

CHAPTER IV

ROCK UNITS OF THE STUDY AREA

This chapter is devoted to the stratigraphic correlation in the study area. The objective of this study is to gain the further insights into the general geology, and into the relationship between the rock types distribution and the structures.

In the present investigation, an attempt had been made to classify the sedimentary succession which composed mainly of limestones and subordinate argillaceous rocks, and bedded chert with the minor amount of fine-grained sandstones, and to identify the related igneous rock rocks. The observation was done on the rock types exposed in the field. The sedimentary rock samples were also collected and about 270 thin-sections were prepared for the study of their petrographic characteristics and essential mineral composition.

4.1 Classification of the Rock Types

The substantial classifications of the different rock types are as followed.

4.1.1 Limestones Classification

The classification of the limestones to be used in this study was described previously by Folk (1959). The reason of using Folk's classification system is merely to have it be coincided with that using in many previous works. In this classification system,

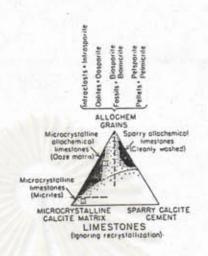
Folk divided the carbonate rocks into four main classes (Figure 10). The first two classes include the rocks composed largely of grains (allochem), termed the allochemical limestones. One of which is dominated by the sparite cement, the other by the micrite matrix. The third class is for the rocks lacking of large observable grains, termed the orthochemical limestones. This third group includes the micrite lime-mud carbonates. The fourth class is for the rocks made up of the in situ skeletal fabrics. For this last group, the autochthonous reef rocks includes the biolithites.

4.1.2 Classification of Argillaceous Rocks

potter et al. (1980) proposed a classification of the fine-grained sedimentary rocks, based on the features of genetic significance, grain size and stratification as shown in Table 2. The classification of these rock types is done using the tetrahedron scheme (Krumbein and Sloss, 1963). In this tetrahedron, the quartz vertex represents the sandstone, the clay vertex, the shale, the carbonate vertex, the limestone, and the chert vertex, the chemically formed silica sediments. The four sides of the tetrahedron are established into four triangular diagrams to show the variations of rock types with the different proportions of the fundamental constituents (Figure 11).

4.1.3 Sandstone Classification

The classification systems for the sandstones are those of modified Pettijohn's (1954, 1957) (Figure 12 a), of modified Dott's (1964) (Figure 12 b), and of Folk's (1968) (Figure 12 c).



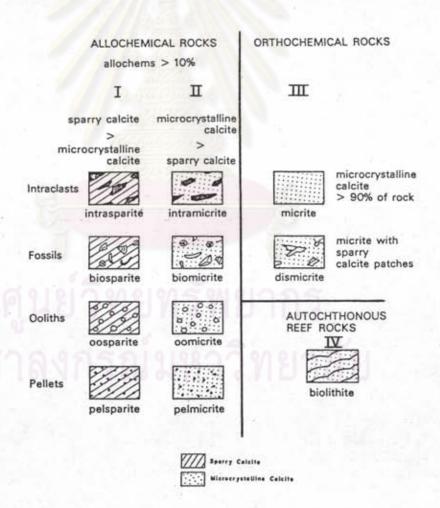


Figure 10 Graphic classification table of limestones (After Folk, 1959).

Table 2 Classification of argillaceous rocks (After Potter et al., 1980)

Percentage clay-size constituents			6-32 33-65		66-100	
Field Adjective			Gritty	Loamy	Fat or Slick	
MONIMOUNATED	Beds	Greater than 10 mm	BEDOED	BEDDED	BEDDED	
BUNNING	Less than 10 mm		LAMINATED SILT	LAMINATED MUD	LAMINATED CLAYMUD	
INDURATED	- Beds	Orsaler Ihan 10 mm	BEDDED	MUDSTONE	CLAYSTONE	
	Less than 10 mm		LAMINATED SILTSTONE	MUDSHALE	CLAYSHALE	
DEED		POW	QUARTZ ARGILLITE	ARG	ILLITE	
METAMORPHOSED		of metam	QUARTZ SLATE	SL.	ATE	
MET		В НІСН	PHYLU	TE AND/OR MICA	SCHIST	

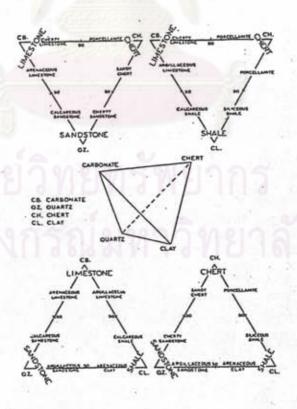


Figure 11 The fundamental tetrahedron for the carbonate-quartz-chert-clay system (After Krumbein and Sloss, 1963).

