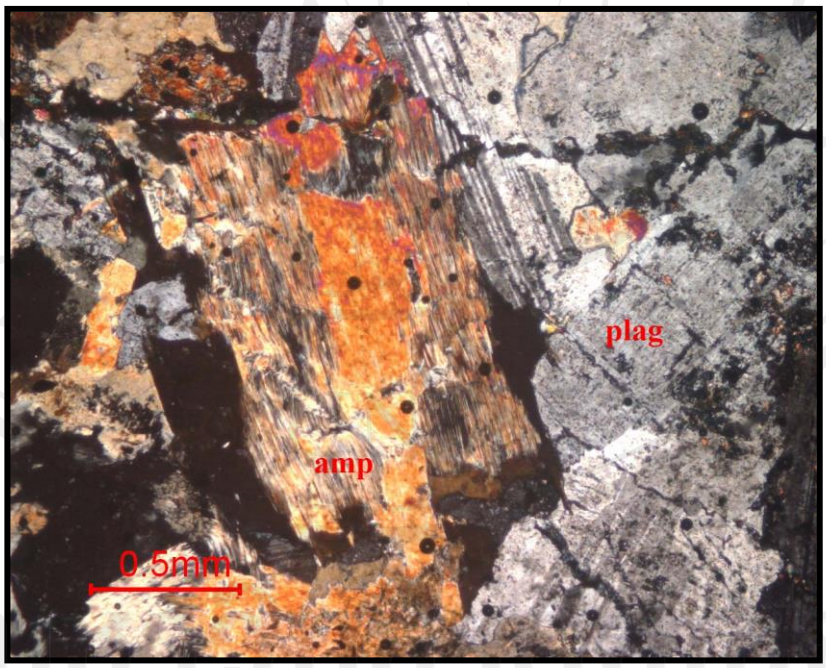

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Figure 3.7 Photomicrographs of Group I Gabbro (sample number MS10B4) showing amphibole (amp) and plagioclase (plag) (a) Ordinary light (b) Crossed polars

X=yellow, Y=green, Z=deep green. The pleochroic formula implies that it is hornblende. It is medium to highly altered to chlorite/serpentine, titanite/leucoxene, Fe-Ti oxide and some grains have fractures of brown minerals cut through them.

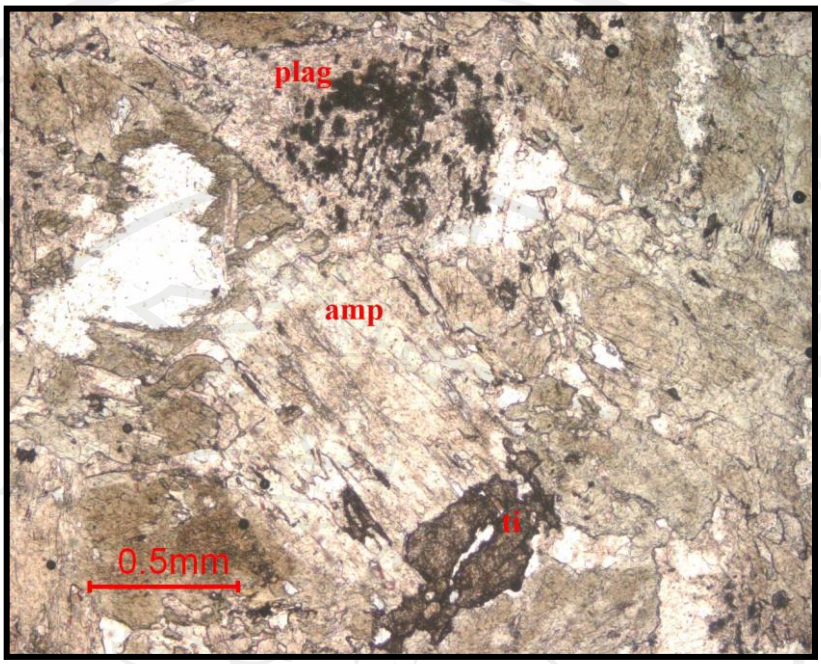
Plagioclase crystals have two grain sizes in this sample. First, plagioclase is euhedral-subhedral outline (averaged size 4 mm across). Second, plagioclase is subhedral (averaged size 10 mm across). Felted plagioclase and coarser grain sizes enclosed by finer grain sizes are present in the sample. It is medium replaced by titanite/leucoxene, chlorite/pumpellyite, sericite, clay and epidote.

Diortite

Diorite of the Group I has non-foliated, medium coarse grained texture, and is made up of green and white minerals. Its weathering surfaces have brownish yellow color. The rock is made up of dark green and white minerals. Dark green minerals are mafic minerals and white minerals are feldspars. They do not react with diluted hydrochloric acid and non-magnetic to slightly magnetic properties.

Under the microscope (Fig 3.8), diorite is medium-coarse grained, seriate texture. It is made up mainly of plagiocalse, amphibole and small amounts of opaque minerals, unidentified mafic minerals, quartz and apatite. It may form interstitial quartz and felty texture. Secondary patches of epidote, chlorite, titanite/leucoxene and tiny veins (sizes up to 0.25 mm across) are infilled with titanite/leucoxene ,chlorite/pumpellyite, epidote. Also, presents are locally aggregates of consertal quartz (averaged size 0.2 mm across), epidote, calcite and chlorite in some samples.

Plagioclase is medium grain, with averaged size 3.0 mm across. It is subhedral to anhedral outline and may form corroded outlines and sieve texture. It shows felted plagioclase. Locally, consertal quartz crystals are embedded in some plagioclase grains. It is medium-highly replaced by largely of sericite, epidote, chlorite, titanite/leucoxene and minor carbonate, clay.Inclusion of apatite is present in plagioclase.



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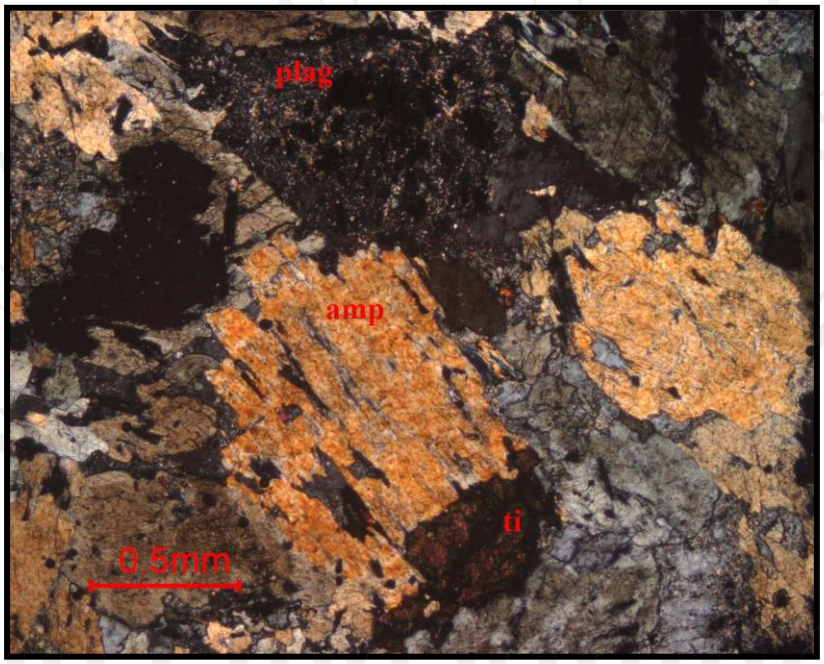

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Figure 3.8 Photomicrographs of Group I Diorite (sample number MS5B6(13)) showing amphibole (amp), plagioclase (plag) and titanite (ti) (a) Ordinary light (b) Crossed polars

Amphibole is euhedral-anhedral outline, (averaged size 4.0 mm across). It may form corrode outline and sieve texture. Amphibole has a pleochroic formula as follows: X=yellow, Y=brownish green, Z= green. The pleochroic formula suggests that they are Hornblende. Locally, consertal quartz crystals are embedded in some amphibole grains.They are medium altered to largely of titanite/leucoxene, chlorite/serpentine, with subordinate biotite, Fe-Ti oxide.

