CHAPTER III

GEOLOGY OF CHAE SORN ANTIMONY-GOLD PROSPECT

The geology of Chae Sorn prospect and its adjacent area is given in Figure 3.1 and drilling location is given in Figure 3.2. The cross-section approximately along AA′and BB′(Figure 3.1) or along line 15 and 16 (Figure 3.2) is shown in Figure 3.3 and 3.4 respectively. The area is underlain for the most part by a metasediment unit on eastern part and a clastic unit in the middle-upper part of the map. The geological contact of these metasediment and clastic units is a fault or shear zone which also hosts the antimony - gold mineralization. A N-S elongated granitoid is exposed on the western most part of the area. This granitoid is a part of the Khuntan batholith which has been dated by Ar^{39} - Ar^{40} method to have the Late Triassic age of 202-213 Ma (Charusiri,1989). The contact of the granite and the clastic unit is likely to be intrusion contact.

Within the fault zone, many cataclastic rocks including phyllonite, schist, stretched sandstone, sheared limestone, sheared diorite and sheared granite were encountered. This fault zone or shear zone trending NNE-SSW, is very close to and approximately the same direction as the Wiang Pa Pao - Khuntan fault which its latest movement was dated by Charusiri (1989) to be Paleogene (40-50 my). Detailed description of the rock units in the area is given in the following paragraph, namely, metasediment unit, clastic unit, granitoid unit and cataclastic unit.

EXPLANATION

Cataclastic unit

- Phyllonite, schist and stretched sandstone
- Limestone (partly sheared)
- Diorite (partly sheared)

Biotite-muscovite granite and tourmaline granite

Carboniferous clastic unit; reddish-brown shale intercalated with sandstones

Silurian-Devonian metasedimentary unit; phyllite, and sandy micaceous bands

LEGEND

mineralized zone	attitude of linearment
fault	geologic boundary
road	stream

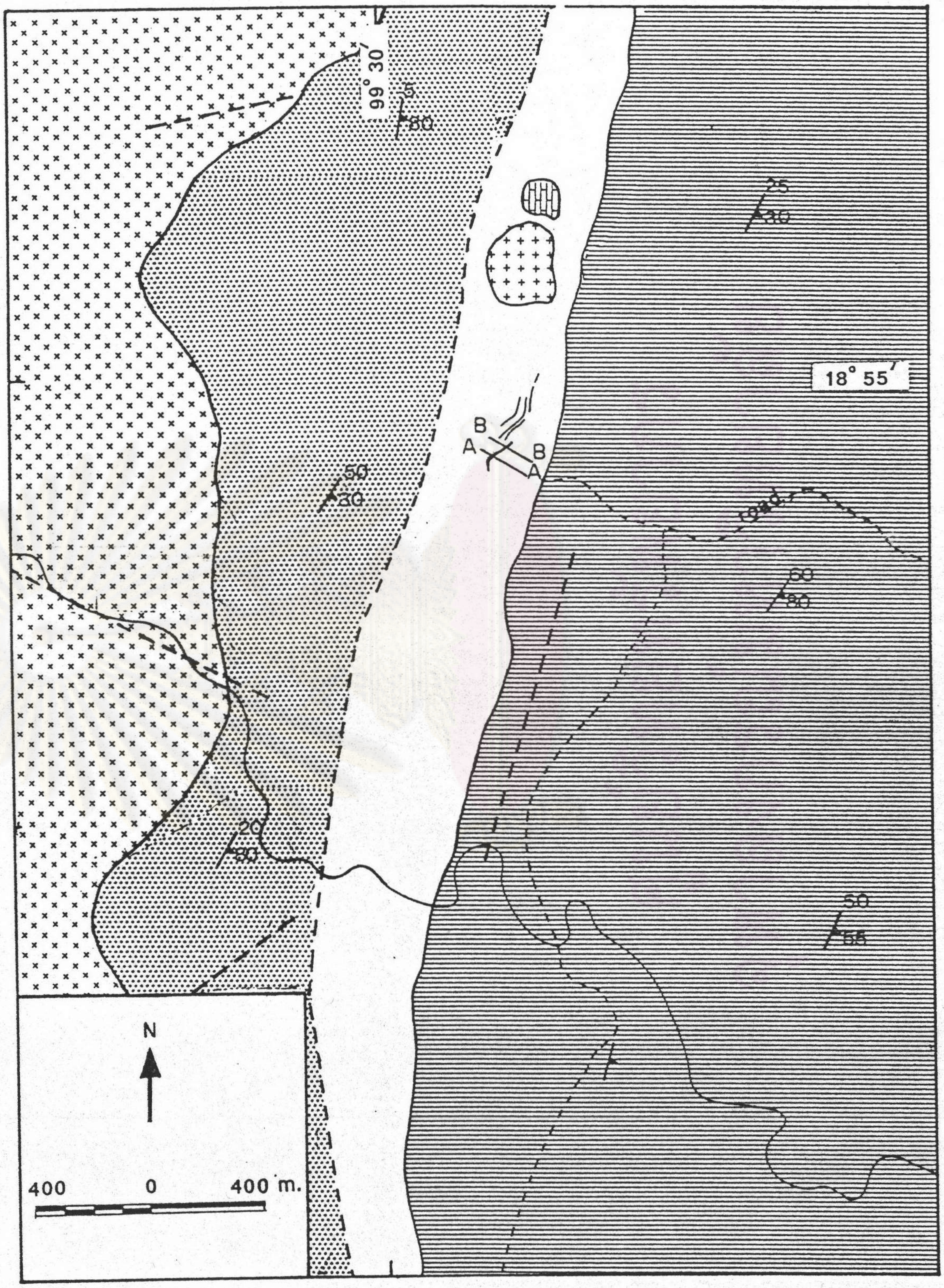


Figure 3.1 Geological map of the study area.

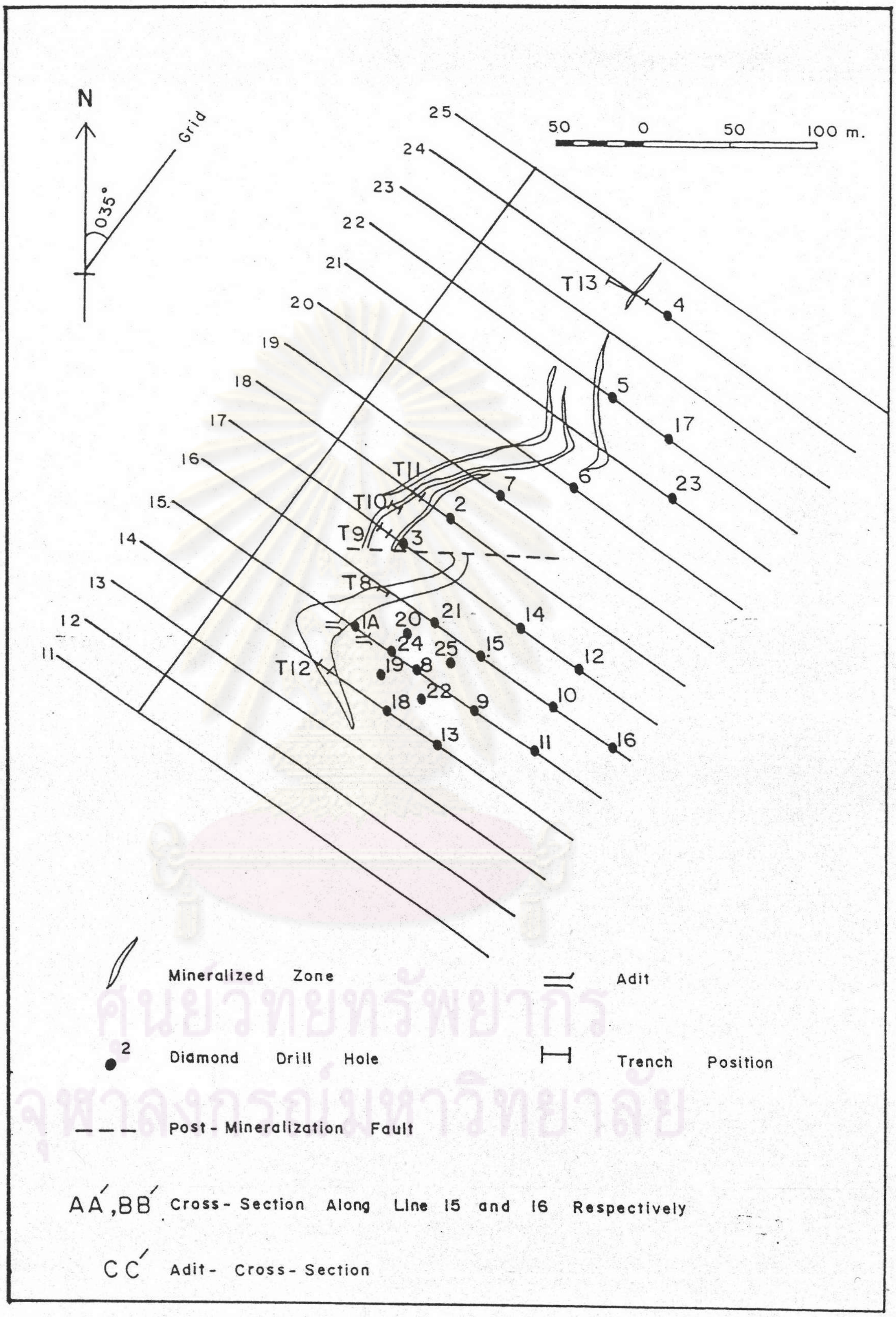


Figure 3.2 Drilling location map.

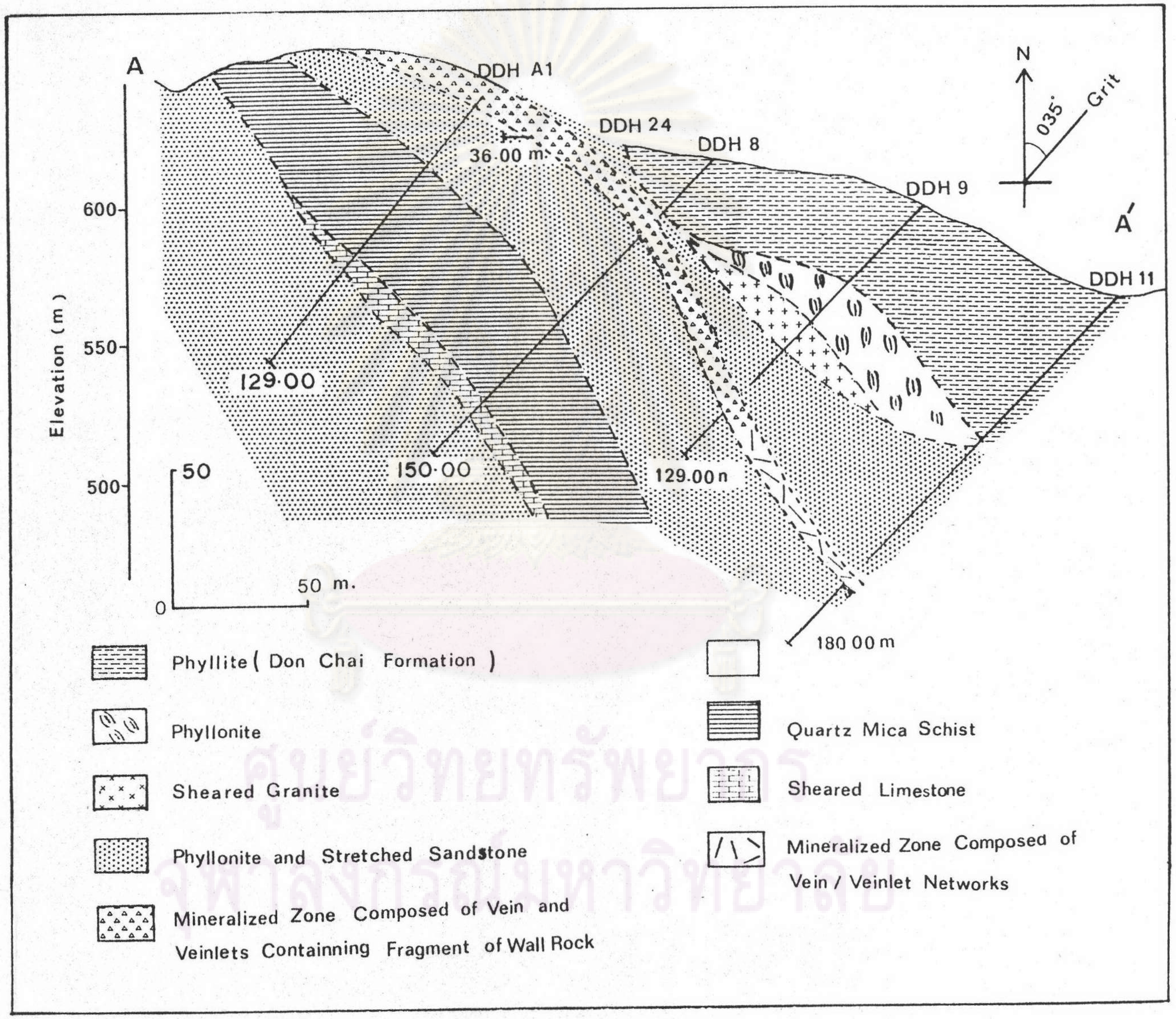


Figure 3.3 Cross-section along AA´ or line 15, modified after SAC (1987).