Cement or motrix		Detrital matrix exceeds 15% Chemical cament obsent		Detritol matrix less than 15%. Voids empty or filled with Chemical cement						
oction	Noch frequents Feldapor exceds exceeds felds rock frequents	Felesosmic groywocke		Arkesic Arkese	Orthoguerizites	Chert <5%				
Send or defrifel fraction		Graywae	Lithic graywocks	Lithic Subgraywocks	Sandstones Prologuartziles	Orthog	Chert > 5%			
	Ouartz content	Vo	rioble; generally <75%	< 75%	>75% <95%		> 95%			

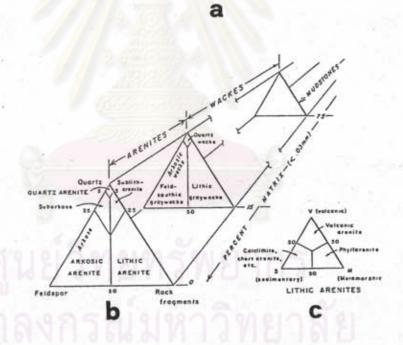


Figure 12 The sandstones classification systems.

(a) System proposed by Pettijohn(1954,
1957); (b) Classification of terrigeneous
sandstones (Pettijohn, 1975 modified from
Dott, 1964); (c) Subdivision of lithic
arenites (After Folk, 1968).

According to Pettijohn's system, the sandstones are defined into several classes in terms of the proportion of detrital quartz, feldspar, and rock particles and on the presence or absence of an interstitial matrix. Those with 15 or more percent matrix constitute the "wacke"; those with less matrix are the "ordinary" (ortho) sandstone. In Dott's classification, three main families are definded as:(1) those in which quartz from 95 or more percent of the framework fraction, the quartz arenites (orthoquartzites); (2) those containing 25 or more percent feldspar which also exceeds the rock particles, the arkoses; and (3) those characterized by over 25 percent of the rock particles, the lithic sandstones (lithic arenites). The subclasses are also defined within the major families. These are, for examples, subarkoses, and sublithic sandstones or arenites. The lithic arenites class is subdivided according to Folk (1968) on the basis of the type of the rock fragments presented. The dominant rocks in the group are the graywackes, of which there are two further important subdivisions, the lithic graywackes in which the quantity of the rock particles exceeds that of feldspars, and feldspathic graywackes if vice versa. The quartzwackes are a relatively minor and rare class within the wacke group.

4.1.4 Volcaniclastic Sediments Classification

The coarse-grained volcaniclastic sediments, volcanic breccias and agglomerates are composed largely of the rock fragments or bombs. These of the medium-grained, the tuffs, consist of glass, mineral crystals or crystal fragments, and rock particles. They may therefore be classed according to the proportions of these components

(Figure 13 a). The further subdivision of the various possible mixtures may follow as in Figure 13 b (Pettijohn, 1975).

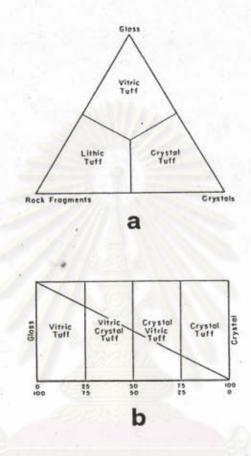


Figure 13 The tuffs classification system. (a) Nomenclature and classification of tuffs, (b) Further nomenclature and classification of vitric and crystal tuffs (After Pettijohn, 1975).

4.2 Sedimentary Rock Units

In the field investigation, the successive stratigraphy is generally described by the rock types of the units and subunits, the conformable relationship between the units, the associated fossils, size of beds (Table 3), etc.. According to the work of Hinthong (1981), the rock units of Ratburi Group which expose in the present study area are Phu Phe, Nong Pong, Khao Khad and Sap Bon formations and the igneous rocks from Khao Yai Volcanics and

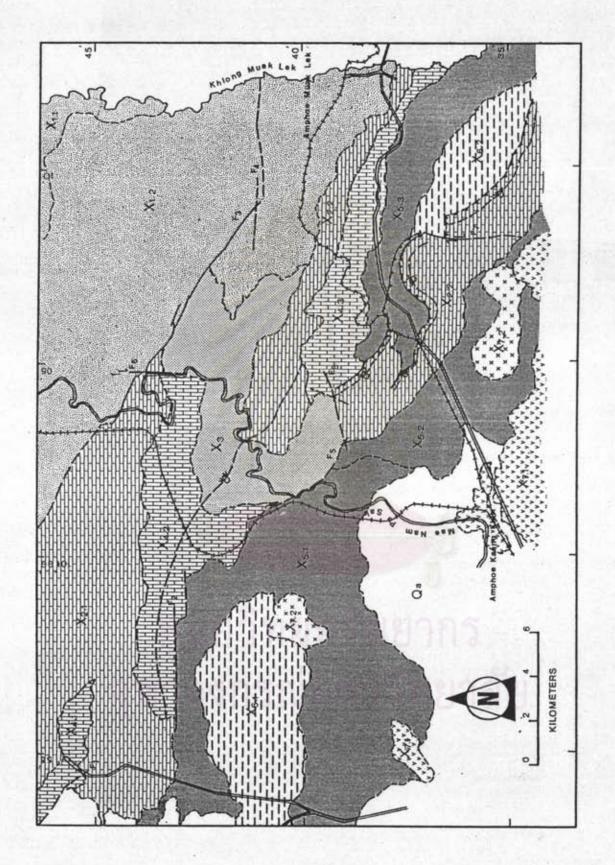
Phra Ngam Diorite. However for some suitability, according to the field observation by the present writer, the sedimentary rocks in