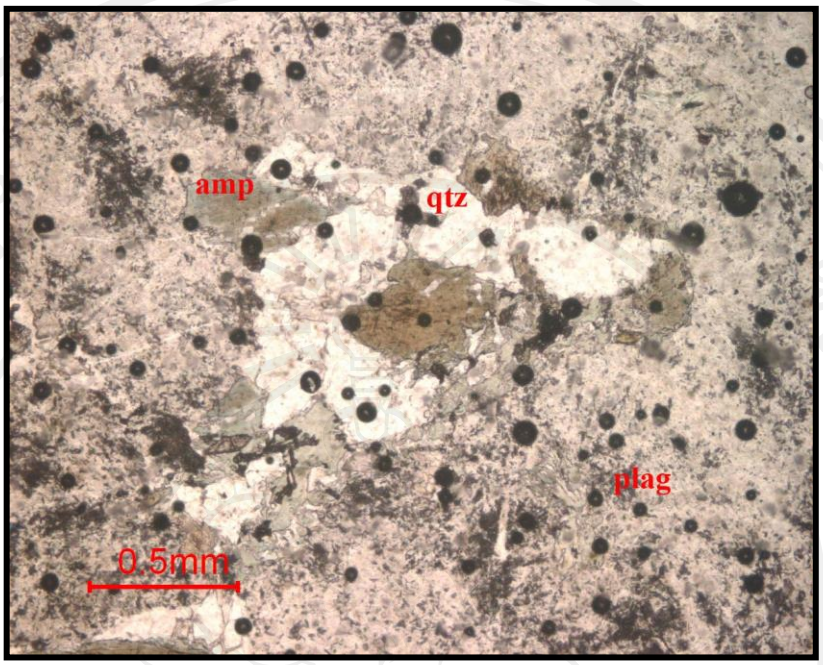
Unidentified mafic minerals are euhedral outline (averaged size 1.5 mm across). It has many fractures and is extremely replaced by chlorite/serpentine, Fe-Ti oxide.

Quartz is anhedral outline (averaged size 0.5 mm across). It shows interstitial texture to amphibole. Opaque minerals are anhdral (averaged size 2.0 mm across) and have irregular outlines. Opaque minerals are irregular outlines (averaged size 1.0 mm across). Their rims are mostly enclosed by titanite that may result from reaction rim. Titanite is euhedral-subhedral outline, with grain sizes up to 1.0 mm across. It may form aggregates.

Monzodiorite

These rocks have medium grained, and are made up of black and white minerals. Their weathering surfaces have brownish yellow color. The rock is made up of dark green and white minerals. Dark green minerals are mafic minerals and white minerals are feldspars. They do not react with diluted hydrochloric acid and non-magnetic magnetic properties.

Under the microscope (Fig 3.9), monzodiorite is medium-coarse grained texture, consists mainly of amphibole and plagioclase and small amounts of opaque minerals and quartz. Secondary patches of titanite/leucoxene, epidote, chlorite are present in the rock. Tiny veins (sizes up to 1.0 mm across) are infilled with largely of titanite/leucoxene, chlorite/pumpellyite, and minor quartz, epidote.



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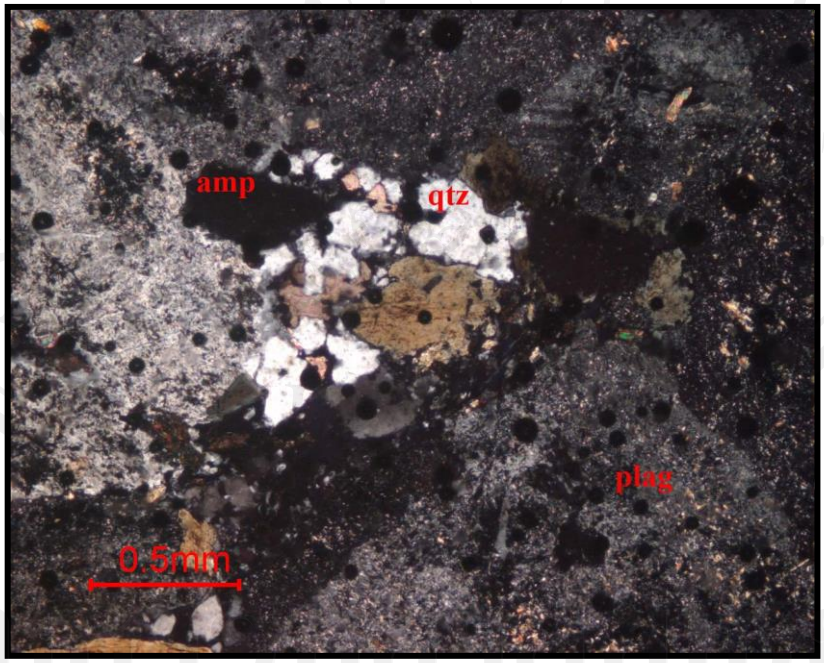

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Figure 3.9 Photomicrographs of Group I Monzodiorite (sample number MS6.3B5(D)) showing amphibole (amp), plagioclase (plag), quartz (qtz) and interstitial intergrowths (a) Ordinary light (b) Crossed polars

Plagioclase is medium grain, with averaged size 4.0 mm across. It is subhedral outline and felted plagioclase. It is medium-highly replaced by largely of sericite, epidote, titanite/leucoxene and minor carbonate, clay.

Amphibole is euhedral-anhedral outline. It is medium grain (averaged size 2.0 mm across), may form skeleton shape and sieve texture. Amphibole has a pleochroic formula as follows: X=yellow, Y=brownish yellow, Z=green. The pleochroic formula suggests that they are Hornblende. They are medium altered to largely of chlorite, biotite, Fe-Ti oxide.

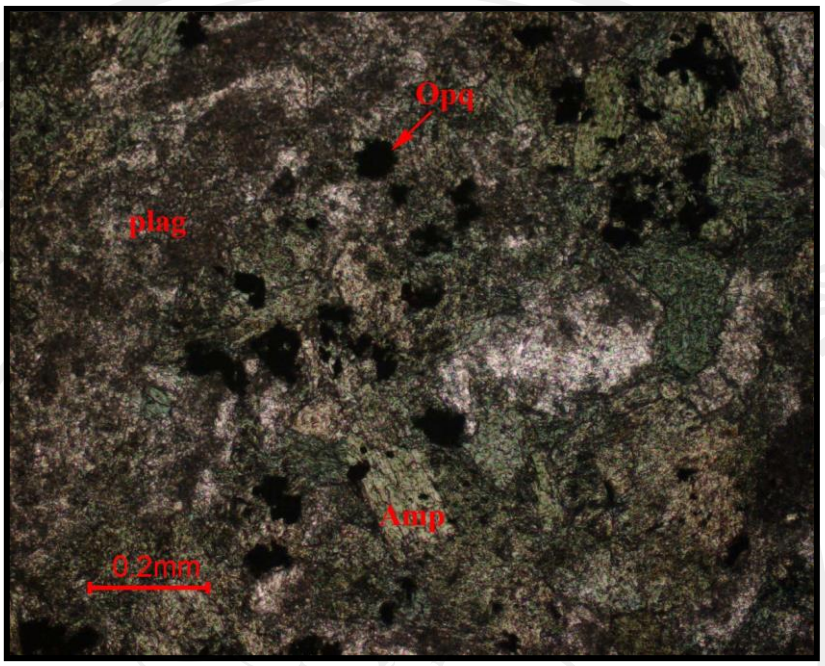
Quartz is anhedral outline (averaged size 1.0 mm across). It shows interstitial texture to amphibole. Opaque minerals are anhdral (averaged size 2.0 mm across) and have irregular outlines.

Microgabbro

Microgabbro has non-foliated rock sample and dark green, with a yellownish brown weathering surfaces. It shows medium-coarse grained texture. The rock is made up of dark green and white minerals. Dark green minerals are mafic minerals and white minerals are feldspars. It shows non-magnetic to moderately magnetic properties.

Under the microscope (Fig 3.10), the studied mafic rocks have averaged grain sizes ranging from 0.5 to 3 mm across, and therefore, the term “microgabbro” is applied for the finer-grained rock. These rocks are coarse grained, seriate texture and composed largely of plagioclase, with subordinate amphibole and opaque minerals. Secondary patches of epidote, chlorite,pumpellyite and titanite. Tiny veins (up to 0.25 mm across) of chlorite/pumpellyite, epidote, are cut through amphibole, plagioclase, and opaque minerals. Secondary patches of epidote, chlorite, titanite and are present in the rock sample.

Plagioclase is subhedral-anhedral outlines, with averaged size 6.0 mm across. In some samples, plagioclase has two grain sizes in this sample. First, plagioclase is medium grain, with averaged size 1.0 mm across. It is euhedral-subhedral outline,



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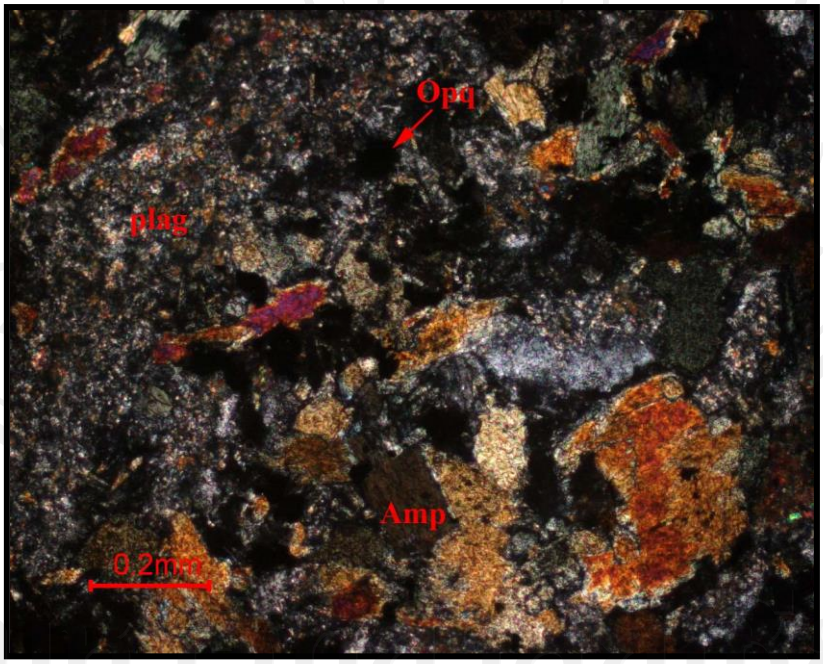

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Figure 3.10 Photomicrographs of Group I Microgabbro (sample number MS12B3) showing amphibole (amp), plagioclase (plag) and opaque mineral (opq) (a) Ordinary light (b) Crossed polars

felted plagioclase. Second, plagioclase is coarse grain, with averaged size 10.0 mm across. It is felty texture and some grains show sieve texture and corroded outline. It is medium to highly altered to largely of sericite, epidote, chlorite/pumplellyite, titanite/leucoxene and minor carbonate, clay. Inclusion of amphibole is in some plagioclase grains. Some grains show slight kink-band feature.