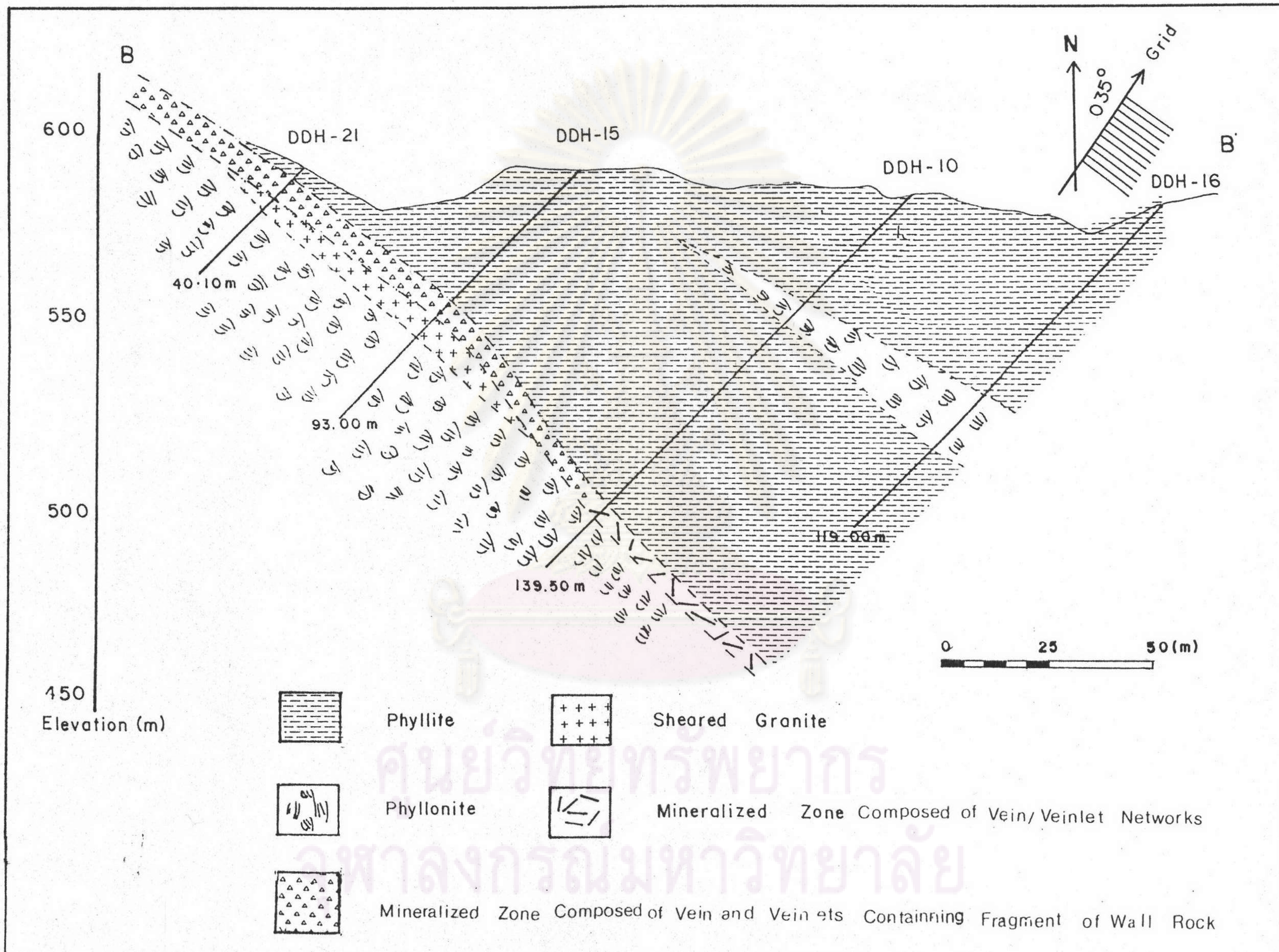


Figure 3.4 Cross-section along BB′ or line 16, modified after SAC (1987).

3.1 Metasediment Unit

This unit is probably equivalent to Don Chai Group of Silurian - Devonian age (Piyasin,1972). It covers the eastern part of the study area as well as encountered by the DDH. This unit comprises mainly phyllite with minor interbedded sandy micaceous bands. In the field the rock shows a well developed phyllitic structure (slaty cleavage, Figure 3.5) and is generally less folded. The general trend of phyllitic structure is almost N-S with moderate east - dipping. However, it may be locally sheared at some places far away from the main shear zone.

In hand specimen, phyllite is black, soft and generally shows well developed phyllitic structure (Figure 3.6), eventhough some of them are less perfect. The phyllitic structure is probably caused by the development of S_1 foliation (see the following paragraph). Here the rock is considered to be phyllite as it is notably coarser grain than slate and particularly displays well developed a silky shean to the surface of cleavage (phyllitic structure).

Mineralogically, the phyllite is composed essentially of sericite, chlorite and quartz. The accessory minerals include tourmaline and iron oxides. Sericite is the most predominant mineral and occurs as very small flakes or aggregates. It is commonly found in association with fine-grained quartz especially in quartz-riched portion. It should be noted that in quartz-riched portion sericite tends to form coarser flakes. Moreover, sericite apparently becomes much larger flakes in deformed quartz veinlets.

Microscopically, phyllitic structure is defined by the preferred orientation of micaceous minerals (Figure 3.7). The original sedimentary structure such as bedding (S_0) is still well preserved in some samples. The phyllitic structure (S_1) forms a low angle to the bedding plane (S_0) as having been encountered both in hand specimen (Figure 3.8) and under microscope (Figure 3.9). The compositional layering of mica - riched layer and quartz - riched layer is often observed. Moreover, the earlier phyllitic structure (from the samples collected far away from the shear zone) has been subjected to the later deformation resulted in strain-slip cleavage (S_2 ; Figure 3.10) well developed in crenulated mica-rich layers. The strain - slip cleavage (S_2) appears coincident with the limbs of asymmetrical fold (Figure 3.11).

The interbedded sandy micaceous bands or layers are a dark gray, fine-grained metasandstone (Figure 3.12). This rock is composed mainly of quartz with minor feldspars (plagioclase and probably some potash feldspar), sericite, chlorite and tourmaline. Iron oxides are common opaque minerals. Most of the quartz and other grains are generally fine - grained (generally $<$ 0.2 mm. in diameter). However, some of them are up to 0.5 mm. in diameter. Deformation texture can be clearly observed in this rock. Many quartz and feldspar grains have been stretched (Figure 3.13), and recrystallized as well as show wavy extinction. Sericite forms as small long narrow flake oriented parallel to the stretched direction of quartz grains.

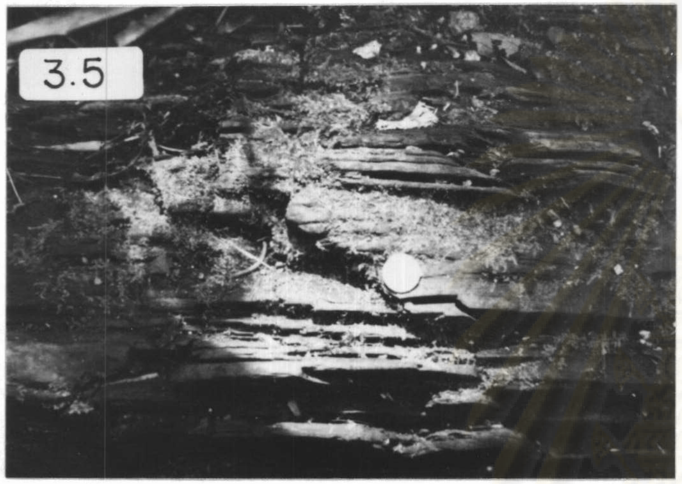
It should be noted that this metasedimentary unit was

Figure 3.5 Exposure of phyllite along stream bank showing phyllitic structure.

Figure 3.6 Hand specimen of phyllite showing well developed phyllitic structure.

Figure 3.7 Photomicrograph of phyllite showing phyllitic structure. Note it is slightly folded at the top of photograph. (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).

Figure 3.8 Hand specimen of phyllite showing phyllitic structure (S_1) forms a low angle to the bedding plane (S_0)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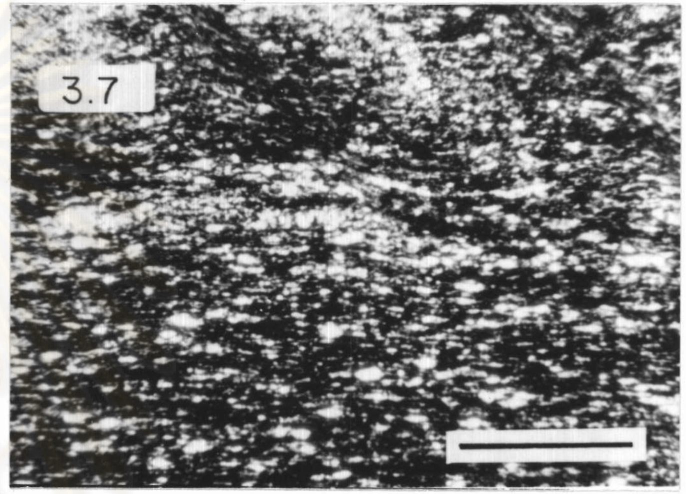
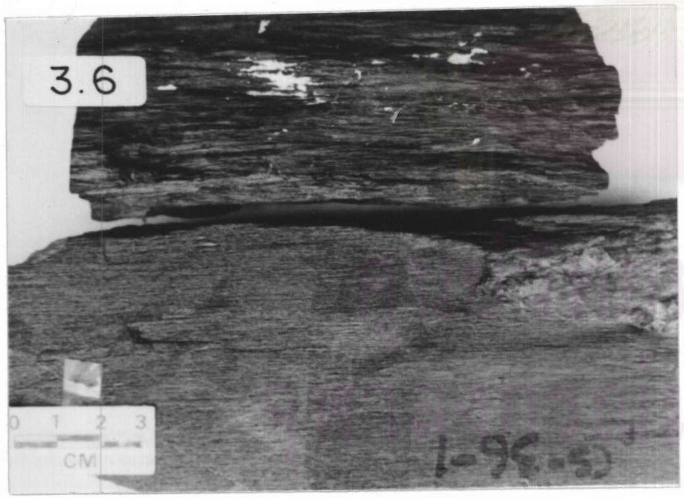

3.7


3.6
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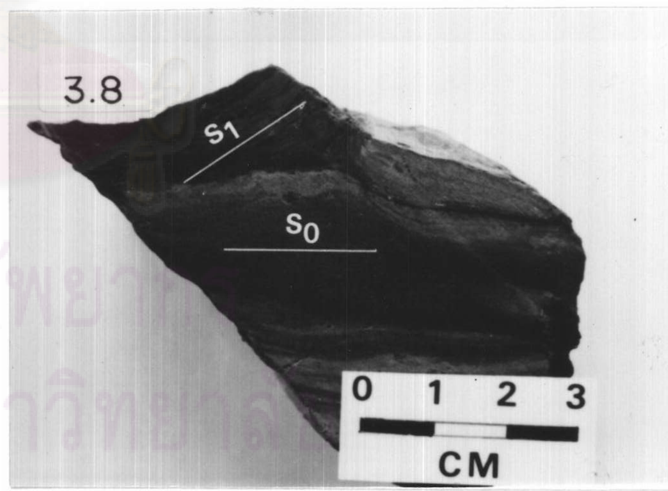
3.8
S_1
S_0
0 1 2 3
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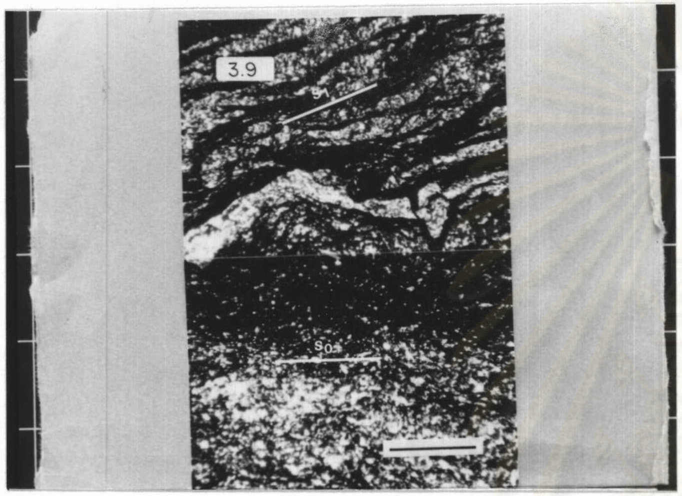
Figure 3.9 Photomicrograph of phyllite showing phyllitic structure (S_1) forming a low angle to the bedding plane (S_0). (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).