Table 3 Classification of Bedding Thickness
(After McKee and Weir, 1953,
Modified by Ingram, 1954.)

	very thick-bedded
4///	thick-bedded
Beds	— 30 cm (about 1 ft)—
Deas	10 cm (about 4 in.)
	thin-bedded 3 cm (about 1 in.)
656	very thin-bedded 1 cm (about 34 in.)
	laminated
Laminae	thinly laminated 10 in.)

the study area were re-grouped, from the oldest to the youngest, according to the lithologic and physical features, stratifications and structures into six informal units, X1 to X6. Each units were further subdivided into members as illustrated in Figure 14, totally 13 members. The subdivision was attempted wherever the extent of the rocks is obvious. The X1.1 and X1.2 members in this study are equivalent to Nong Pong Formation of Hinthong (1981) except the Southern part of X1.2 which is a part of Pang Asok, the southern part of X2.2, Phu Phe Formation, the southern part of X5.1 together with X5.2, X5.3 and X6.2, Sap Bon Formation, and all the rest, Khao Khad Formation.



Geologic map of the study area showing the extention of 13 rock members. Figure 14

EXPLANATION

Sedimentary rock

Alluvial gravel, mund, silt, and clay of floodplain and swamp deposits.

UNCONFORMITY

QUATERNARY

Qa



X61.X62

Shales, limestones with siltstone and chert interbeds.

Shales may be calcareous or silty, brown, medium gray to black. Limestones: micrite and pseudosparite, some with fossile, thin to medium bed, medium to dark gray.

Siltatone: reddish brown to brownish gray. Bedded chert: brownish gray to black. Fossils: fusulinids and crinoid stems.



X51.X5.2.X5.3

Limestones, shales and bedded chort with some sandstones. Limestones: pseudosparite and micrite, some with fossils, thin to massive bed, medium gray. Shales: oftenly calcareous or slaty, brown, medium to dark gray. Bedded chort: brown to black, partly porcellanite. Sandstones: graywacke, quartz arenite and quarts wacke, fine—to medium—grained, thin bed, brown to medium gray. Fossils: fusulinids and crinoid stems.



X41.X4.2.X4.3

Limestones with less interbeds mudstone, shales, sandstones, siltstone, and porcellanite. Limestones: micrite to pseudosparite. Some with fossils, medium to massive bed, medium gray, with few chort nodules. Hudstone: brown to medium gray. Shales: may be calcareous, brownish gray to black. Sandstones: quartz wacke and lithic wacke, fine—to medium—grained, thin to medium bed, brown to medium gray. Siltstone: calcareous gray. Porcellanite: brown to light gray. Fossils: fusulinids, corals and crincid stemm.



Xa



X21-X22

Limestones:micrite, pseudosparite, some with fossils, medium to massive bed, light to dark gray shale in the lower part. Fossils: fusulinids and crinoid stems.

Limestones with mudstone and intercalated tuffs with mudstone some with fossils pellets or interclasts in part dolomitized medium to massive bed, medium gray with chort bands and nodules. Fossils: fusulinids, corals and crinoid stems.

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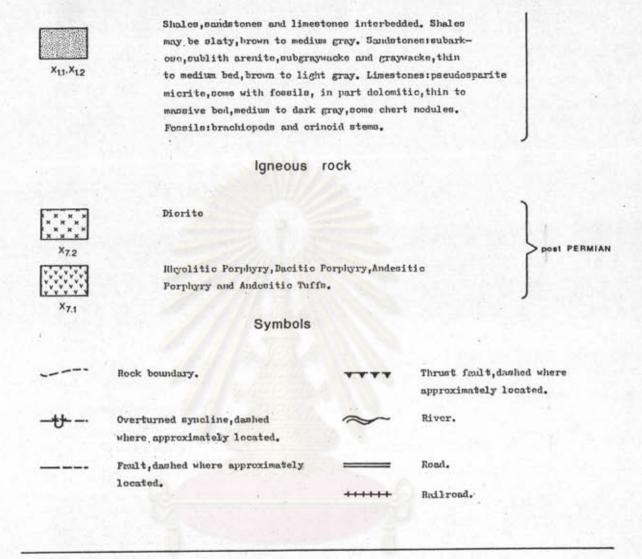


Figure 14 cont.

4.2.1 Rock Unit Xl

This rock unit is the lowest of the stratigraphic succession and exposed in the northeastern part of the area. The physiographic feature is commonly observed to be gently to moderately rolling hills. The bedding planes mostly incline to the southern directions though the dipping into the other directions is not rare. From the field investigation, the outcrops are poorly exposed. However, the lithologic section was carefully measured. The X1 rock unit is subdivided further into two members, namely, X1.1 and X1.2 members (Figure 15).

4.2.1.1 X1.1 Member

The X1.1 member, the lowest member of the lithological sedimentary succession study area, is characterized by light to medium gray, yellowish brown and brownish gray shale and light to medium gray brownish gray and yellowish brown, and thin— to medium-bedded subarkose and sublith—arenite. They are interbedded with medium to dark gray and thin— to medium bedded pseudosparite, micrite and biosparite. The thickness of this member is approximately 236 meters. The unit was found to be distributed throughout to the northeastern part of the area. The body outline of this member is considered to be tabular with a varying thickness. As the outcrops are poorly exposed, the lithological characteristic of the member is accordingly limited. No attempt has been made to further subdivide this member into the smaller lithostratigraphic units.