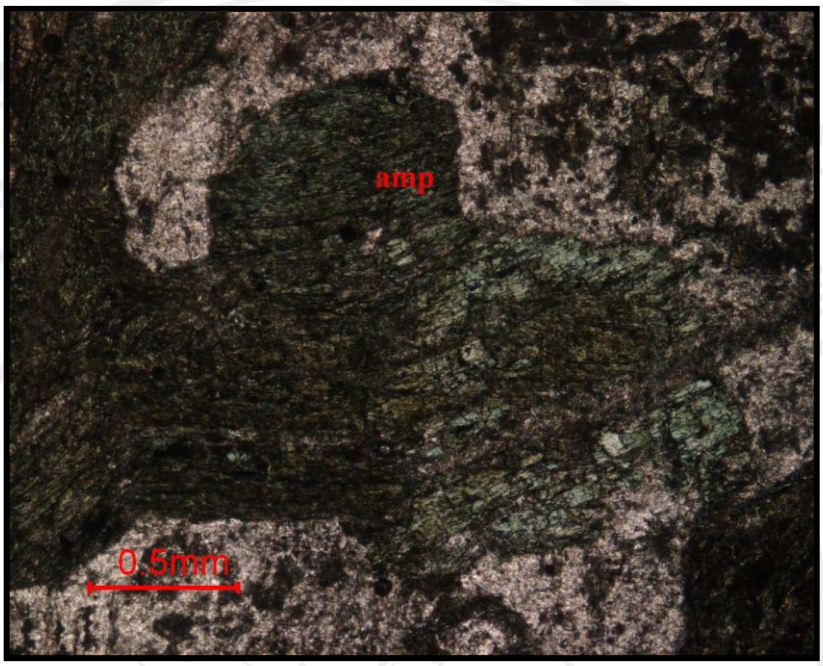
Amphibole crystals are anheral-subhedral outline and skeletal shape. Some grains show kink–band feature. In some samples, Amphibole crystals can be separated into two types by their shapes and sizes as follows: (1) coarse grain (sizes up to 5.0 mm across) and (2) medium grain (sizes up to 1.0 mm across). The coarse grains are subheral outline, while the fine grains are anheral outline. The amphibole grains are subequant and prismatic shape. Amphibole has a pleochroic formula as follows: X=yellow, Y =greenish brown, Z=green. The pleochroic formula suggests that they are hornblende. It has a lot of fracture and is medium altered to mainly of chlorite, Fe-Ti oxide, epidote, titanite/leucoxene. Inclusion of apatite is present in these rocks. Some grains show slight kink-band feature (Fig 3.11).

Opaque minerals are anhedral (averaged size 0.5 mm across) and have irregular outlines.

Microdiorite

Microdiorite has non-foliated, green color and minor white color. The green color is mafic minerals and the white color is felsic minerals, with lath shapes. It is medium grained crystals. Weathering surfaces have yellownish brown. It is fine-medium grained texture. It shows non-magnetic to slightly magnetic properties and does not react with diluted hydrochloric acid.

Under the microscope (Fig 3.12), the studied mafic rocks have averaged grain sizes ranging from 0.5 to 3 mm across, and therefore, the term “microdiorite” is applied for the finer-grained rock samples. These rocks are fine-medium grained texture, and made up principally of plagioclase, amphibole and small amounts of quartz, opaque minerals, unidentified mafic minerals. It may shows interstitial quartz



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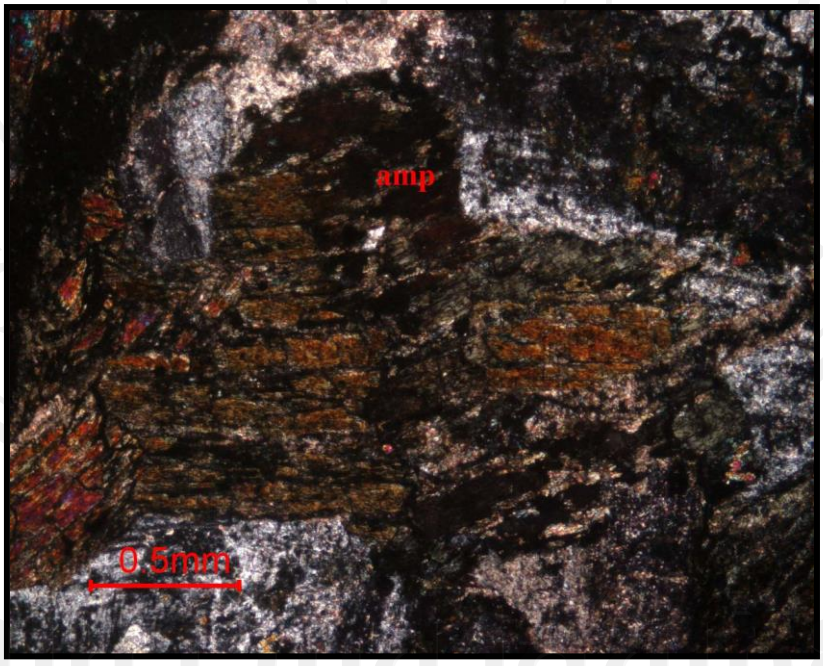

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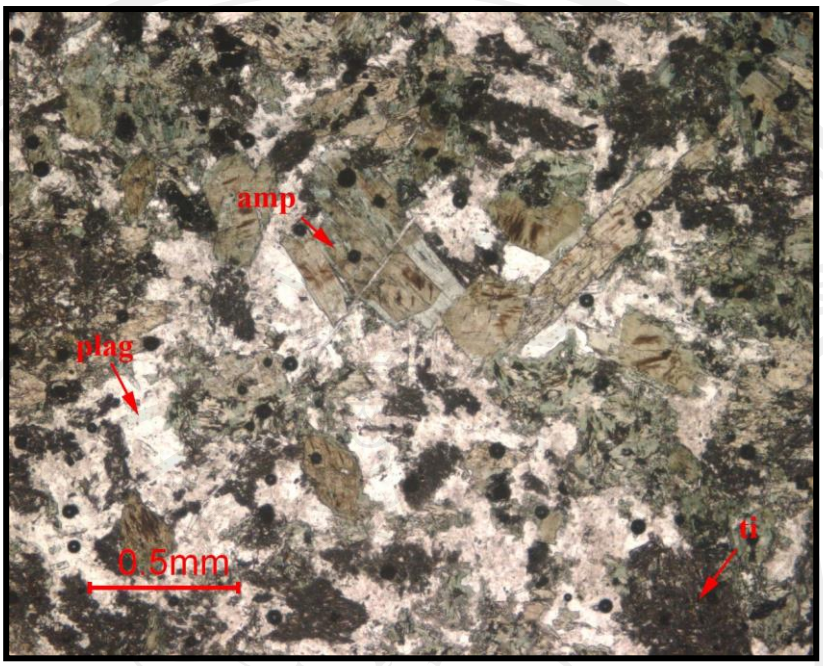
Figure 3.11 Photomicrographs of Group I Microgabbro (sample number MS16B1) showing kink-band feature of amphibole (amp) (a) Ordinary light (b) Crossed polars