Figure 3.10 Photomicrograph of phyllite showing S_1 (foliation), S_2 (strain-slip cleavage). (Bar-scale = 0.23 mm; transmitted light, crossed nicols).

Figure 3.11 Photomicrograph of phyllite showing strain-slip cleavage (vertical) coincident with the limbs of asymmetrical folds in phyllitic structure. (Bar-scale = 0.23 mm ; transmitted light, crossed nicols).

Figure 3.12 Hand specimen of sandy micaceous band in phyllite.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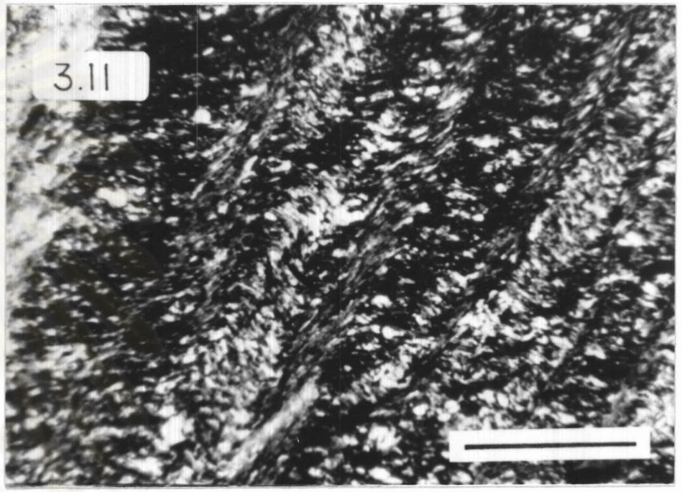
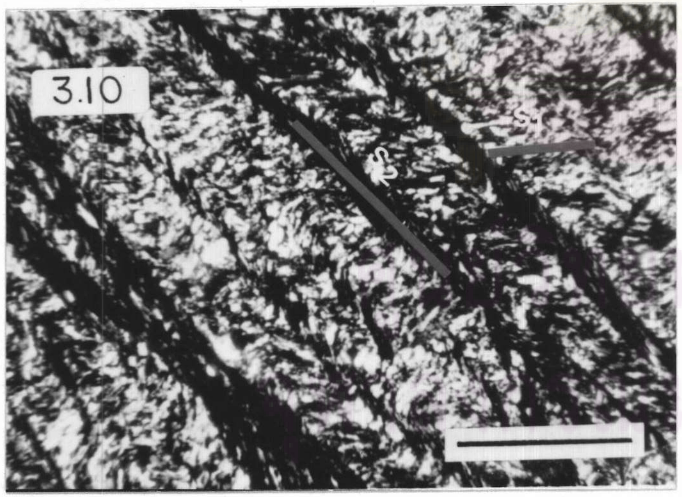

3.11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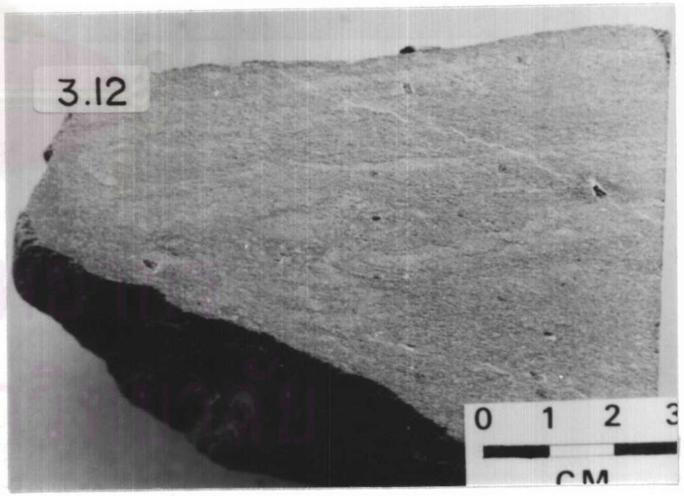

3.12
0 1 2 3
CM

subject to at least two episodes of regional deformation (marked by S_1 and S_2) prior to the local cataclastic deformation in the shear zone which will be described shortly.

3.2 The Clastic Unit

This unit may be equivalent to Mae Tha Group of Carboniferous age described by Piyasin (1972). It covers most of the western half of the study area (see Figure 3.1). The rocks consist predominantly of shale with minor interbedded and/or intercalated sandstone. The general strike of lineament is approximately NE-SW with moderate-dipping (50^{o} - 75^{o}) to the east. This unit is less deformed in comparision with the metasediments.

Shale is well exposed along stream bank (Figure 3.14). In hand specimen, the rock is commonly reddish brown and, lesser common, grayish green in color on the fresh surface, soft to hard and moderately to well developed fissility (Figure 3.15).

Microscopically, shale is fine - grained, composed predominantly of sericite, quartz, chlorite, minor feldspar and tourmaline with substantial amount of ferric-oxide cement. The grain size of quartz and feldspar is usually < 0.02 mm. in diameter. However, grain size of > 0.02 mm. in diameter has also been encountered in small amount at some parts. Ferric-oxide cement may be rich at some spots and occasionally forms layer like or lenses. The fissility is defined by the preferred orientation of sericite (Figure 3.16).

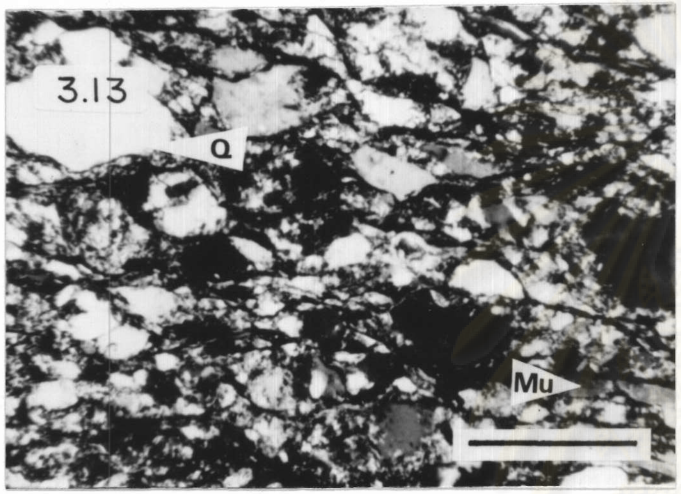
The sandstone is interbedded or intercalated with shale as

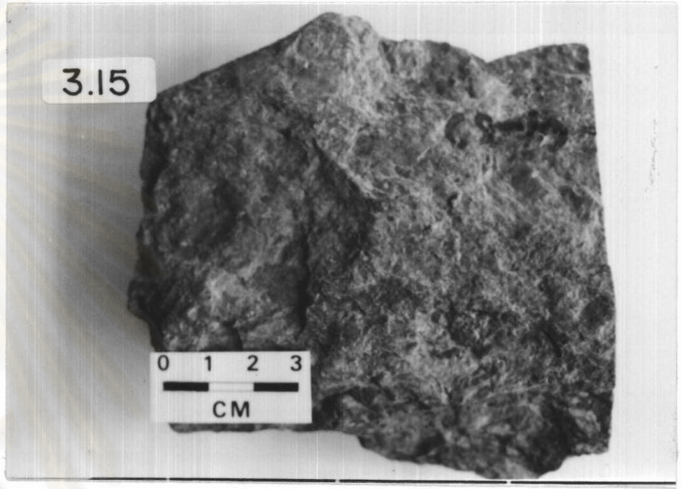
Figure 3.13 Photomicrograph of sandy micaceouse rock showing stretched quartz (Q) and muscovite (Mu). The dark material filled along grains is iron oxides. (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).

Figure 3.14 An outcrop of shale showing well developed fissility moderately dipping toward the east (Looking toward the north).

Figure 3.15 Hand specimen of shale showing moderately developed fissility.

Figure 3.16 Photomicrograph of shale, showing preferred orientation of sericite and quartz. (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).


3.13
Q
Mu


3.15
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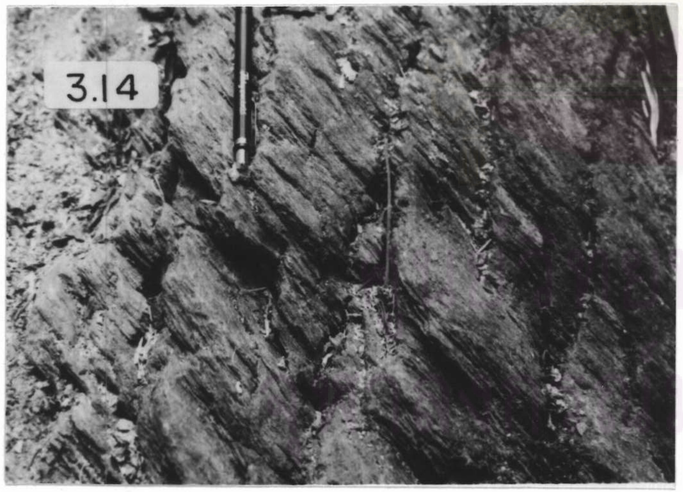
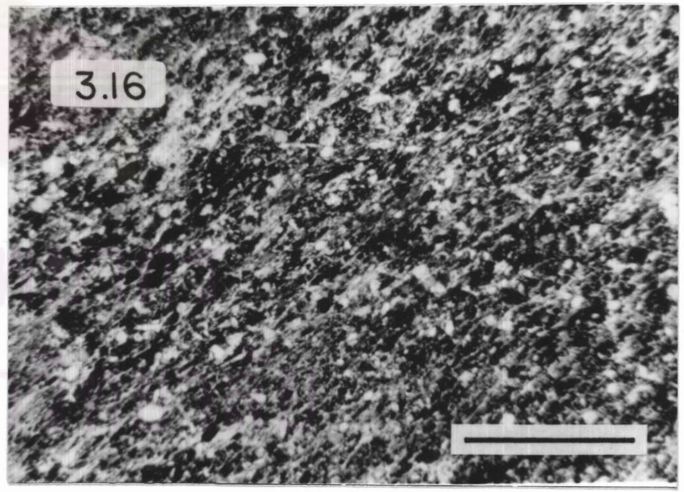

3.14


3.16

mentioned earlier and mainly exposed along stream. The thickness of beds is variable ranging from few meters to few ten meters. Compositionally, the sandstone can be classified as calcareous arkosic sandstone. It is brownish gray, medium-grained (Figure 3.17) moderately sorted, angular to subangular. Mineralogically, framework grains are composed mainly of quartz with subordinate feldspars and calcite (Figure 3.18). Feldspars comprise both K-feldspar and plagioclase but the former is more predominant, especially microcline. The matrix is composed of fine-grained feldspar and clay minerals. The framework grains and fine matrix are partially cemented by calcareous material.

3.3 Granitoid Unit

At least two varieties of granitic rock which have been encountered in the granitoid body exposed on the western part the area. They are fine to medium-grained slightly porphyritic biotite-muscovite granite and tourmaline-($\pm$muscovite-biotite) granite. Detailed description of each variety is given in the following paragraphs.

3.3.1 Fine-,to medium-grained slightly porphyritic biotite-muscovite granite.

This granite is fine to medium-grained with slightly porphyritic texture. The rock is well exposed along Nam Mae Soi as well as along its tributary. This type of granite is believed to cover the major part of the area. The rock is quite fresh and less deformed.

Megascopically, the rock is characteristically light gray and fine-,to medium-grained. It shows porphyritic texture (Figures 3.19 and 3.20). The megacryst (about 2-4 volume percent) is mainly potash-feldspar, which ranges in size from 0.5-5 cm. The mineral constituents of the groundmass are quartz, potash-feldspar, plagioclase, biotite and muscovite.

Under microscope, the rock is holocrystalline and hypidiomorphic (Figure 3.21).

Quartz has the approximate grain size of 0.7 mm. and generally forms as large irregular patches and aggregates of small grain interstitial to K-feldpar and plagioclase. Myrmekitic quartz in plagioclase (Figure 3.22) and graphic quartz in microcline are also encountered but not common.