4.2.1.2 X1.2 Member

The X1.2 member conformably overlies the X1.1 member with a gradational continuous contact. The lithology of this member is characterized by mostly medium gray, medium— to massive—bedded micrite, pseudosparite, biomicrite, biosparite and dolomitic biosparite, and yellowish to reddish brown, light to medium gray, greenish gray and gray shale and slaty shale, and yellowish and reddish brown, brownish gray and light to medium gray, thin— to medium bedded and fine— to medium grained subgraywacke and graywacke. Though the outcrops are so scatterred, the thickness was approximated to be 528 meters.

4.2.2 Rock Unit X2

This rock unit overlies the Xl unit, partly with a continuous gradational contact and partly a fault contact (F3-fault in Figure 14). The physiographic feature is composed mainly of moderate to high ridges with the valleys. The bedding planes, striking parallel to the ridge trend, and mostly dipping from southeast to southwest, some from northwest to northeast. The outcrops are generally sparse because of a very high degree of weathering. This rock unit is composed mainly of limestones and dolomitic biosparite. The ridges trend east-west in the western part and slightly change the course to southeast-northwest in the eastern part of the area. The varying thickness of the unit is approximately 700 - 745 meters. The limestones always contain the chert bands, chert nodules or lenses, with the igneous dikes and sills. The fossils, corals, crinoid stems and fusulinids, were only found in the chert.

Description	Linestones interbedded with shale, slaty shale and sandstone. Linestones:micrite, pseudouparite, biomicrite, biosparite and dolomitic biosparite, medium to massive bed, medium grey, chert nodules. Shale and slaty shale: yellowish and reddish brown, greating grey, and light to medium grey. Sandstone: fine-to medium-grained, medium bed, yellowish and reddish brown, and light to medium grey. Shale interbedded with sandstone. Shale: yellowish and reddish brown, brownish grey and light to medium grey. Sandstones: subgraywacke and gray. Sandstones: subgraywacke and light to medium grey. Sandstones: subgraywacke and light trey. Limestones interbedded with shale and sandstone. Limestones interbedded with shale: yellowish brown and closhing grey. Sandstone: fire-to medium-grained, thin to medium bed, reddish brown and light grey. Fossila: brachiopods and orinoid stems. X1.2 MBR.
ГітһоІоду	
Description	Limestones interbedded with shale. Limestones: pseudospurite and miorite, thin to medium bed and andium to dark grey. Shale: brownish grey and light to medium grey. Shale: yellowish brown, brownish grey and light to medium grey. Sandstone: fine-to medium-grained, thin to medium prey. Limestones: psoudosparite, and light to medium grey. Limestones: psoudosparite, escrite and biosparite, thin to medium bed and medium to dark grey. X1.1 MBR.
Lithology	
Thickness (m)	300 200 100

.5 Stratigraphic columns of XI:1 and XI.2 members.



Figure 16 The subgraywacke of X1.2 member at the grid reference 32682429, east of Ban Sap Pradu.





Figure 17 The slaty shale-sandstone interbeds of the X1.2 member at grid reference 32072173, north of Khao Chan.

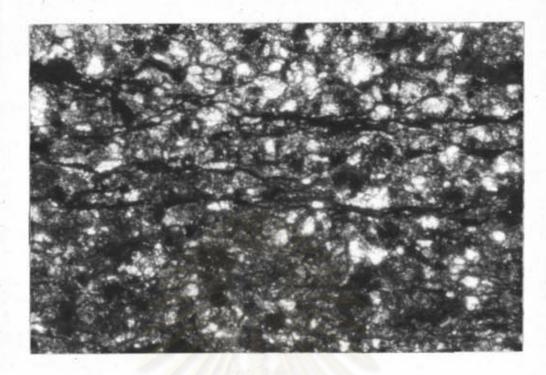


Figure 18 Photomicrograph of subgraywacke of X1.2 member at grid reference 34912547, west of Khao Sawang. (45x, crossed nicols)

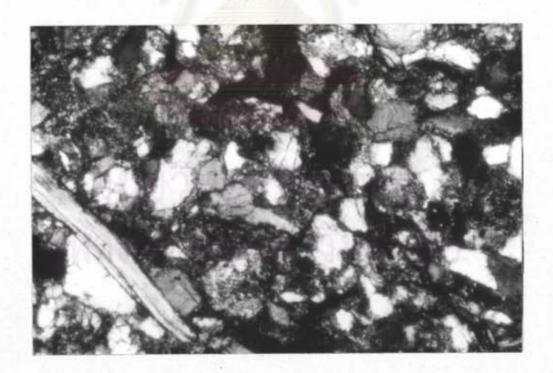


Figure 19 Photomicrograph of graywacke of X1.2 member at grid reference 32182407, east of Ban Sap Pradu. (45x, crossed nicols)

The dolomitic biosparite layer in this unit is used as a marker bed. The X2 unit is subdivided into X2.1 and X2.2 members on the basis of lithology and the separated locations of rock distribution as shown in Figure 20.