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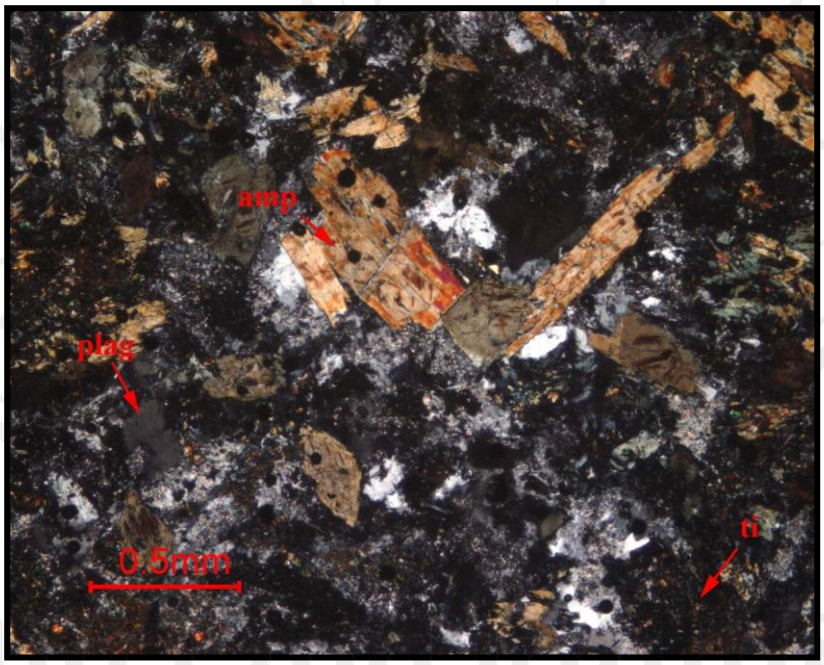

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Figure 3.12 Photomicrographs of Group I Microdiorite (sample number MS65B5) showing amphibole (amp), plage (plagioclase) and ti (titanite) (a) Ordinary light (b) Crossed polars

to amphibole and intergranular texture. Secondary patches of chlorite, epidote, titanite/leucoxene are present in the rock. Tiny veins (sizes up to 0.2 mm across) infilled with epidote, chlorite/pumpellyite, calcite are locally present in the rock.

Amphibole has subhedral-anhedral (averaged sizes 1.0 mm across), prismatic and equant. It may form corroded outlines, with sieve texture. It may form intergranular texture and to plagioclase laths. Amphibole has a pleochroic formula as follows: X=yellow, Y=brown, Z=greenish brown. The pleochroic formula suggests that they are hornblende. They are slightly-medium altered to largely of chlorite/serpentine, with subordinate titanite/leucoxene, Fe-Ti oxide.

Plagioclase is anhedral outline (averaged size 1.0 mm across), corroded outlines and sieve texture. It shows felted plagioclase. It is medium-highly replaced by largely of sericite, titanite/leucoxene, with subordinate chlorite, epidote. Inclusion of apatite is present in plagioclase.

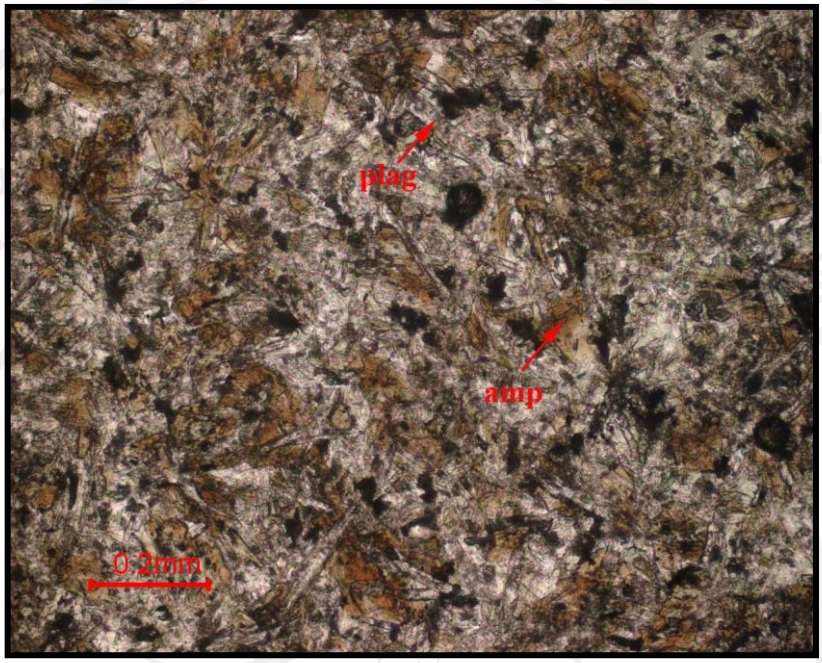
Unidentified mafic minerals are euhedral outline (averaged size 2.5 mm across). It has many fractures and is extremely replaced by chlorite/serpentine, Fe-Ti oxide.

Quartz is anhedral outline (averaged size 1.0 mm across). It shows interstitial texture to amphibole and corrode outline, has non-undulatory extinction. Opaque minerals are anhdral (averaged size 2.0 mm across) and have irregular outlines.

Andesite/Basalt

This non-foliated sample has dark gray color, with a yellownish brown weathering surfaces. It has very fine grained texture, and tiny white veins (up to 0.5 mm across) are present in the sample. It does not react with diluted hydrochloric acid and non-magnetic to slightly magnetic properties.

Under the microscope (Fig 3.13), this rock shows very fine-grained, ophitic/subophitic and intergranular texture. Its constituents are plagioclase and amphibole, minor opaque minerals, and very small amount of apatite. Secondary patch of titanite, chlorite are commonly present in the rock. Tiny veins and fractures



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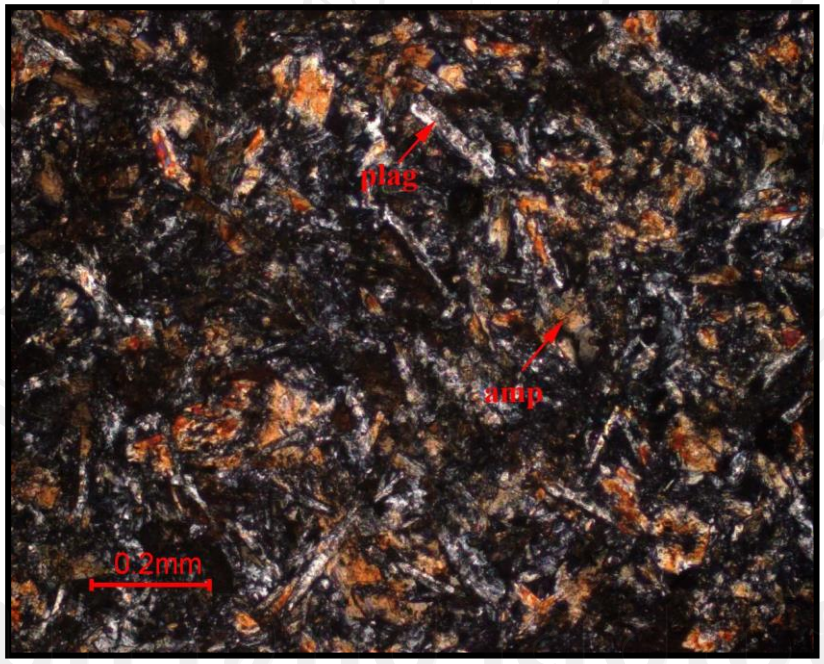

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Figure 3.13 Photomicrographs of Group I Andesite/Basalt (sample number MC6.3B5(B)) showing amphibole (amp), plagioclase laths (plag) and ophitic/subophitic intergrowths (a) Ordinary light (b) Crossed polars

(sizes up to 0.2 mm across) mainly of calcite, with subordinate quartz, titanite, epidote, chlorite, Fe-Ti oxide are infilled in the sample.

Plagioclase has euhedral outlines and lath shapes (averaged size 0.2 mm across). It shows felted plagioclase and some areas shows intersertal texture to chlorite. It is slightly replaces by titanite and chlorite.

Amphibole is brown, euhedral to subhedral outlines (averaged size 0.6 mm across). It has prismatic and subequant shape. It is ophitic/subohitic and to plagioclase laths. A small amount of them are intergranular to plagioclase laths. Amphibole has a pleochroic formula as follows: X=pale brown, Y=brown, Z=dark brown. The pleochroic formula suggests that they are hornblende .The grains are slightly altered to titanite and chlorite.

Opaque minerals have irregular outlines (averaged size 0.2 mm across).

3.2 Group II Rocks

3.2.1 Occurrence

The Group II rocks are distributed in the Mae Chan area (Fig 2.2), Chiang Rai Province. The samples were collected from Ban Prang Pharatchathan3, Doi Yang Sum Kai, Doi Ku Kaeo, Ban Pha Taek, Ban Suan Sak Kio Thap Yang, Doi Pa Sak, Ban Wiang Klang, Ban San Koi, Wat Pa Maha Mongkhon, Ban Takhian Dam and Doi Ngaem (Mae Fah Luang University) that occur outcrop (Fig 3.14 and 3.15) and float rocks (Fig 3.16 and 3.17). The Group II rocks are composed of mainly gabbro (sample number MC18B2, MC20B4, MC64B4, MC64.3B4, MC47B8, MC48B8, MC56B8, MC60B8, MC63B8), diorite (sample number MC37B3(D), MC39B3), microgabbro (sample number MC25B5, MC44.2B8, MC45B8), microdiorite/microgabbro (sample number MC17.2B2, MC37B3(B)), Andesite/Basalt (sample number MC40B3) and basalt (sample number MC69.1B1 and MC53B8).