Potash-feldspar in the groundmass has the grain size ranging from 0.3 to 1.5 mm. which occurs as microcline and microcline-perthite. It usually forms an anhedral to subhedral. The euhedral tabular crystal is rare, except the megacryst which occurs as large tabular crystal. The microcline megacryst frequent contains poikilitic inclusions of plagioclase, biotite, quartz (Figure 3.23) and muscovite. Besides, it also contains apatite inclusion.

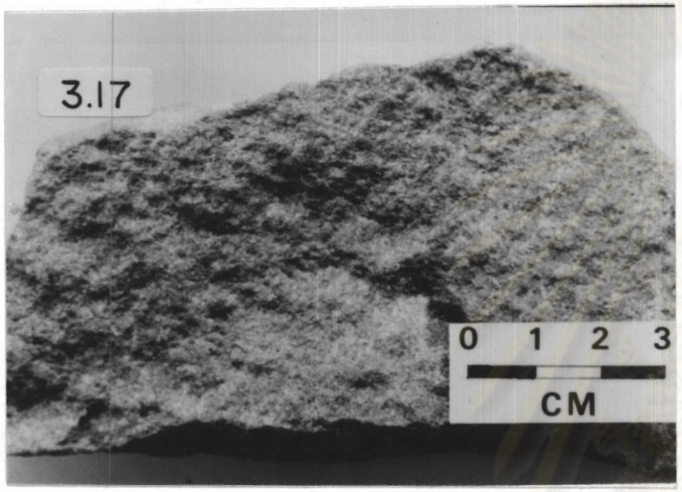
Plagioclase has grain size ranging from 0.4 to 2.4 mm. and generally forms as subhedral tabular crystals. It commonly shows albite and albite - Carlsbad twins. Pericline and Carlsbad twins are less prominent . Normal zoning is often observed in plagioclase. Occasionally zonation may be obscured by alteration.

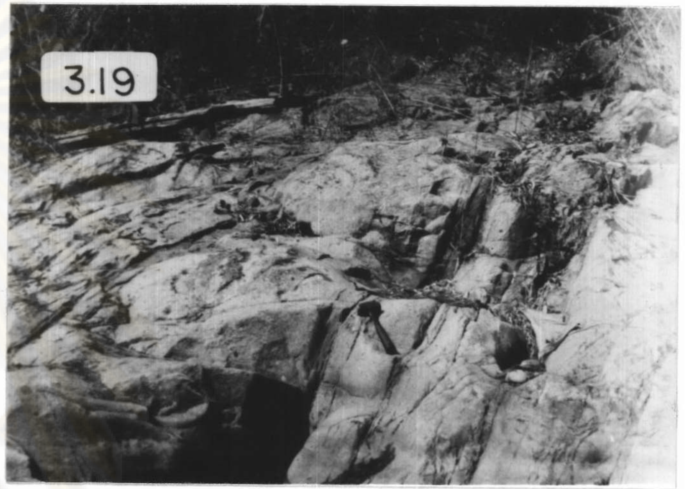
Figure 3.17 Hand specimen of calcareous arkosic sandstone.

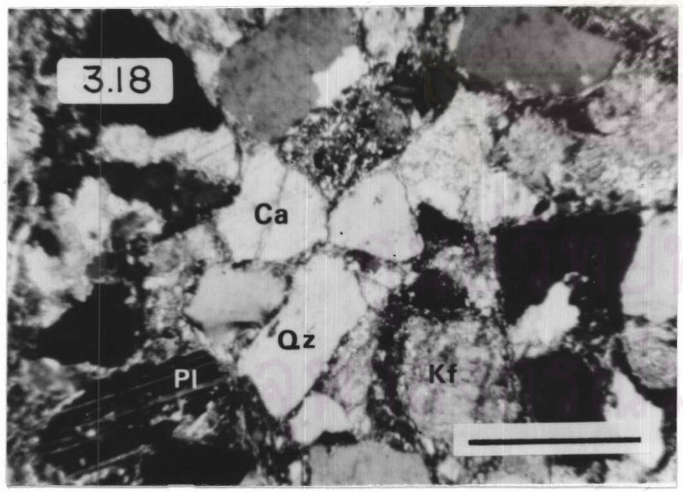
Figure 3.18 Photomicrograph of calcareous arkosic sandstone showing framework grains of quartz (Qz), plagioclase (Pl), K-feldspar (Kf), calcite (Ca) and the matrix partially cemented by calcite . (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).

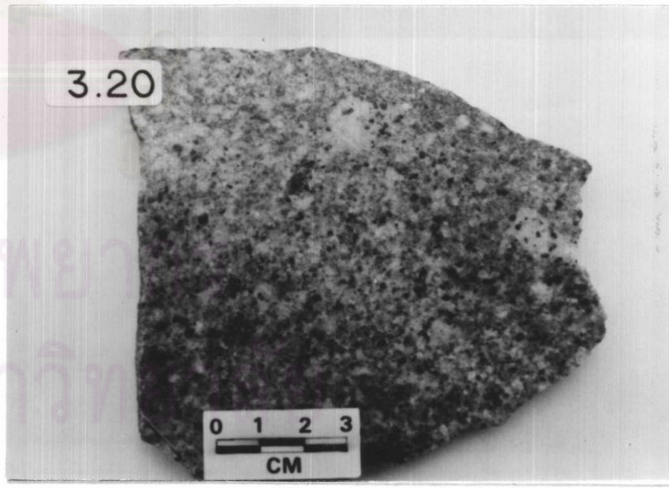
Figure 3.19 An exposure of fine-, to medium-grained biotite-muscovite granite exposed along the bank of Nam Mae Soi (stream).

Figure 3.20 Hand specimen of fine-, to medium-grained biotite-muscovite granite, showing few K-feldspar megacrysts. Note that the dark mineral is biotite.


3.17
0 1 2 3
CM


3.19


3.18
Ca
Qz
Pl
Kf


3.20
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CM

The majority of plagioclase has subjected to slight to moderate alteration, particularly in the core of crystal. Sericite is a common alteration product of plagioclase. Furthermore, it is often developed into a coarser muscovite.

Muscovite is ranging in size from 0.4 to 1.0 mm. and generally occurs as small flakes or aggregates , both filling interstitial to other minerals such as quartz, K-feldspar and plagioclase and intergrowth with microcline or microcline-perthite. The former one often associated with biotite. Some muscovites are thought to be the alteration product of biotite. Other accessary minerals are apatite zircon and iron oxides.

3.3.2 Fine-,to medium-grained tourmaline-(+muscovite-biotite) granite.

Megascopically, this type of granite is leucocratic, light gray to almost white, inequigranular (Figure 3.24). It occasionally shows a dark spot of tourmaline aggregates. The rock is unfoliated but shows some deformation. This rock contains essentially quartz, K-feldspar, plagioclase with minor muscovite. Biotite may or may not be present. Tourmaline is distinctively abundant ferromagnesian minerals.

This granitic rock is exposed along Nam Mae Soi as small outcrop within the biotite-muscovite granite. The rock is rather fresh similar to the first type.

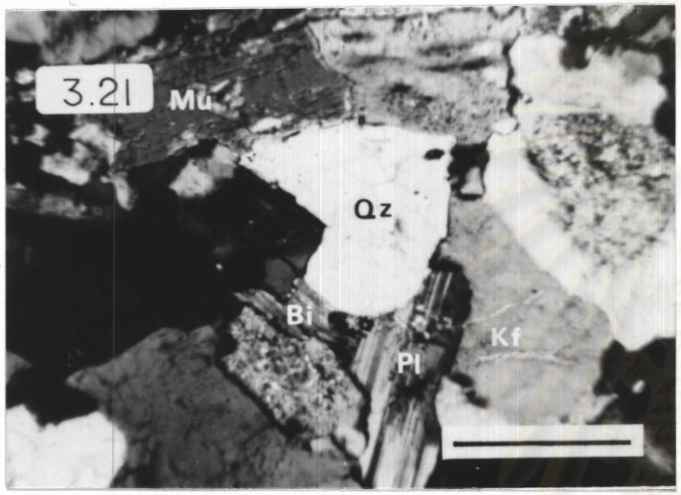
Microscopically, the rock is holocrystalline and

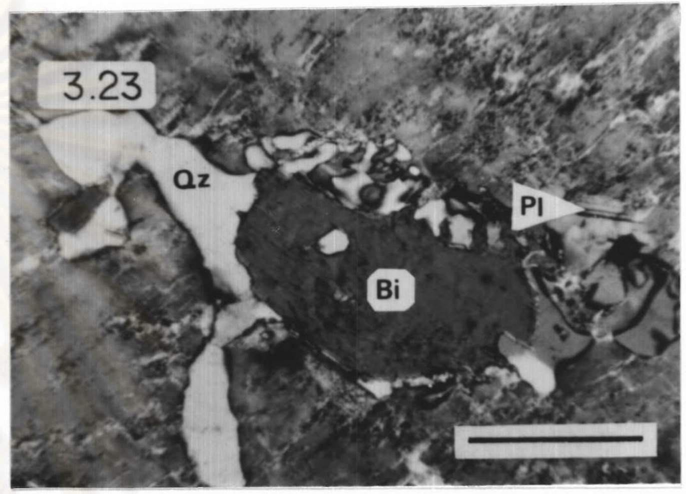
Figure 3.21 Photomicrograph of fine-,to medium-grained biotite-muscovite granite showing quartz (Qz), K-feldspar(Kf), plagioclase(Pl), muscovite (Mu) and biotite (Bi). (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).

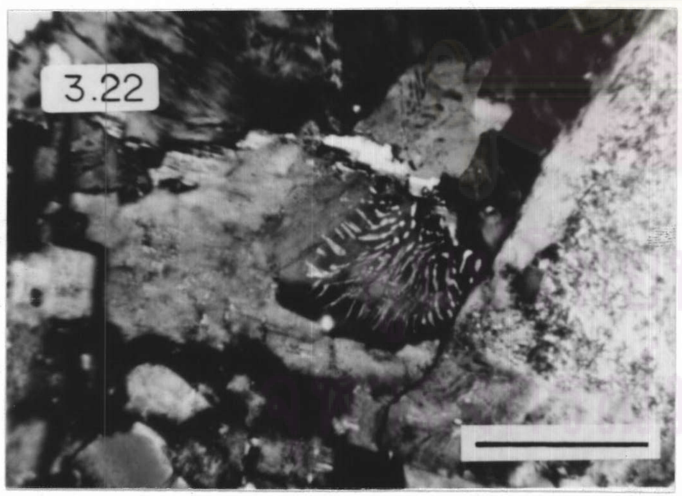
Figure 3.22 Photomicrograph of fine-, to medium-grained biotite-muscovite granite showing myrmeketic quartz in plagioclase bounded by microcline on top, microperthite at the bottom and large altered plagioclase on the right of photograph. (Bar-scale = 0.23 mm ; transmitted light, crossed nicols).

Figure 3.23 Photomicrograph of fine-, to medium-grained biotite-muscovite granite showing inclusions of biotite(Bi), quartz(Qz) and plagioclase(Pl) in large microcline megacrysts. (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).

Figure 3.24 Hand specimen of fine-, to medium-grained tourmaline- (±muscovite-biotite) granite. Dark color is tourmaline riched spots.


3.21
Mu
Qz
Bi
Pl
Kf


3.23
Qz
Pl
Bi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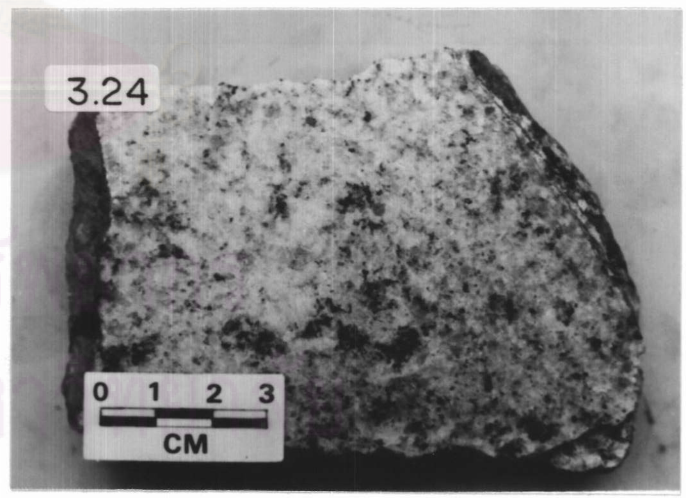
3.24
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hypidiomorphic. Quartz has grain size ranging from 0.4-2.0 mm. and usually forms large anhedral grains and small interstitial aggregates. However, those formed as inclusions in K-feldspar are usually fine-grained. Quartz also contains inclusion of muscovite flakes.