4.2.2.1 X2.1 Member

The X2.1 member overlies X1.2 member with a fault contact, the F3-fault (Figure 14). The orientation of the strata is rather uniformed, dipping southward. The lithology of this member is characterized by medium gray, thick—to massive bedded micrite, pseudosparite, biomicrite, biosparite, biosparite, biosparite, parite, pelmicrite, intramicrite (?) and dolomitic biosparite, with chert bands and nodules, and yellowish green and greenish gray mudstone. The fossils of fusulinids, corals and crinoid stems are preserved in the chert. The outline of this member is considered to be a large lense-shaped body. The maximum thickness of the member is approximately 745 meters while the length is about 17 kilometers.

4.2.2.2 X2.2 Member

The X2.2 member conformably overlies the X1.2 member with a continuous gradational contact. The member mostly inclined to the south. The lithology of this member is characterized by medium gray, medium bedded micrite, pseudosparite, biomicrite, biosparite, dismicrite and pelmicrite, and yellowish and brownish green, yellowish gray and medium gray mudstone, and pale green, green and red tuff layers. The fossils of corals, fusulinids and crinoid stems were observed to be contained in the

chert. The outline of the member is considered to be tabular and the total thickness is 700 meters.

The tuff layers associating the limestone are especially useful. The layers are thinly laminated to medium bedded and are clearly recognized only in the X2.2 member. The outcrops containing the volcaniclastic layers could be observed near Khao On, Khao Mai Nuan, Khao Phu Phe, Khao Lom Phat, Khao Tham and Khao Nam Tok.

The tuffs were thought to be originated by a sedimentary process.

They were embedded and interbedded parallel to the limestone beds in a single zone, 5 to 30 meters thick. These tuffs are petrographically classified to be vitric, crystal and lithic tuffs, and mostly modified to be vitric crystal and crystal vitric tuffs.

Moreover, they are used as an important marker bed in this rock region.

4.2.3 Rock Unit X3

The rock unit of X3 is recognized to be the most complex unit. It overlies the X1.2 member with both a fault (F3 - fault) contact and a continuous gradational contact, and underlies conformably the X2.2 member with a mixed gradational contact as observed in a location south of Khao Pha Daeng. The physiographic feature is generally mountatineous with Khao Pha Daeng, Khao Hin Dat and Khao Hin Pun. The bedding planes mostly inclined to the southwest directions. The lithology is characterized by light to medium gray, thick- to massive bedded micrite, preudosparite, biomicrite and biosparite, and dark gray to black shale. The general outline is determined to be lenticular. The thickness of approximately 752 meters is measured for the unit.

No attempt has been made to further subdivide this rock type into the smaller lithostratigraphic units. In the present study, the rock unit X3 is also called the X3 member to be conincided with the members of the other units (Figure 20).

4.2.4 Rock Unit X4

This rock unit mixes complicately with the rocks of X2 and X3 with a mixed gradational contact. The physiographic feature composed mainly of moderate to high ridges with valleys. The beds mostly dip to the south and southwest directions. The outcrops are generally poor. The rock type of X4 is subdivided into 3 equivalent members, the X4.1, X4.2 and X4.3 members based on the lithology and their separate locations (Figure 31). The varying thickness is from 94 to 491 meters. The outline of these members are both lense- and tabular shaped.

4.2.4.1 X4.1 Member

The X4.1 member is lense-shaped and lies within the X2.1 member with a mixed gradational contact. The outcrops are clearly exposed at the road cut on Highway 21 between Kilometers 11 and 12. The lithology is generally characterized by the yellowish gray and medium gray, medium bedded micrite, dismicrite, biomicrite and pseudosparite with some chert nodules, light to medium gray calcareous shale, yellowish and brownish gray, to light gray calcareous siltstone, yellowish and greenish gray, light to medium gray, thin bedded mudstone, and yellowish and brownish gray, mostly light gray and fine-grained quartz wacke and lithic wacke. The section is measured to be approximately 94 meters thick.