These rocks are dark gray to greenish black in color and Weathering surfaces are yellow to reddish brown color. The samples have mainly medium grained texture that show equigranular to seriate texture, while they have fine grained texture that

Figure 3.14 The outcrop of Group II Diorite at grid reference 922251 (Miss. Potejamarn Jareunphon, 160 cm tall, is to scale)

Figure 3.15 The outcrop of Group II Gabbro at grid reference 999275 (Mr. Jaturapan Boonsa, 172 cm tall, is to scale)

Figure 3.16 The float rocks of Group II Microdiorite/Microgabbro at grid reference 008350 (the hammer is 28 cm long)

Figure 3.17 The yellow-reddish brown weathering surface and float rocks of Group II Gabbro at grid reference 939151 (the pencil is 15 cm long)

show ophitic/subophitic texture. The mafic igneous rocks in the Mae Chan area are associated with the Triassic-Permian rocks made up largely of maroon to light gray rhyolite, rhyolitic tuff and tuff, sandstone, siltstone, shale an gray limestone. Also, mafic igneous rocks are associated with porphyritic biotite granitic intrusion, with aplite and pegmatite dyke.

3.2.2 Lithology and Petrography

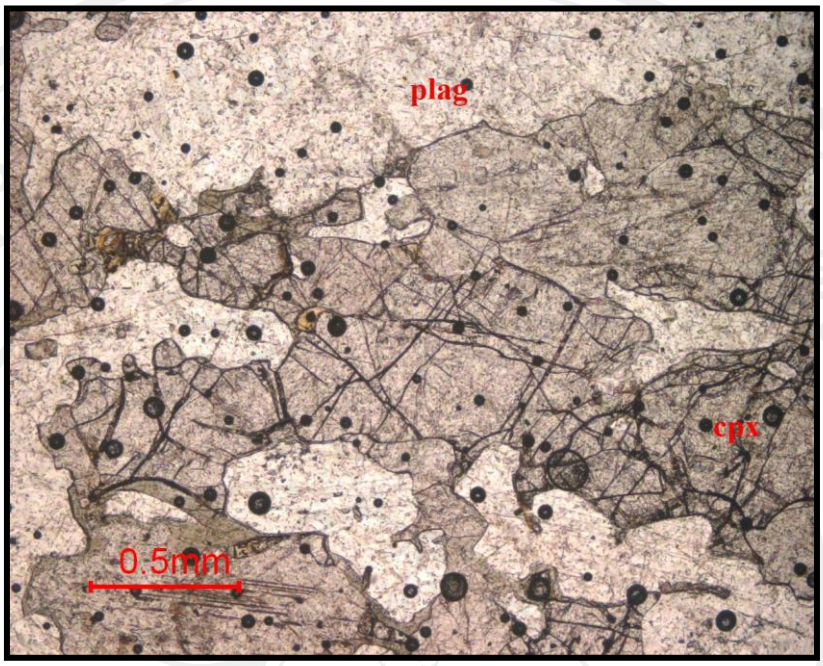
Gabbro

This non-porphyritic, medium- coarse grained rock has dark gray to brownish gray, dark green color. Weathering surfaces have a yellow to reddish brown color. It has a very small amount of fractures, with white veins (less than 1 mm thick) of quartz are present in the rock. It does not react with diluted hydrochloric acid and non-magnetic to slightly magnetic properties.

Under the microscope (Fig 3.18), these rocks are medium-grained, seriate texture. It is mainly of plagioclase, clinopyroxene, with a small amount of orthopyroxene and opaque minerals. Secondary patches of chlorite, green amphibole are present in small amount. Tiny vein (less than 0.5 mm thick) of epidote, chlorite/serpentine and titanite/leucoxene are locally present in a small amount. Some plagioclase, pyroxene and opaque minerals are partly enclosed by yellow colored minerals resulting from reaction rim.

Plagioclase is subhedral-anhedral outline (averaged size 4.0 mm across), with An-content in a range of 68-75 via optical method (Michael-Levy method). Plagioclase grains form mostly parallel or same direction. Some plagioclase grains show corroded outlines, embayment, and have inclusion of clinopyroxene, apatite in some grains. It is very slightly replaced by a small amount of titanite/leucoxene, chlorite/pumpellyite, sericite, clay.

Clinopyroxene is colorless to pale pink, anhedral outline (averaged size 4.0 mm across). Some grains show herring bone, twin and sieve texture and have inclusion of plagioclase, apatite, opaque minerals in some cases. Some crystals show



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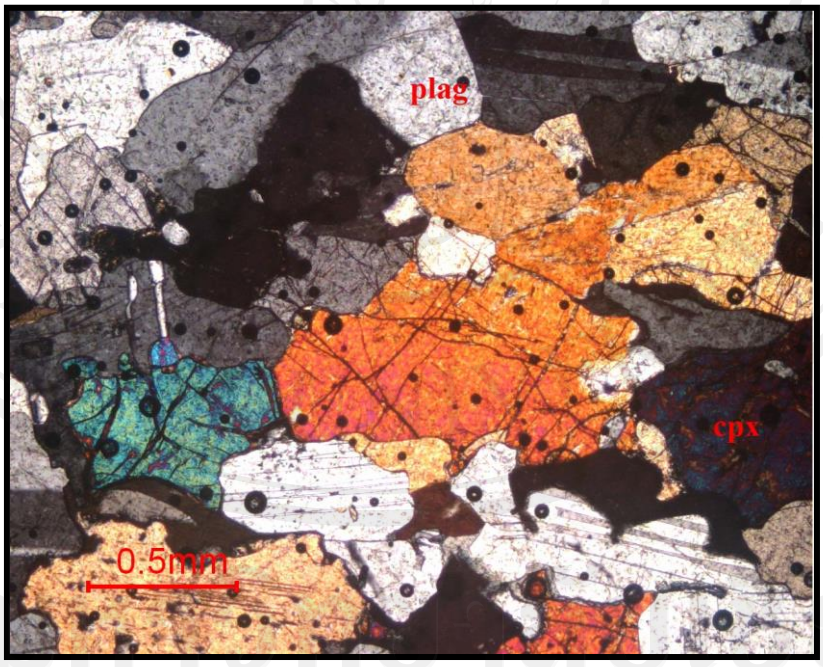


b)

Figure 3.18 Photomicrographs of Group II Gabbro (sample number MC18B2) showing clinopyroxene (cpx), plagioclase (plag) (a) Ordinary light (b) Crossed polars

character of exsolution structure that is made up of lamellae clinopyroxene in orthopyroxene host. It is very slightly to highly replaced by a small amount of chlorite, titanite/leucoxene. Some grains have fractures, alteration products along fractures are composed of green amphibole, epidote and serpentine.

Orthopyroxene is colorless to pale pink, anhedral outline (averaged 2.0 size mm). Some crystals show character of exsolution structure that is made up of lamellae clinopyroxene in orthopyroxene host. Orthopyroxene is slightly to highly replaced by chlorite/serpentine, titanite/leucoxene, Fe-oxide. Some grains have small amount of fractures that contain green amphibole, epidote and serpentine.

Olivine is brown color, anhedral outline (averaged size 5.0 mm across). Fractures are commonly present in the orthopyroxene crystals including chlorite/serpentine, iddingsite.

Green amphibole (averaged size 3.0 mm across) is subhedral-anhedral outline, short prismatic and subequant. The amphibole crystals have a plechroic formula as follows: X=yellow, Y=greenish yellow, Z=deep green. The pleochroic formula implies that it is hornblende. It is medium to altered to chlorite/serpentine, titanite/leucoxene, Fe-Ti. It is commonly cut across by tiny vein.

Brown amphibole is sieve texture. The amphibole crystals have a plechroic formula as follows: X=yellow, Y=greenish brown, Z=brown. The pleochroic formula implies that it is hornblende.

Unidentified mafic minerals are anhedral outline (averaged size 1.2 mm across). It is completely replaced by chlorite/serpentine, titanite/leucoxene, Fe-Ti oxide. Fractures are commonly present in the crystals including chlorite/serpentine, iddingsite.

Opaque minerals are rounded outline, skeleton shape (averaged size 0.2 mm across). It shows symplectitic intergrowth with unidentified mafic minerals. Some grains are embedded in clinopyroxene.

Diorite

This non-foliated, non-porphyritic diorite is dark green and violet distributed throughout the rock, with yellow to reddish brown weathering surfaces. It has a medium-grained texture. It does not react with diluted hydrochloric acid and non-magnetic to slightly magnetic properties.

Under microscope (Fig 3.19), diorite has medium-coarse grained, seriate texture. It is made up largely of plagioclase, amphibole and minor quartz, opaque minerals. Tiny veins (up to 0.4 mm across) of chlorite/serpentine are locally present in the sample. Secondary patches of chlorite, titanite/leucoxene, epidote are present in the sample.