Potash-feldspar predominantly occurs as microcline and microcline-perthite of which the later is more common . It generally forms as anhedral grains with grain size ranging from 0.8 to 4.0 mm. but average is about 2.0 mm. Microcline-perthite often contains inclusions of plagioclase, muscovite, quartz. The alteration is almost absent.

The grain size of plageoclase ranging from 0.8-3.0 mm. but commonly about 1.0 to 2.0 mm. It usually forms as subhedral tabular crystal (Figure 3.25) and fills interstitial among other minerals. Simple albite and Carlsbad-albite twins are quite common whereas pericline twin is less common. Zoning in plagioclase is not common, but where observed it shows normal zonation.

Muscovite generally occurs as small flakes and/or aggregates filling interstitial among other minerals and also as inclusions within microcline-perthite. Muscovite often forms in association with biotite or chloritized biotite.

Biotite generally occurs as small tabular crystals. In fact it has been transformed to chloritized biotite with dark brown pleochroism. It generally occurs interstitial among other minerals such as quartz, feldspar. Some biotite grains are partially altered to chlorite and probably muscovite.

Tourmaline occurs as an important ferromagnesian mineral in this rock with the average grain size range from 0.5 to 1.0 mm. It generally forms as subhedral grain filling interstitial among quartz and feldspar as well as intergrowth with microcline and/or microcline-perthite (Figure 3.26). The other accessary minerals are apatite and zircon.

3.4 Cataclastic Unit

The cataclastic rocks are mostly confined to a narrow zone located between the clastic unit and the metasediment unit (see Figure 3.1). The rocks in the thrust zone in fact consist not only cataclastic rock but also include uncrushed or weakly sheared rocks most of which are schist, sandstone, diorite, granite and carbonate rock. The cataclastic rocks are clearly derived from the previously mentioned rock type; therefore, it is preferred to describe the sheared rock with relation to their parent rocks.

3.4.1 Phyllonite

The term "phyllonite" is given to the rock that macroscopically resembles phyllite but that is formed by mechanical degradation (mylonization) of initially coarser rocks (William,1958 and Spry, 1969). The term used here is preferred to include the rock that originally derived from rather fine-grained rock (phyllite).

In hand specimen, the phyllonite is black, soft and readily split along a predominant schistosity. It often contains deformed quartz lenses (Figure 3.27) in which it occasionally appears as augen which has been stretched along foliation.

Mineralogically, the phyllonite is composed essentially of sericite, chlorite and quartz. The accessary minerals include carbonate and opaque minerals (i.e., iron oxides and pyrite).

Microscopically, the phyllonite texturally resembles a phyllite but it is apparently different in detailed fabric. The foliation is characterized by one prominent direction (Figures 3.28 and 3.29). However, other orientation of foliation has also been observed in the same section. Besides, a predominant foliation is occasionally cut or sheared. A lenticular structure (see Figures 3.28 and 3.29) is found to be a characteristic feature of this rock. A relict of lens of partially recrystallized quartz aggregated is commonly observed. Here it resembles mylonitic rock. Moreover, quartz also exhibits brittle and ductile deformations (Figure 3.30). This phyllonite has also undergone some recrystallization as indicated by coarser-grained sericite.

3.4.2 Schist

Schist was encountered by several drilling holes particularly DDH nos. 1a, 5, 6, 8, 9 and 11. In hand specimen, the rock is light brown to dark gray with well defined schistosity (Figure 3.31) and sometimes shows highly folded. Schist within the sheared zone is partly sheared (see in next paragraph) because it is located toward the outer portion of the shear zone.

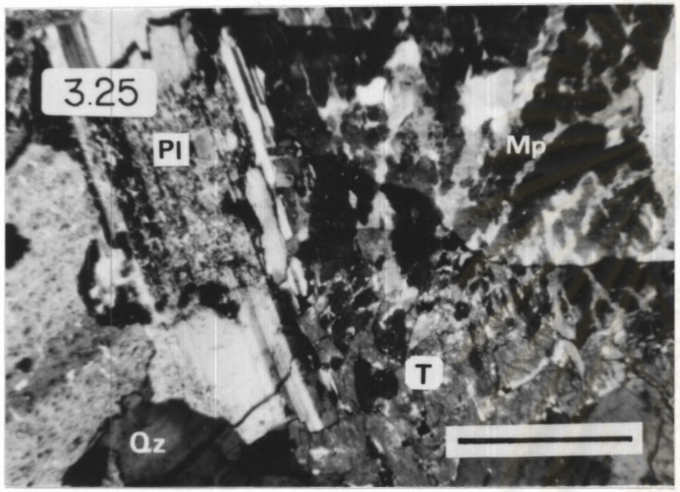
Mineralogically, the schist is composed principally of quartz

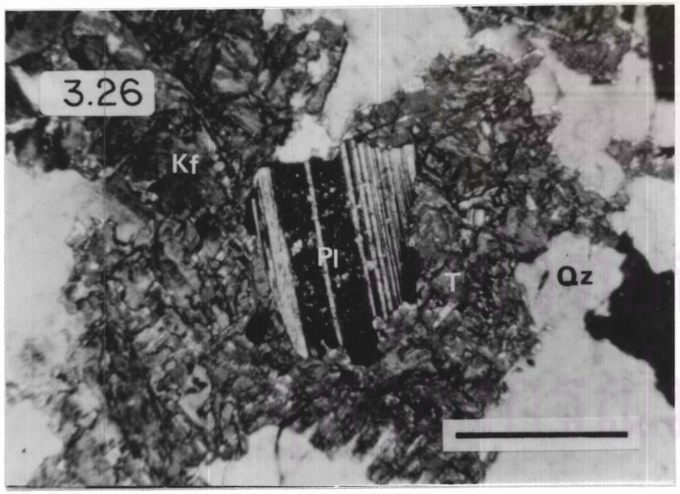
Figure 3.25 Photomicrograph offine-, to medium-grained tourmaline-(±muscovite-biotite) granite showing plagioclase(Pl), micro - perthite (Mp) , tourmaline(T) and quartz(Qz). (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).

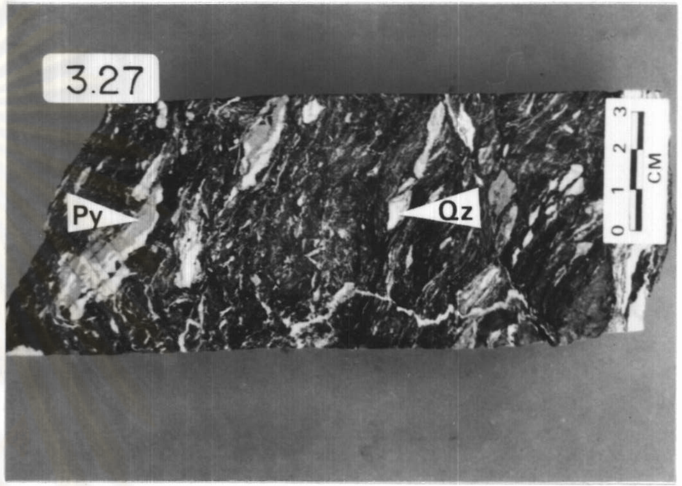
Figure 3.26 Photomicrograph of fine-,to medium-grained tourmaline-(±muscovite-biotite) granite showing K-feldspar(Kf), plagioclase(Pl), tourmaline(T) and quartz(Qz). (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).

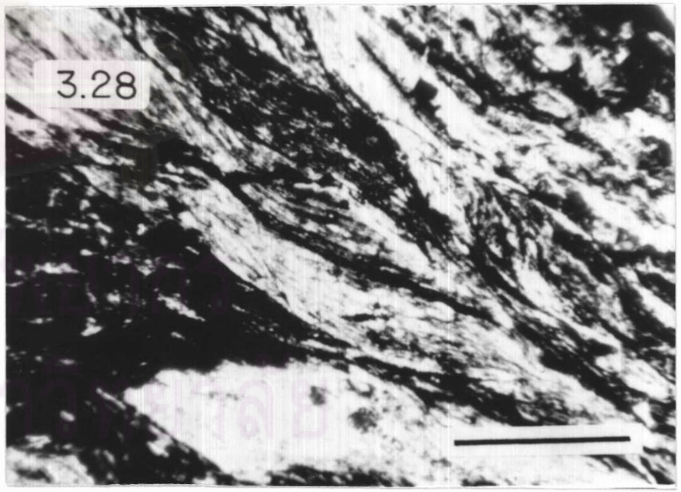
Figure 3.27 Hand specimen of phyllonite showing well developed foliation and also containing quartz lenses (Qz), pyrite (Py).

Figure 3.28 Photomicrograph of phyllite showing lenticular structure particularly at the center of photo. (Bar-scale = 0.23 mm; transmitted light, crossed nicols).


3.25
Pl
Mp
T
Qz


3.26
Kf
Pl
T
Qz


3.27
Py
Qz
0 1 2 3
CM


3.28

with subordinate muscovite, biotite and minor chlorite plus calcite. The accessory minerals consist of tourmaline and opaque minerals. The rock is represented by quartz-muscovite-biotite schist. Quartz generally occurs in quartz-riched layers in association with small flakes of muscovite. Muscovite mainly occurs in mica-riched layers which are occasionally associated with biotite, chlorite and calcite. Biotite forms as tabular crystal. In general, it exhibits as porphyroblasts having yellowish brown to deep brown pleochroism (Figure 3.32). Some biotites show kink banding or bending. Chlorite occurs in small amount and forms as flaky aggregates or patches associated with biotite. Calcite is almost always present. Tourmaline is a common accessary minerals which occurs as anhedral crystal shape.

The schistosity is defined by compositional layering of quartz-riched layers and mica-riched layers. Moreover, the mica-riched layers are often folded (Figure 3.33). The early schistosity (S_1) has been superimposed by the later deformation which produced a strain-slip cleavage (S_2 ; Figure 3.34) resemble that observed in phyllite of metasediment unit mentioned earlier.

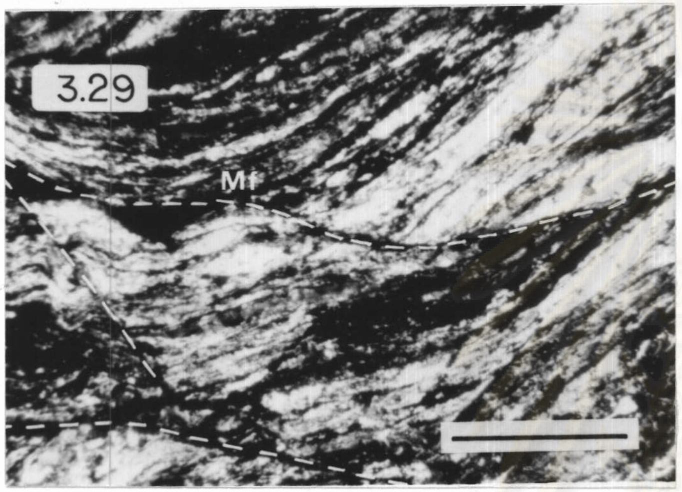
In general, schist is locally affected by shearing. However, it is less deformed in comparison to phyllite and sandstone. Microscopic study shows that quartz also exhibits ductile (Figure 3.35) and brittle deformation as well but the former one is more widespread. Besides, the similar feature is shown by tourmaline where it present. Muscovite and biotite often display kink banding. Particularly, muscovite is strongly crushed (Figure 3.36). The nature of large muscovite crystals in above photo may suggest that the

Figure 3.29 Photomicrograph of phyllonite showing similar structure of that Figure 3.28 and microfault (Mf). (Bar-scale = 0.23 mm; transmitted light, crossed nicols).

Figure 3.30 Photomicrograph of phyllonite showing stretched quartz at the center of photo.(Bar-scale = 0.23 mm ,transmitted light, crossed nicols).

Figure 3.31 Hand specimen of schist showing well developed schistosity. Note the folding (Lower specimen).