Description	Aserte, 36 Sellecte Postilati	Libertones to court, Pestinitutistics. Libertonesizzerite and biceserite, sedium to massive miturity, pesudomparite, sedium bed, sedium to dark bid grey and black. Shale interbession vith learnated libertones, Shale:	dark grey to black and calcite vendets, Limestoness signifies and providenges to, sentiue bed, and sendiue to dark grey and black. Linestones presidenges to, excertto, Morpasito, thick to	Asserve bad,seeding to dark groy and rare chart. Passilationalizade and exists elect.	X3 MBR.
Гігрогоду					
Description	Lisestans interheded and internalated with sudatons. Lisestans pseudomyarits, biomicrits is and part and rays of rays of rays dert. Nadatonstyphicutes and brownesh green, and sedium grey.	Linestones intermisted with sudstate. Linestones: storite, prosudosparite, biometrite, biometrite this to seedies for seedies from grey. Butstanes greenish brown, yellowesh grey and sedius grey.	Limestoneers for the presidentalite, blosforite, blongar- ite "destortte, sedius is seasive bed, sedius prry, sher hade and sodules. Persilar carals and fresilands.	Lisestones:us.crite.biomicrite,biomparite,dolomitic biomparite and dismicrite,sedium to manatum bed, sedium gray and tuffb layars in some mod. regions, and chert hands and modules(fossile in chert). Possile:fundinide and crimoid etems.	X2.2 MBR.
Γίιμοιοσλ					,
Description	Lisestanss interhedded and invertuiated with sudatone. Lisestansstministration parties, biomicalite, palmicalite and delonatite biosparate, seekinn to thick bed, pedius proyabert bands and nodules. Rudatonerthia bed, yellowish grantard gray, Possilerflundinids and extent.	Linestonesimicritis, paradosparitis, biomicritis, biomicritis, biomaritis, biomaritis, biomaritis, biomaritis, biomicritis, endium to think bed, and inclina gray, chart hants and modules (fostita in chart). Passizationalinida, crinoid stema and corais.		innormaterite, presidentarite, biemicrite, biemes- desparit, thick to examine bed and redding gry. Nucleosestylliers by green and greenish gry. Tessils: fundinide, cornis and crimoid stons.	Х2.1 МВЯ.
Гііроіоду					
Thickness (m)	80	807	909		900

Figure 20 Stratigraphic columns of X2.1, X2.2 and X3 members.



Figure 21 Strings of chert nodules and lenses developed parallel to the beds of limestone of X2.2 member at grid reference 32483103, Khao Chan.



Figure 22 Chert nodules, lenses and bands developed parallel to the beds of limestone of X2.2 member, grid reference 29161409, Khao Tham.

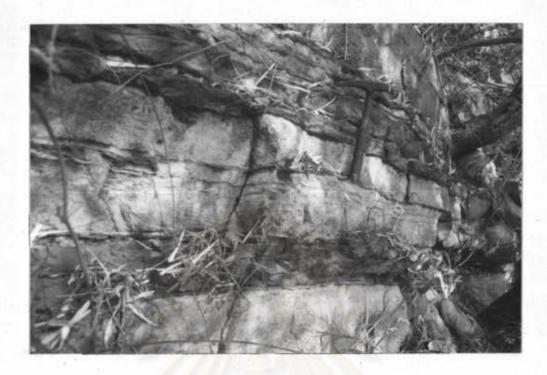


Figure 23 Tuff layers interbedded with biomicrite of X2.2 member at grid reference 21561958, Khao On.

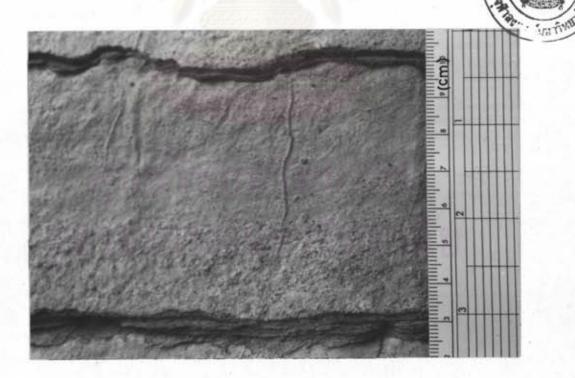


Figure 24 Tuff layers interbedded with biomicrite of X2.2 member at grid reference 28121669, Khao Phu Phe.



Figure 25 The fusulinid in X2.1 member at grid reference 20383039, Khao Nong Thom.



Figure 26 The crinoid stem (?) in X2.2 member at grid reference 32692084, Khao Chan.

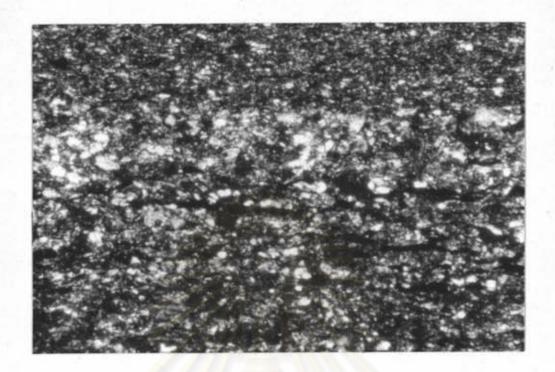


Figure 27 Photomicrograph of calcareous shale of X2.1 member at grid reference 05903270, beside Highway 21. (45x, crossed nicols)



Figure 28 Photomicrograph of the typical dolomitic biosparite of X2.1 and X2.2 members.

(45x, crossed nicols)

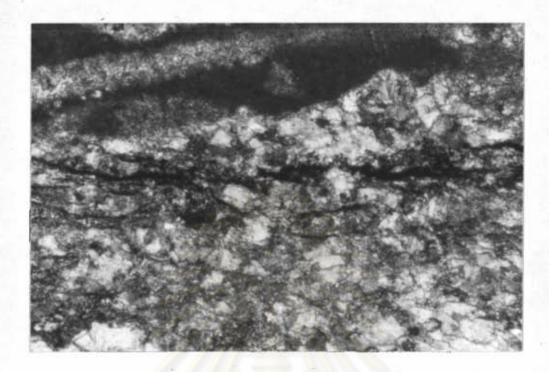


Figure 29 Photomicrograph showing the stylolytic seam in biomicrite of X2.2 member at grid reference 34422062, Khao Makok (45x, crossed nicols).