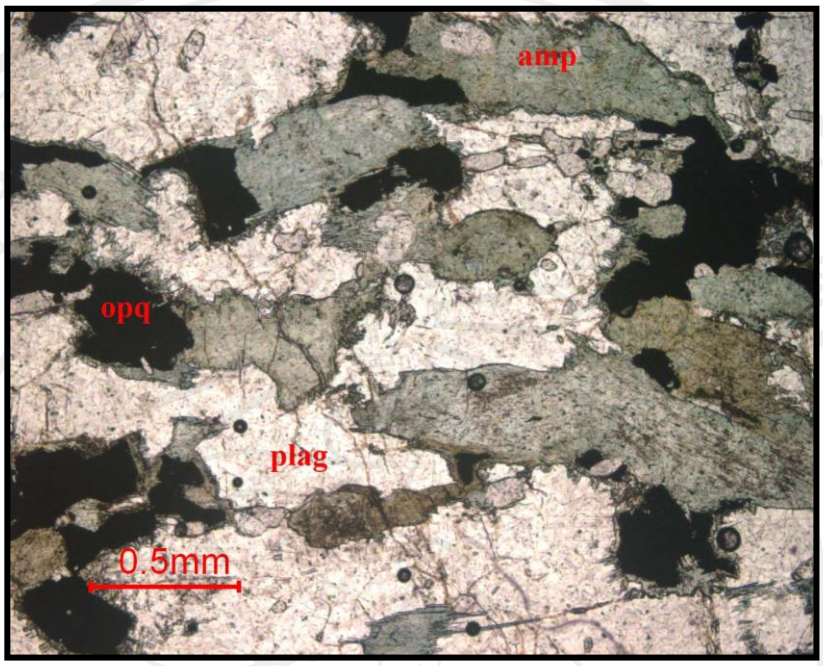
Felted plagioclase grains have two grain sizes, with An-content in a range of 65-70 via optical method (Michael-Levy method). First, plagioclase is eubhedral outline averaged size 8.0 mm across). Second, plagioclase is subhedral outline (averaged size 3.0 mm across). It is slightly to moderately altered to titanite/leucoxene, chlorite/pumpellyite, sericite, clay. Inclusion of apatite is present some grains.

Green amphibole (averaged size 6.0 mm across) is subhedral-anhedral outline, short prismatic and subequant. The amphibole crystals have a plechroic formula as follows: X=yellow, Y=green, Z=deep green. The pleochroic formula implies that it is hornblende. It is medium to altered to chlorite/serpentine, titanite/leucoxene, Fe-Ti oxide and some grains have brown minerals enclosed them.

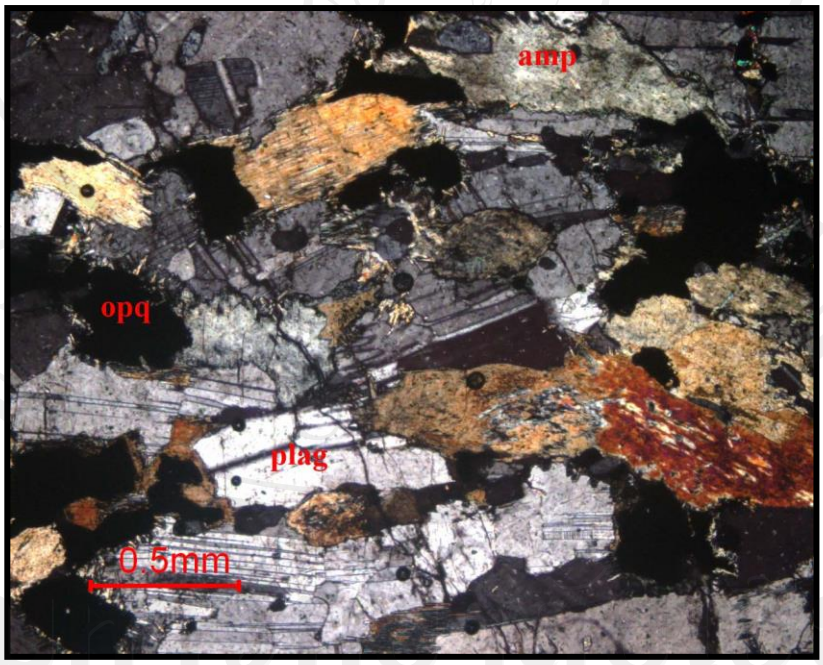
Quartz is anhedral outline (averaged size 3.0 mm across). It has non-undulatory extinction. Opaque minerals are anhedral outline (averaged size 1.0 mm across).

Microgabbro

Microgabbro is non-foliated, non-porphyritic and dark green to brownish gray, with yellow to reddish brown weathering surfaces. It has a medium-grained texture



a)



b)

Figure 3.19 Photomicrographs of Group II Diorite (sample number MC39B3) showing green amphibole (amp), opaque mineral (opq) and plagioclase (plag) (a) Ordinary light (b) Crossed polars

and a very small amount of fractures in the rock sample. It does not react with diluted hydrochloric acid and non-magnetic to slightly magnetic properties.

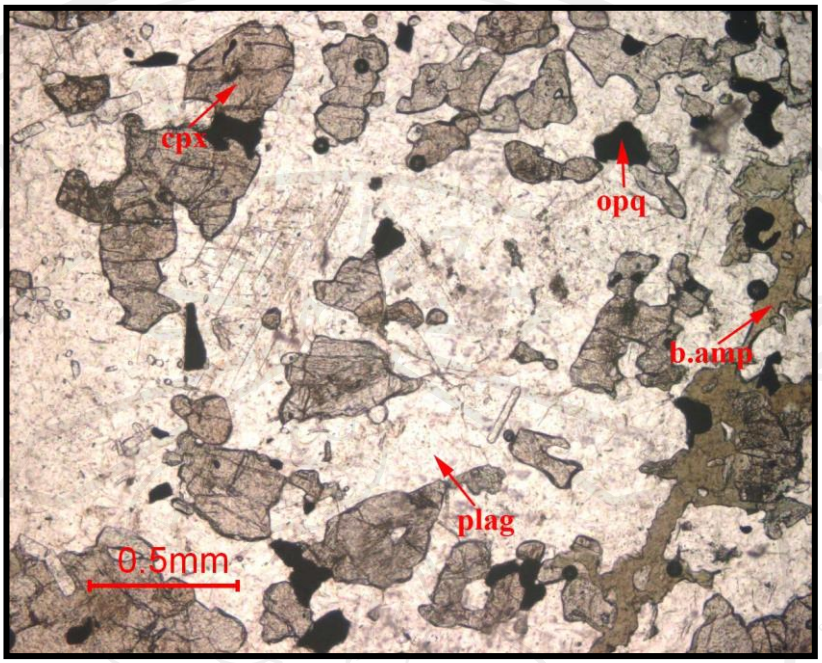
Under microscope (Fig 3.20), these rocks have fine-grained, equigranular texture. It is made up mainly of plagioclase, clinopyroxene and minor orthopyroxene, brown amphibole, olivine and opaque minerals. Tiny veins (size up to 0.2 mm across) of chlorite, calcite are locally present in the sample.

Plagioclase has An-content in a range of 65-75 via optical method (Michael-Levy method). Plagioclase has two grain sizes. First, plagioclase is eubhedral outline (size up to 6.0 mm across). Second, plagioclase is lath and equant shape (averaged size 1.0 mm across). The coarser grain sizes enclosed by finer grain sizes of plagioclase and clinopyroxene are present in the sample. The coarse grains are slightly altered to titanite/leucoxene, chlorite/pumpellyite, sericite, clay, while the fine grains are unaltered. Inclusions of pyroxene, quartz, apatite are present some grains.

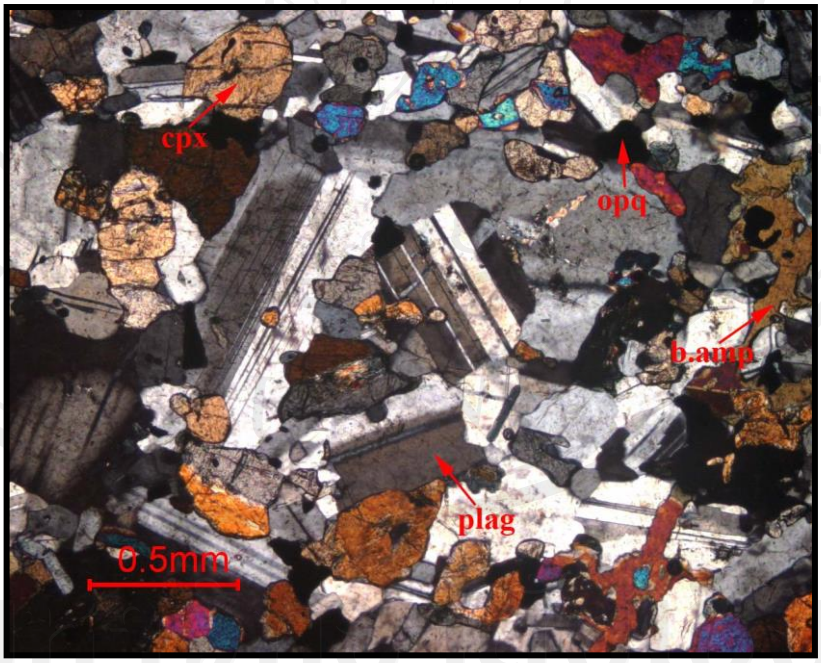
Clinopyroxene is anhedral outline (averaged grain 2.0 mm across). Some grains show herring bone texture and character of exsolution structure that is made up of lamellae clinopyroxene in orthopyroxene host. It has many fractures including chlorite/serpentine and inclusion of opaque minerals in this sample. It is unaltered to very slightly altered.