Figure 3.32 Photomicrograph of schist showing compositional layering of quartz-riched and mica-riched layers, muscovite (Mu), biotite (Bi). (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).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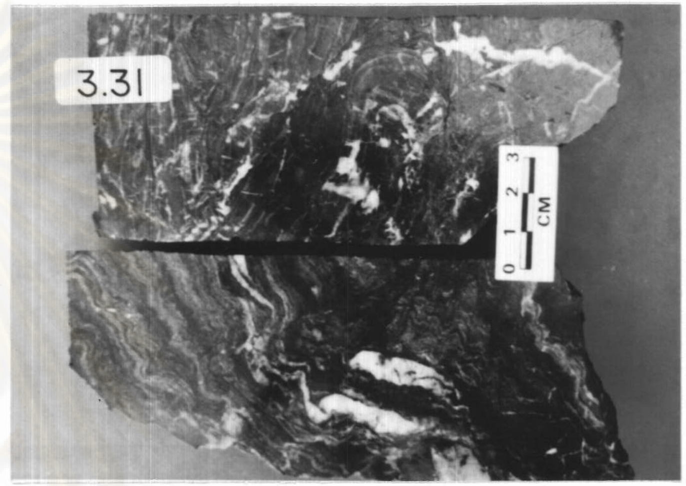
Mf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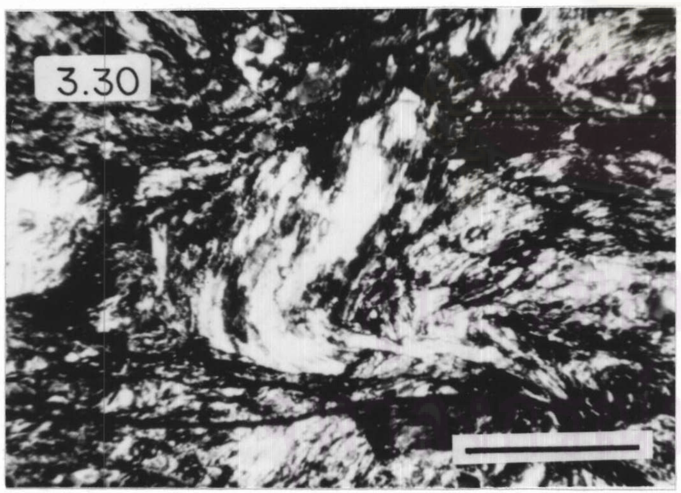
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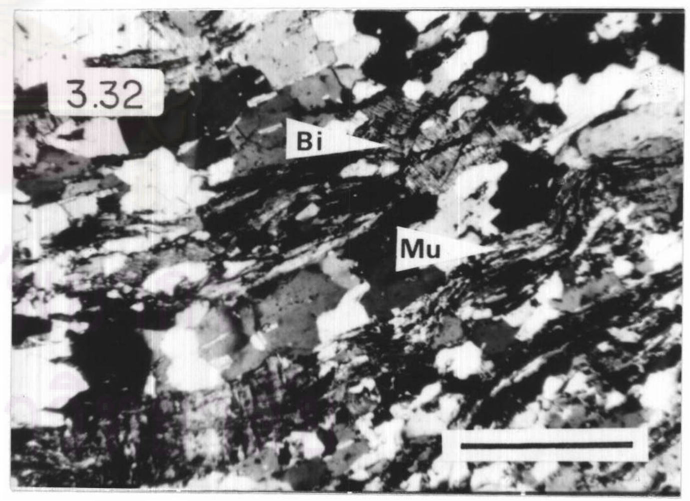
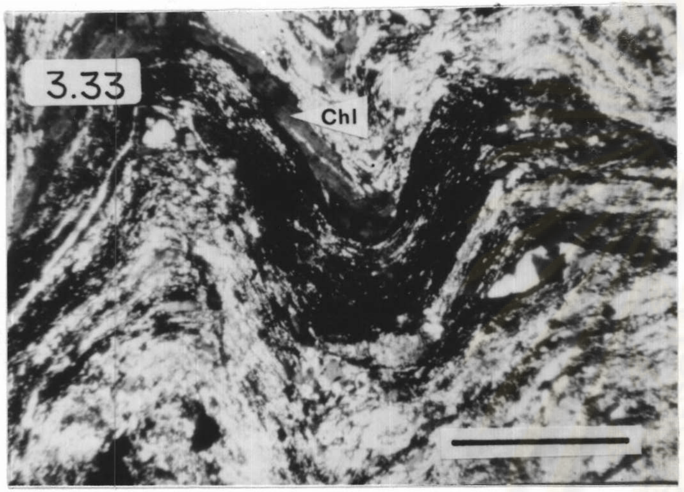

3.32
Bi
Mu

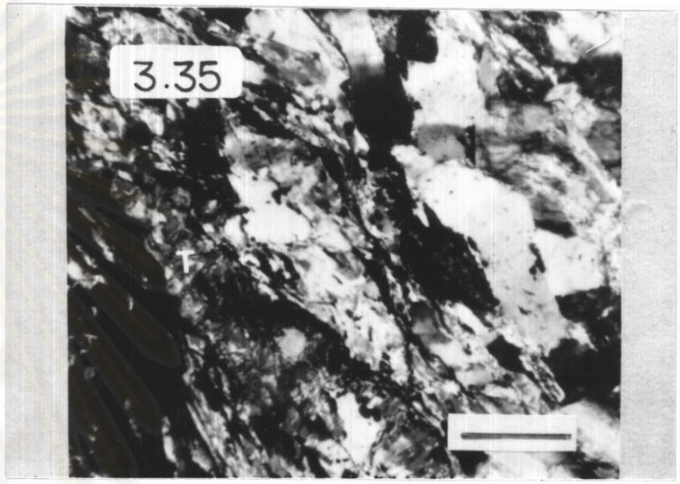
Figure 3.33 Photomicrograph of schist showing folded S_1 (foliation). Note that the abnormal blue is chlorite. (Bar-scale = 0.45 mm.; transmitted light, crossed nicols).

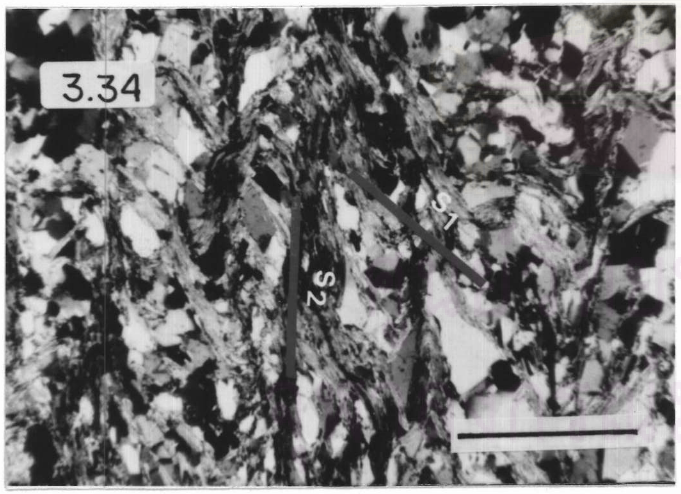
Figure 3.34 Photomicrograph of schist showing S_1 (foliation), S_2 (strain-slip cleavage). (Bar-scale = 0.23 mm ; transmitted light, crossed nicols).

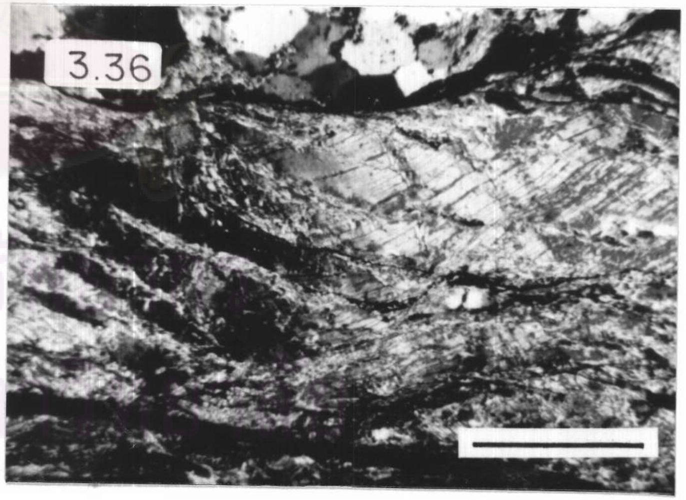
Figure 3.35 Photomicrograph of schist showing tourmaline (T) and quartz (top center) exhibiting ductile deformation. (Bar-scale = 0.45 mm; transmitted light, uncrossed nicols).

Figure 3.36 Photomicrograph of schist showing crushed muscovite marked by set of micro-fractures parallel to long axis of photograph and also shows wavy extinction (left). (Bar-scale = 0.45 mm; transmitted light, crossed nicols).


3.33
Chl


3.35
T


3.34
S1
S2


3.36

schist might have been subjected to thermal recrystallization before shearing.

3.4.3 Sandstone and Stretched Sandstone of Mae Tha Group

Sandstone has been encountered by several DDH, for instance, DDH nos.1A, 1, 2, 3, 5, 8, 9, 11 etc. It generally occurs as lenses of few meters thick down to small lenses of 1 cm. thick (Figure 3.37). They are generally surrounded by phyllonite and/or phyllite. In handspecimen, the rock is hard, tough and resembles silicified sandstone (Figure 3.38) in some places. The color is gray to dark gray, yellowish brown to brown and usually fine-grained.

Mineralogically, the sandstone is composed essentially of quartz, feldspars (microcline and plagioclase) plus small amount of tourmaline. The matrix may consist of clay minerals and the cementing material is mainly iron oxides. Both microcline and plagioclase feldspars are partially altered to sericite and calcite.

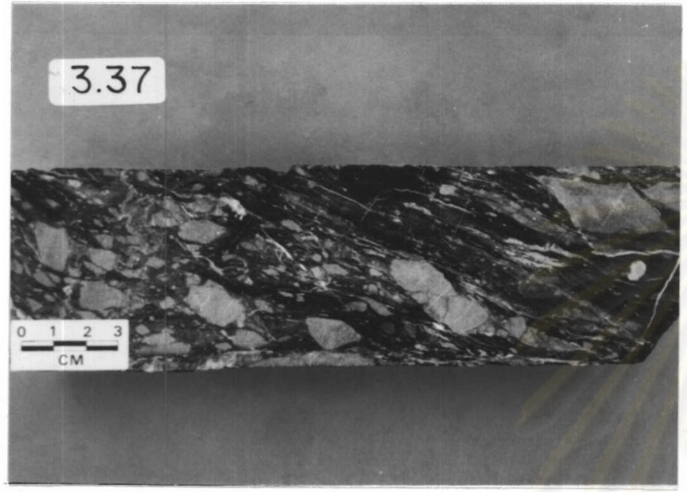
Microscopically, the sandstone is originally fine-grained, moderate to well sorted. However, the rock shows moderately foliated (Figur 3.39) in some samples probably due to earlier regional deformation (Figure 3.39). The sandstone found in the sheared zone is variably superimposed by the cataclastic deformation. It was undergone weakly to highly shearing. Quartz exhibits both ductile (Figure 3.40) and more widely brittle (Figure 3.41) deformation. Feldspars may exhibit a similar behavior as shown by quartz but they are less pronounced. They generally form as elongate grain parallel to the foliated matrix. Slightly recrystallization of crushed quartz

Figure 3.37 Core specimen showing small stretched sandstone lenses surrounded by phyllonitic rock material.

Figure 3.38 Core specimen of stretched sandstone which occurs as thick lens. Bar-scale = 3.5 cm).

Figure 3.39 Photomicrograph of stretched sandstone showing moderate foliation that is marked by preferred orientation of quartz, feldspar grains and partly sericite matrix. (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).

Figure 3.40 Photomicrograph of stretched sandstone showing stretched quartz and partly crushed material (top center).(Bar-scale = 0.23 mm ; transmitted light , crossed nicols).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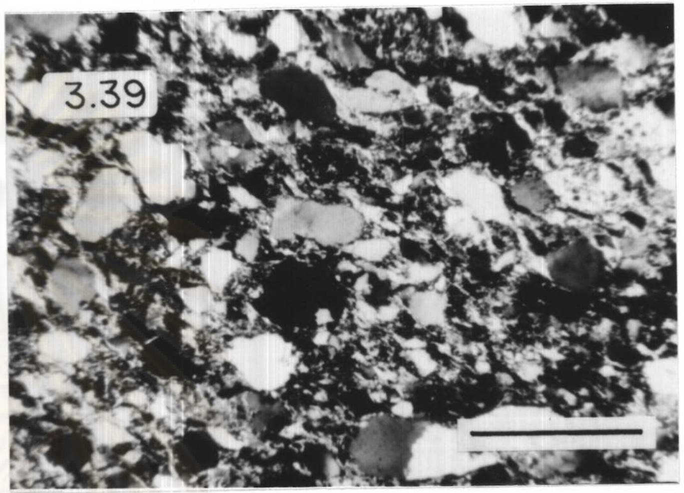
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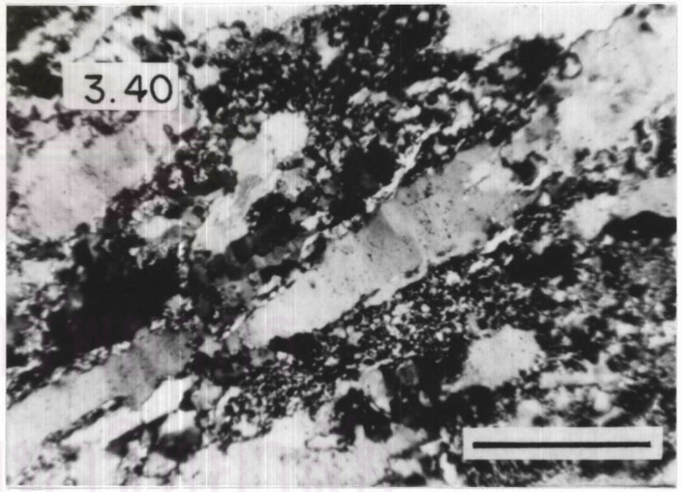
3.38


3.40

has also been observed. The cataclastic deformed sandstone in this area is preferred to call "stretched sandstone" because it has not been so highly deformed to call mylonite or it probably can be called as mylonitic sandstone.