Figure 30 Photomicrograph of micrite of X3 member at grid reference 19662150, Khao Pun (45x, crossed nicols).

4.2.4.2 X4.2 Member

The X4.2 member is rather of elongated lense-shaped or tabular shaped. This member conformably overlies the X2.1 member with a mixed gradational contact, and underlies the X3 member with an abrupt contact. The lithology of this member is commonly characterized by yellowish and brownish gray, mostly medium— to thick bedded micrite, pseudosparite, and biomicrite with some chert nodules, yellowish brown to yellowish brownish and greenish gray mudstone, and dark gray to black calcareous shale. The fossils of fusulinids, crinoid stems and corals are also observed. The thickness of the member was measured to be approximately 411 meters.

4.2.4.3 X4.3 Member

The X4.3 member conformably overlies the X2.2 member with a mixed gradational contact. The topographic feature is generally moderate to high mountainouous areas which locate along the eastern side of the study area. The lithology is characterized by mostly medium gray, medium— to massive bedded micrite, biomicrite, biosparite and pseudosparite with some chert nodules, light and yellowish brown, light to medium gray, medium bed and fine— to medium grained of sublith—arenite and quartz wacke, pinkish to yellowish brown and light to medium gray shale, and yellowish brown and light gray, and thin— to medium bedded porcellanite. The fossils of crinoid stems and fusulinids were also

Description	Liseatones interbedded with sandstans, Lineatoness signifit, biesicrits, biesicrits, biesicrits, biesicrits, biesicrits, biesicrits, biesicrits, biesicrits, biesicrits, and pseudose particular nessis. partic, desartones interbedded with sandstans and porcellantifies, Lineatones interbedded with sandstans and porcellantifies, Lineatones interbedded with sandstans and porcellantifies, Lineatones and red, sedium gray are cheer nodules, ludget to exactive bed, sedium gray are cheer nodules, Sandstones interreddes with shale and sandstone, Lineatones interreddes with the sandstone to dark gray, cheer nodules. Shales pinds as red, Sandstones finear to endium-granhed, than to endium bed, yellowish brown and light to endium gray.	X4.3 MBR.
Гііроюду		
Description	Lisestenes intercalated with southers. Lisestenes, micrite, pueudosparaite, biomicrite, filide bed, yellowish grey, and seeking prey, Audatoscyclionish byrus, and grey, Presiles fusuinade and crimetal stone. Lisestenes interbedded and intermisted with calcarement shale. Lisestenes procudency chart nodules. Fortlescorals and crimetal grey, chart nodules. Fortlescorals and crimetals and calcarements intermistated with semantones and calcarements and presidents, biomicrite, and prendesparaite, think to seasone bed, frammath grey, sendine grey and mare chees. Calcarement shalescare grey and mare chees. Calcarement shalescare grey and mare chees. Calcarement shalescare grey to black, fossiles framilinds and crimoid stone.	X4.2 M B.R.
Гігрогоду		100
Description	Lineatenes interhedded with calcarenus shale and calcarcoun wilthtone. Lineatones pseudonparitie, bionicrite, thick bed, miloutal grey and light to endine gry. Calcarenus shalestiffer to endine gry. Calcarenus siltetensyallowith and brownish gry, and ligh gry. Possilas/mulinida. Lineatenes inferte, penulo-spurite, bionicrite, dienefrances and expussion of promise and relieves gry, and seldies of brownish gry, and seldies to dark gry. Mudranes this bed, yillowish and greenish gry, and seldies to dark gry. Mudranes this bed, yillowish and greenish gry, and light to emilia gry, industries the emilia gry, and seldies to dark gry. Andreans this bed, yillowish and greenish gry, and light gry. Possilas and brownish gry, and endited stone.	X4.1-MBR.
Гігроюду		
Thickness (m)	9 9	

Stratigraphic columns of X4.1, X4.2 and X4.3 members.

observed. The lithological section is measured to be approximately 491 meters thick.

4.2.5 Rock Unit X5

The topography of the X5 unit is generally gently rolling hills and occupies the southern part of the area. The outline of the unit is largely of a tabular shape. The outcrops are poorly exposed, therefore the lithological characteristic of this member is also limited accordingly. This rock type is subdivided into the X5.1, X5.2 and X5.3 members (Figure 32). The X5.1 and X5.2 members are continuous, but with the different lithology. The X5.3 member is in a separate location from the other 2 members of the X5 unit. The bedding lanes are mostly inclined to the southeast and southwest directions. The lithological section is carefully measured to be approximately 387 - 1242 members.

4.2.5.1 X5.1 Member

The X5.1 member conformably overlies X2.1 member with a continuous gradational contact, generally overlies X4.1 member with a fault contact (F2 - fault) and a conformable yet abrupt contact and probably overlies X3 member with the F5 - fault contact. The terrain of X5.1 is mostly flat. The lithology is commonly characterized by light colored, yellowish, blackish and reddish brown, black thin bedded chert, medium gray, thin- to thick bedded micrite, pseudosparite and biomicrite, and yellowish brown

and light to medium gray shale. The thickness is approximately 387 meters.