Orthopryoxene is anhedral outline (averaged grain 0.2 mm across). Fractures are commonly present in the orthopyroxene crystals including chlorite/serpentine. Orthopyroxene is slightly replaced by chlorite, while some grains (grain sizes up to 0.3 mm across) are highly altered to titanite/leucoxene, Fe-oxide.

Olivine is colorless to pale pink and anhedral outline (averaged size 2.0 mm across). It has commonly corrode outline and sieve texture. Pleochroism is green to brown. It has many fractures and moderately replaced by iddingsite, chlorite/serpentine, calcite.



a)



b)

Figure 3.20 Photomicrographs of Group II Microgabbro (sample number MC25B5) showing clinopyroxene (cpx), plagioclase (plag), and intergranular texture (a) Ordinary light (b) Crossed polars

Brown amphibole is sieve texture. The amphibole crystals have a plechroic formula as follows: X=yellow, Y=greenish brown, Z=brown. The pleochroic formula implies that it is hornblende.

Opaque minerals are rounded outline, skeleton shape (averaged size 0.6 mm across). It shows symplectitic intergrowth with unidentified mafic minerals. Some grains are embedded in clinopyroxene.

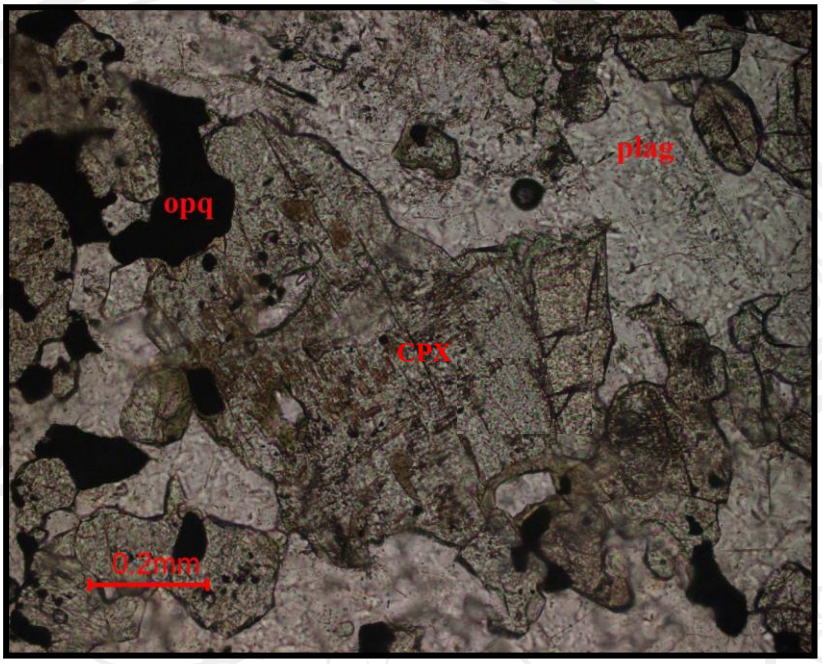
Microdiorite/Microgabbro

This non-foliated, non-porphyritic microdiorite is dark green, and pyrite. Weathering surfaces are yellow to reddish brown color. It has a fine grained texture. Tiny white veins (up to 1.0 mm across) are present in the rock. It does not react with diluted hydrochloric acid and non-magnetic magnetic properties.

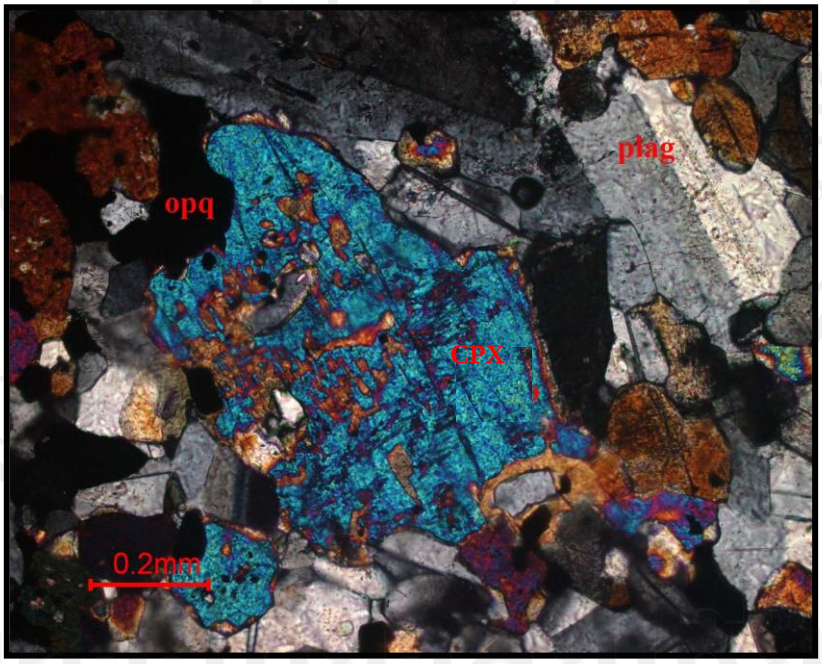
Under microscope (Fig 3.21), microdiorite has fine-medium grained, seriate texture. It shows felty texture. Its constituents are largely of plagioclase, clinopyroxene, olivine and minor quartz, orthopyroxene, opaque minerals and brown amphibole. Secondary patches of chlorite, titanite/leucoxene, epidote are present in the sample. Tiny veins (up to 1.0 mm across) of chlorite/serpentine, epidote are locally present in the sample.

Plagioclase crystals have two grain sizes, with An-content in a range of 60-75 via optical method (Michael-Levy method). First, plagioclase is eubhedral outline and lath shape (averaged size 6.0 mm across). Second, plagioclase is subhedral and equant (averaged size 1.0 mm across). The coarser grain sizes enclosed by finer grain sizes of plagioclase and clinopyroxene are present in the sample. It is unaltered to very slightly altered to titanite/leucoxene, chlorite/pumpellyite, sericite, clay. Inclusion of apatite is present some grains.

Clinopyroxene is colorless to pale pink. It has two grain sizes. First, clinopyroxene is anhedral ouline and show twin and sieve texture (averaged size 5.0 mm across). Second, clinopyroxene is subhedral outline (averaged size 1.0mm across)



a)



b)

Figure 3.21 Photomicrographs of Group II Microdiorite/Microgabbro (sample number MC17.2B2) showing plagioclase (plag) and exsolution structure of clinopyroxene (cpx) (a) Ordinary light (b) Crossed polars

Some crystals show character of exsolution structure that is made up of lamellae clinopyroxene in orthopyroxene host. It is unaltered to very slightly altered.

Orthopryoxene is prismatic and subequant shape (averaged grain 2.0 mm across). Fractures are commonly present in the orthopyroxene crystals including chlorite/serpentine. Orthopyroxene is slightly replaced by chlorite.

Olivine is brown, anhedral outline (averaged size 2.0 mm across). Fractures are commonly present in the orthopyroxene crystals including chlorite/serpentine, iddingsite.

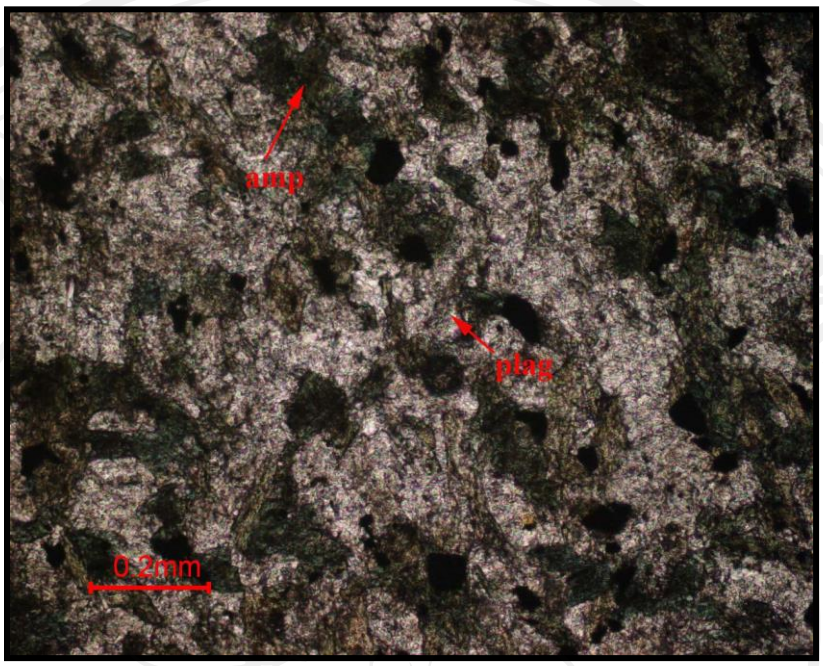
Amphibole (averaged size 2.0 mm across) is subhedral-anhedral outline, short prismatic and subequant. The amphibole crystals have two types: a plechroic formula as follows: X=yellow, Y=green, Z=deep green. The pleochroic formula implies that it is hornblende and a plechroic formula as follows: X=yellow, Y=greenish brown, Z=brown. The pleochroic formula implies that it is hornblende. It is medium altered to chlorite/serpentine, titanite/leucoxene, Fe-Ti oxide. Inclusion of apatite is present some grains.