3.4.4 Carbonate Rock

The carbonate rock cropped out on the small hill northeast of the study area. Besides, it was also encountered by several DDH at rather deep, such as DDH nos. 4, 6 and 8. This rock is considered to located within the shear zone as the evidences given in the next paragraph.

In hand specimen, it is light to dark gray, medium to coarse-grained (Figure 3.42). Mineralogically, it is mainly composed of calcite. Other minor associated minerals are microcrystalline, quartz, muscovite and opaque minerals. The rock, however, is apparently undergone some recrystallization and deformation as indicated by the presence of some cataclastic textures, such as kinked cleavage or glide twins (Figure 3.43), stretched calcite (Figure 3.44). Mortar texture has also been observed (Figure 3.45).

3.4.5 Dioritic Rocks

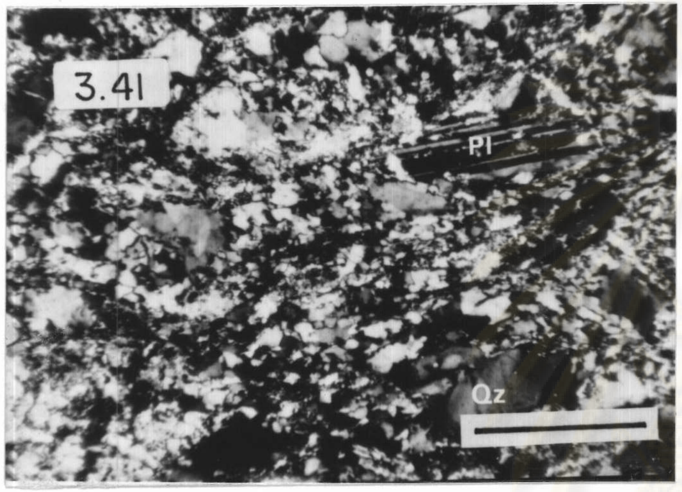
Dioritic rocks are exposed at the north central part of the study areas (see Figure 3.1) along a stream within the sheared zone. Field and drilling core study reveals that the rocks are partly affected by the shearing particularly at the eastern portion of the body . Moreover, at the northern portion of the body, the rocks are slightly foliated. It should be noted that the rocks that were

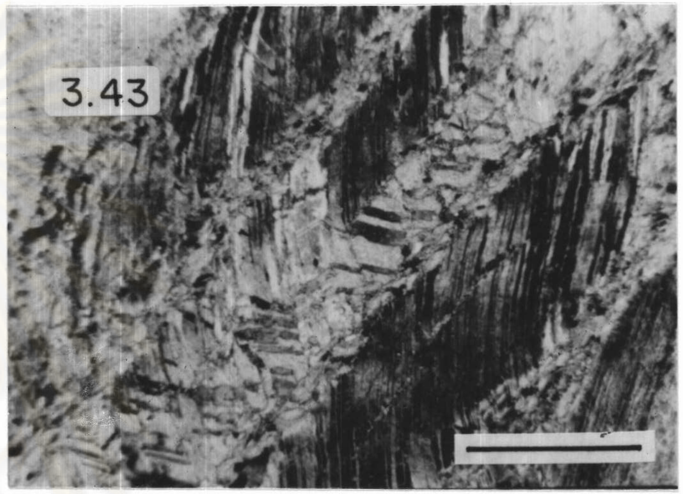
Figure 3.41 Photomicrograph of stretched sandstone showing crushed quartz with some relicts of detrital quartz (Qz), plagioclase (Pl) grains. (Bar-scale = 0.23 mm ; transmitted light, crossed nicols).

Figure 3.42 Core specimen of sheared limestone showing some deformation.

Figure 3.43 Photomicrograph of sheared limestone showing kinked cleavage and partially crushed calcite crystals. (Bar-scale = 0.23 mm; transmitted light, crossed nicols).

Figure 3.44 Photomicrograph of sheared limestone showing stretched calcite. (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).


3.41
Pl
Qz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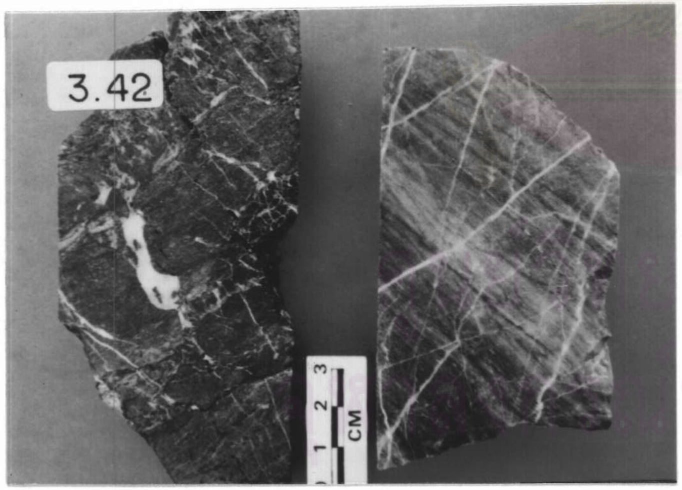
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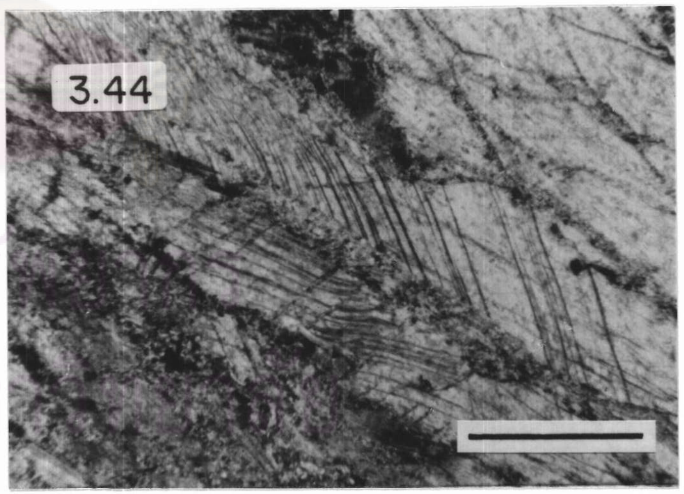

3.44

encountered at further depth by DDH are rather coarse-grained relative to those exposed on the surface, particularly to those of the western portion of the body . Moreover, those were intersected by DDH are generally highly weathered.

Megascopically, the unfoliated diorite is a deep green, fine to medium-grained rock and generally displays inequigranular texture (Figures 3.46 and 3.47). Mineralogically, the diorite is composed essentially of plagioclase, hornblende with minor K-feldspar , quartz and very small amount of biotite. The accessary minerals include apatite and opaque minerals.

Plagioclase generally forms as irregular grain outline. Subhedral crystal is occasionally observed. The grain size is ranging from 0.2 to 0.5 mm. Plagioclase commonly shows albite and albite-carlsbad twins, pericline twin is rare. Zoning in plagioclase is absent. Plagioclase is also forms as poikilitic inclusions in hornblende (Figure 3.48). Much of plagioclase is partially to almost entirely altered to sericite. The alteration may obscure the appearance of twin.

Hornblende is a predominant mafic mineral and generally occurs as anhedral to subhedral crystals with yellowish green to olive green pleochroism. The grain size is ranging from 0.3 to 0.1 mm. in diameter. Pleochroic halo is occasionally found especially in crystal with less visible cleavage. The distribution of hornblende is not uniform through out the section. Hornblende is often altered to chlorite. Some large hornblende crystals contain poikilitic inclusions of plagioclase , biotite and opaque minerals (see Figure

3.48).

Potash feldspar constitutes in small amount and usually forms as irregular crystal outline with average grain size about 0.6 mm. in diameter. It occurs as orthoclase and microcline but the later is less common.

Quartz usually occurs as small anhedral grain with irregular crystal outline filling interstitial among other minerals.

Biotite generally occurs as small flakes and occasionally forms as inclusions in hornblende (see Figure 48). Opaque minerals are commonly found as inclusions in hornblende (see Figure 48), plagioclase and K-feldspar. Opaque minerals mainly occurs as euhedral to irregular grain which is probably magnetite. Apatite forms as minute anhedral to euhedral crystal enclosed by hornblende and plagioclase.

The rock of dioritic composition locally foliates particularly at the northeast margin of the body. In hand specimen, the foliation is generally moderately defined. However, some of them show well defined foliation (Figure 3.49) which is marked by alternating layers or bands of dark and light color minerals.

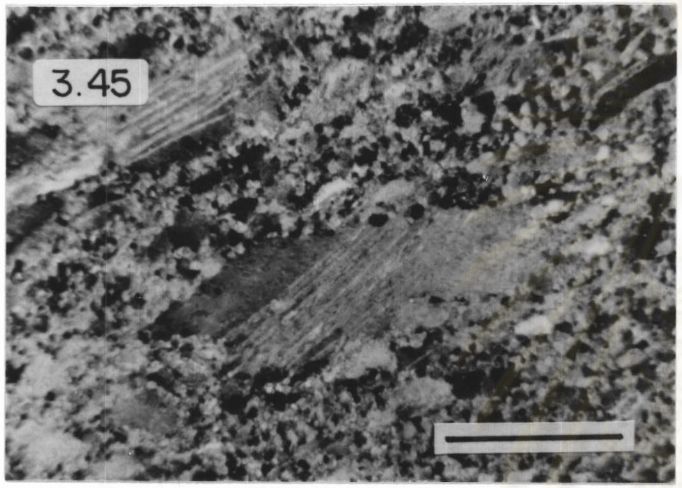
Mineralogical constituent of the foliated diorite is almost the same as that of the unfoliated variety. Under the microscope, the foliation is marked by the preferred orientation of hornblende, plagioclase (Figure 3.50). Moreover, the compositional layerings of hornblende-riched and feldspar - quartz bands are occasionally observed.

Figure 3.45 Photomicrograph of sheared limestone showing mortar texture. (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).

Figure 3.46 Hand specimen of diorite, the left is coarser grained than that of the right.

Figure 3.47 Photomicrograph of unfoliated diorite showing more or less inequigranular aggregate of plagioclase (Pl), hornblende (Hb). (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).