Quartz is anhedral outline (averaged size 2.0 mm across). It has non-undulatory extinction. Opaque minerals are anhedral outline (averaged size 1.0 mm across).

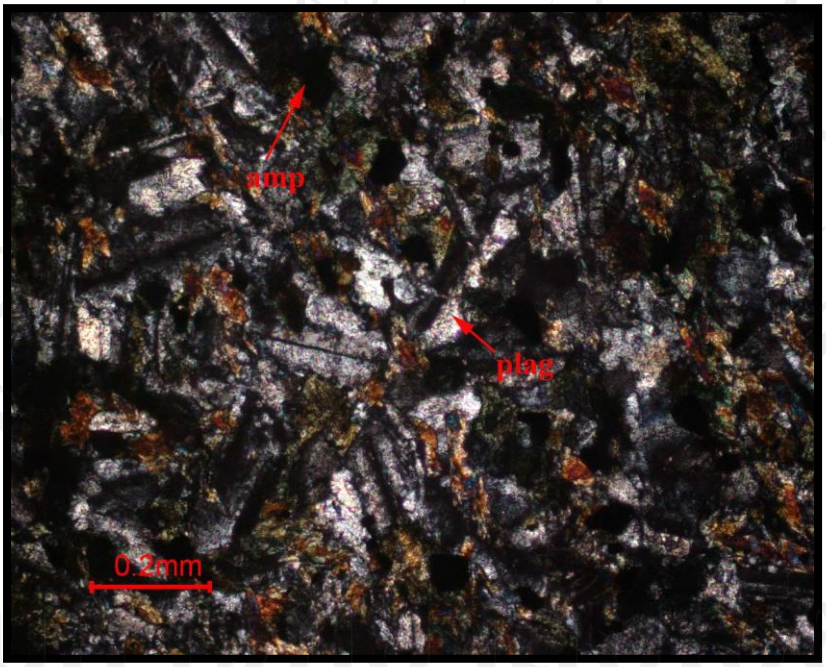
Andesite/Basalt

The sample is very fine grained texture. It has dark gray color, with brownish yellow weathering surfaces. It does not react with diluted hydrochloric acid and non-magnetic to slightly magnetic properties.

Under microscope (Fig 3.22), andesite/basalt is very fine-grained, may form intergranular texture. The sample is composed mainly of plagioclase, amphibole and minor opaque minerals and quartz. Secondary path of chlorite is commonly present in the sample.



a)



b)

Figure 3.22 Photomicrographs of Group II Andesite/Basalt (sample number MC40B3) showing green amphibole (amp), plagioclase laths (plag), and intergranular texture (a) Ordinary light (b) Crossed polars

Plagioclase laths have euhedral outlines. (averaged size 0.4 mm across). It has An-content 70 approximately via optical method (Michael-Levy method). The plagioclase grains show lath shape and felty texture. It is mostly unaltered. Also present is inclusion of apatite in some plagioclase crystals.

Amphibole is euhedral-anhedral outline (averaged size 0.6 mm across). Amphibole has a pleochroic formula as follows: X=yellow, Y=yellownish green, Z=green. The pleochroic formula suggests that they are hornblende. They are medium altered to largely of chlorite, titanite/leucoxene, and Fe-Ti oxide.

Opaque minerals are euhedral to subhedral outlines and may form irregular outlines (averaged sizes 0.4 mm across).

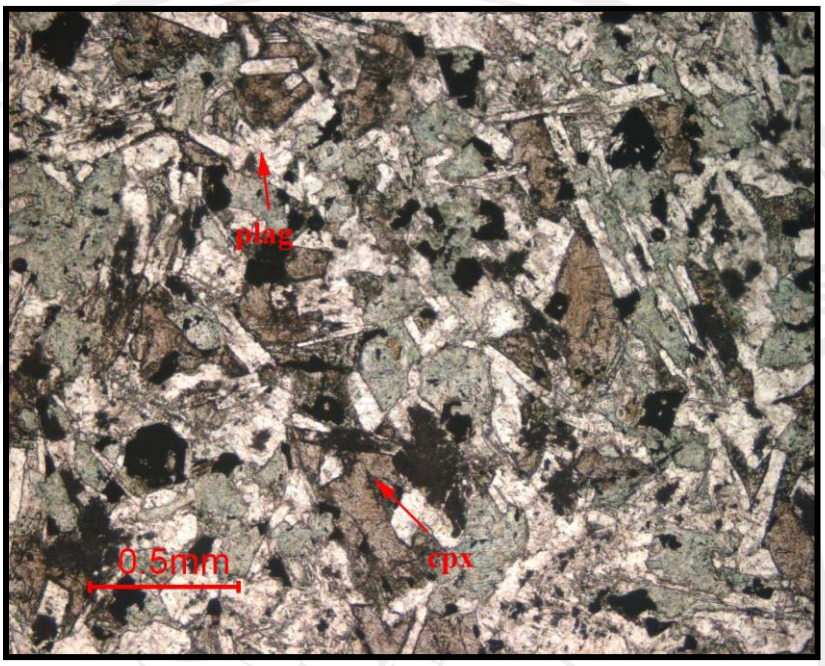
Basalt

The rock sample is non-foliated, and has a graying black color to green, with yellowish brown weathering surfaces. It shows very fine grains. Tiny white vein (less than 1 mm thick) is present in small amount. It does not react with diluted hydrochloric acid and non-magnetic to slightly magnetic properties.

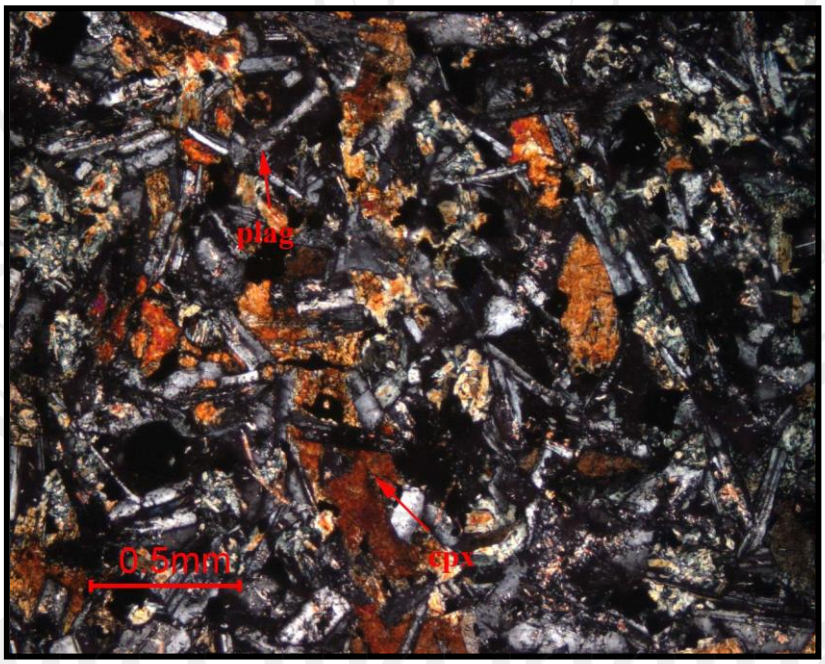
Under microscope (Fig 3.23), these rocks are fine-grained, ophitic/subophitic texture. It comprises plagioclase and clinopyroxene, with small amount of opaque minerals and unidentified mafic minerals, and very small amount of apatite. Secondary patch of chlorite and titanite are commonly present in the rock.

Plagioclase has euhedral outlines and lath shapes (averaged size 0.2 mm across). It has An-content 70 approximately via optical method (Michael-Levy method). Some areas shows intersertal texture to chlorite. It is mostly unaltered to slightly altered to titanite and sericite.. Also present are inclusion of clinopyroxene grains in some plagioclase crystals.

Clinopyroxene is brown color, euhedral to subhedral outlines (averaged size 0.5 mm across). It has prismatic and subequant shape. It shows ophitic/subohitic to plagioclase laths. A small amount of them are intergranular to plagioclase laths. The grains are highly altered to largely of chlorite, with subordinate titanite.



a)



b)

Figure 3.23 Photomicrographs of Group II Basalt (sample number MC69.1B61) showing clinopyroxene (cpx), plagioclase (plag) and ophitic/subophitic intergrowths (a) Ordinary light (b) Crossed polars

Unidentified mafic minerals are euhedral outline, with averaged size 1.0 mm across. It is totally replaced by chlorite/serpentine. Opaque minerals have anhedral and irregular outlines (averaged size 0.2 mm across).