Figure 3.48 Photomicrograph of unfoliated diorite showing poikilitic inclusions of plagioclase crystals (Pl), biotite (Bi) and opaque mineral (O) in a large hornblende crystal (Hb). (Bar-scale = 0.23 mm ; transmitted light, crossed nicols).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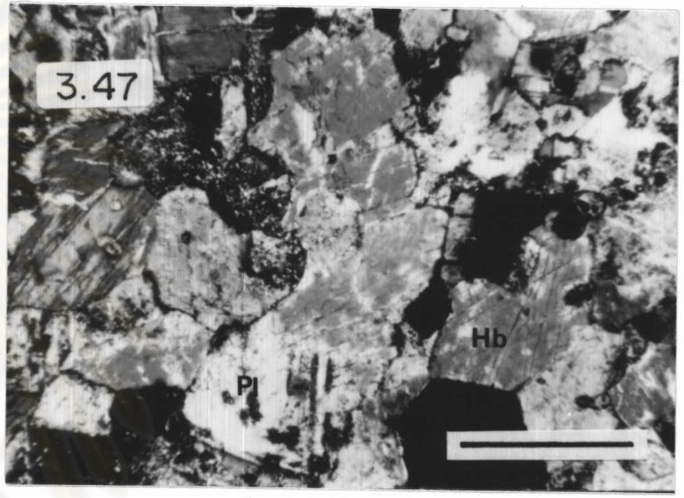
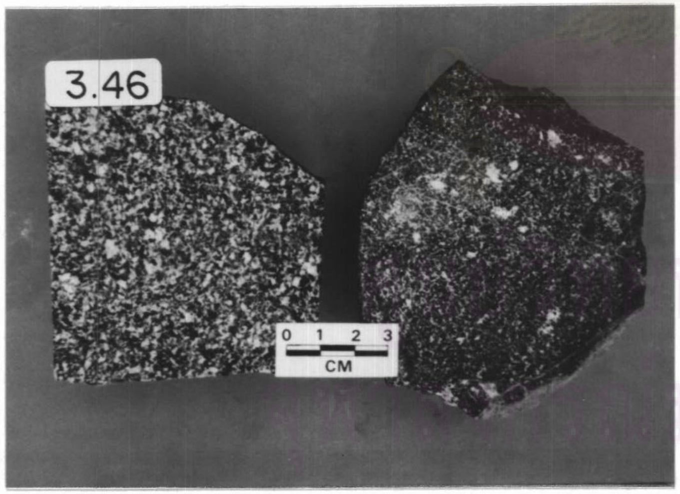

3.47
Hb
Pl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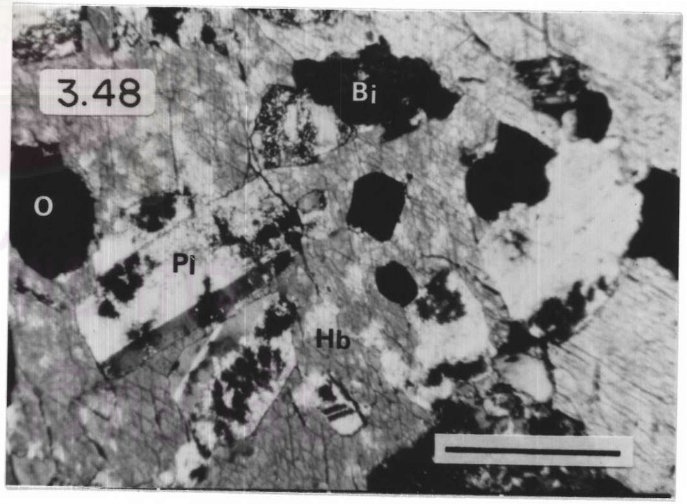

3.48
Bi
O
Pl
Hb

The dioritic rocks that were encountered by some drilling holes e.g., DDH nos.4, 6 and 7 are found to have been subjected to shearing. The evidences are clearly shown undermicroscope by quartz wherever present (Figures 3.51 and 3.52). This sheared rock is classified as protomylonite because it is lesser deformed to be called as mylonite. It should be noted that the rock is highly altered, most of hornblende are altered chlorite. However, some fresh hornblende are also observed.

3.4.6 <u>Sheared Granite (Mylonite)</u>

The granite is intersected by several drilling holes (see Figure 3.3) ranging from a few to several meters thick particularly encountered by DDH nos.2, 3, 5, 9, 12 and 14. Generally, the rock is highly weathered and partly sheared.

Megascopically, it is medium to coarse-grained and varying in color due to alteration, generally pale green to reddish brown. It generally shows weakly to moderately foliated? as defining by dark color matrix and feldspar porphyroclasts (Figure 3.53).

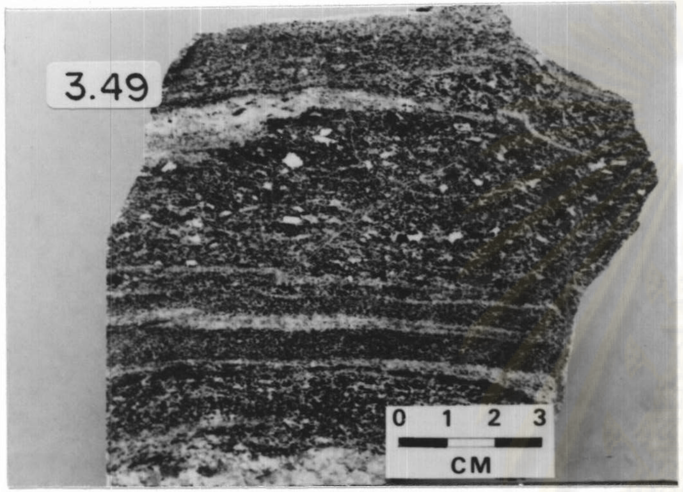
Mineralogically, most of porphyroclasts are feldspar (Figure 3.54) with minor quartz. Feldspars, both K-feldspar and plagioclase, have been partially to completely altered. However, plagioclase is relatively less altered as compared with K-feldspar. Plagioclase occasionally shows kinked albite twins . Quartz generally displays undulatary extinction and mortar texture (see Figure 3.54). Moreover, suture grain boundary is commonly observed. In the highly sheared the rock is classified as mylonite or more prefering to called

Figure 3.49 Hand specimen of foliated diorite showing compositional layering marked by dark and light bands. (each layer is shown in Figure 3.50).

Figure 3.50 Photomicrograph of foliated diorite showing compositional layering of mafic-rich layer and felsic-rich layer. (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).

Figure 3.51 Photomicrograph of protomylonite (shaered diorite) showing crushed quartz (left) and chlorite (ch), chlorite is probably derived from hornblende. It should be noted that the amount of quartz is abnormally high particular in this photo. probably due to later introduction. (Bar-scale = 0.45 mm; transmitted light, crossed nicols).

Figure 3.52 Photomicrograph of protomylonite (sheared diorite) showing undulatary extinction in quartz and also shows hornblende (yellow color). The high amount of quartz is due to similar reason as given by Figure 3.51. (Bar-scale = 0.45 mm; transmitted light, crossed nicols).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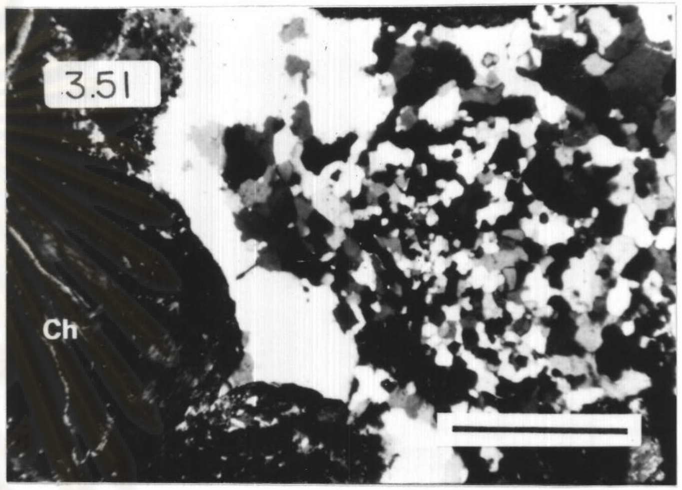
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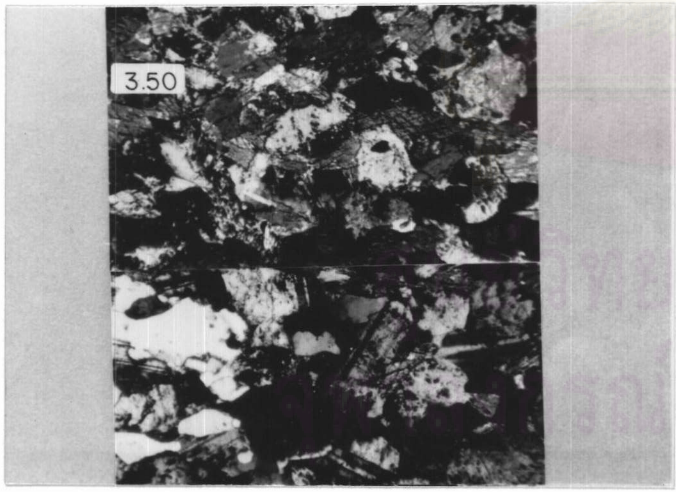
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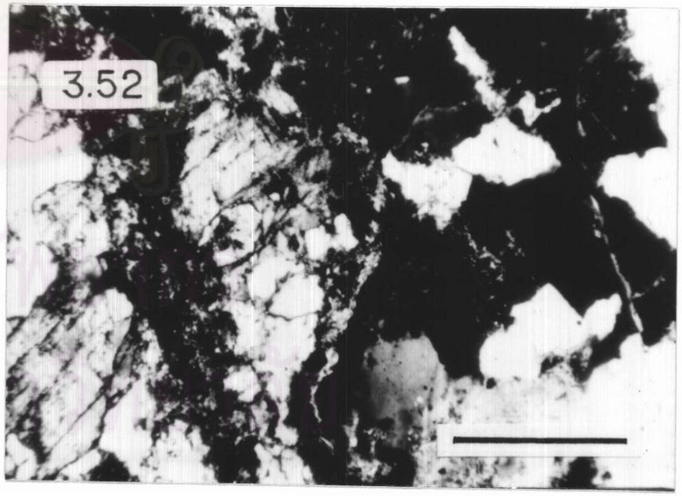

3.52

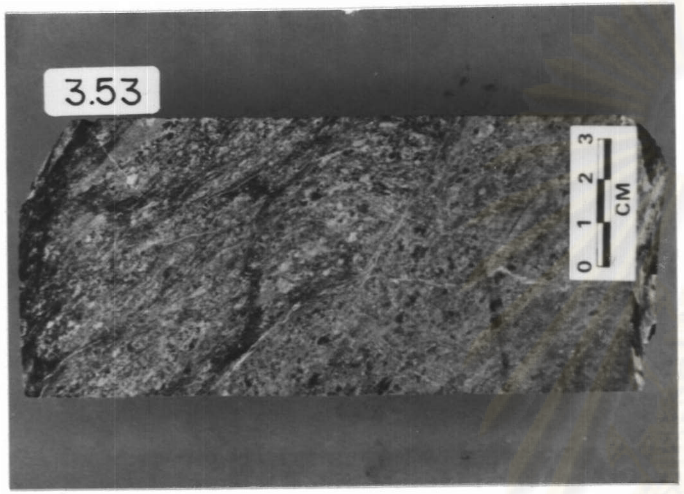
mylonitic granite (Figure 3.55).

This sheared granite might originally be the Khuntan granite that was incorporated into the thrust zone and has been overprinted by cataclastic deformation.

Figure 3.53 Hand specimen of mylonitic granite showing poorly defined foliation marked by preferred orientation of chlorite?, feldspar porphyroclasts .

Figure 3.54 Photomicrograph of mylonitic granite showing crushed quartz (top) and augen of feldspar (F). (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).

Figure 3.55 Photomicrograph of mylonitic granite showing that most porphyroclasts are feldspar (F). (Bar-scale = 0.45 mm ; transmitted light, crossed nicols).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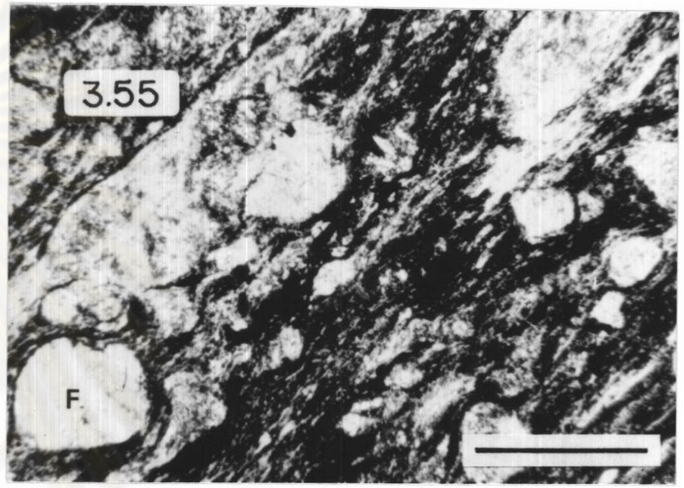
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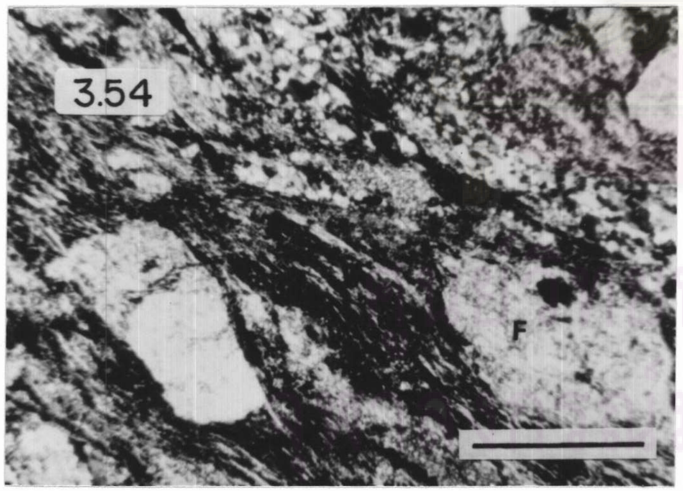
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