4.2.5.2 X5.2 Member

The X5.2 member conformably overlies the X2.2 member with an abrupt contact, and X3 with F5 - fault contact. The outcrop is generally poorly exposed. The topography is flat and gently rolling. The lithology is characterized by medium gray, medium bedded, micrite, pseudosparite, biomicrite, and biosparite, yellow, green, red, pink and gray to black calcareous shales, brownish gray and light to dark gray shale and slaty shale which is similar to calcareous shale in color, yellowish brown and light to medium gray, thin- to medium bedded, fine- to medium-grained sandstones of quartz arenite and quartz wacke, and yellowish brown, light to medium gray, mostly thin bedded chert. The total thickness of the section is approximately 1,242 meters.

4.2.5.3 X5.3 Member

The X5.3 member conformably overlies the X4.3 member with a mixed gradational contact (Figure 33). The topographic feature is mostly the rolling hills. The outcrops are generally poor. The lithology is predominately characterized by reddish and yellowish brown, yellowish green brownish and greenish gray, and light colored shales, medium gray, medium bedded micrite, biosparite and biomicrite, and greenish, yellowish, reddish and

Description Descr	Description	Shale interhedded and interchiated with Linestones.	Shaleslight to yellowies brown brownesh grey, calcite wenders and partially calcarous covers, Linestonessalcrite, presedentarits, bioriorits, bioriorits, blongarits, thin to seedlus hed and seedlus grey.	Shaie intercedded and intercalated with andstone. Shaieslight grey, greenish grey, and reddish and yellowish bryon. Jamastone: graywade, fine-te ser- dism-grained, sedian bed, and greenish, yellowish and residish bryon. Toselle: namonites(7).	Shale interhedded and intercalates with Sizestones. Shale:intermish and yellowish green, and yellowish brown. Limestonics:preudorparite, biosparite,	modius bed and medium to dark grey.	Sandatone interbedded and interculated with Linestones and shale, Sandatoceignweeke,fine-	grained, seeding bed, 11ght and brownsh grow and yellowish brown. Limestoncerpreedooparits, signification, biosparits, seeding bed and seeding groy, Shales	yellowish and reddish brown, placish red and sentime to dark gray.		X5.3 MBR.
Cherr interpreted vith lieuwane and interchalased vith shale, theretakes the second vith shale, the second vith shale v	Гііроіоду								Sills		
Chert imerbudged with illegeneous and imerculated with shale, therefore, and the shale, therefore and interculated and election for adding brown, sarily porcellands. Cherticulated for the shale, described and interculated with illegeneous and election graph, possible for all promises and entangle some. Chert interpreded and interculated with illegeneous and entangle some. Chert interpreded and interculated with illegeneous and entangle and entangle and entangle and interpretation of the bed and entangle and interpretation of the bed and entangle and entang	Description	Shales interieded and intercalated with Linestones and senderone. Shalest-calcureous shale and slaty shale. Calcureous shale; green, green, red, pink and grey to black, calcute weighter. Stary shalestellar to an experient of the color shalestellar.	slaty cleaveges, landstonerfixe-to esdiw-grained and thin: bed, theestones except, proudosperite, bloopsarie, modius bod and medium gray. Possile: floudinide and orinoid stems.	Lineatona interbedded and intercalated with shale and slaty shale, Limestones prondomarite, micrite, biomicrite, andies gray. Medium gray and partially calcarous	coment, flary shalesidar gray to brack, cantifer vessiles and slary cleavages. Possiles/desidade and estimated atoms.	Linestones imterpoded vith shale, Linestoness micrite, proudorparife, blomparite, median bed, aedius to dark grey, Jänlei brownah grey, sedius to	dark grey and partially calcartons casent.	Lieuzones interbedded and intermisted with there are an emissione. Lieuzonesmiente and mensioned an anotice had orner. Clearables	processor in a spin man and a section of the sectio	Lisestons internalated with sandstons, Lisestoness micrite, penulosparite, assitus bed, medium gray, Sondytener (ins-to wedium-grained, thin to sendium bed, yellowab brown and	11cm to endus pry.
Гігроіоду	Γίιμοίουγ										
	Description		2		and state, Cherrithin bet, pale to blackish brown, black, Liemtones:possidererits, storite, thin to thick bed and emilian grey. Shale:brownesh grey and	sedium grey, Possilar funditaids and crimmid stone.		918	กร	ลัย	X5.1 MBR.
g g (w)				المنعنعنا							

Stratigraphic columns of X5.1, X5.2 and X5.3 members.



Figure 33 The mixed gradational contact between X4.3 and X5.3 members at Siam City Cement Co. Ltd. quarry, grid reference 24711935.



Figure 34 The cross bedding indicating a normal sequence in biosparite at the mixed gradational contact between X4.3 and X5.3 members at the Siam City Cement Co. Ltd. quarry, grid reference 24711943.



Figure 35 Photomicrograph of biomicrite of X5.1 member at grid reference 09861757, Khao Hin Pun. (45x, uncrossed nicols)



Figure 36 Thinly laminated to laminated argillaceous limestone of X5.2 member at grid reference 20101685, the shale pit of Siam Cement Co. Ltd.

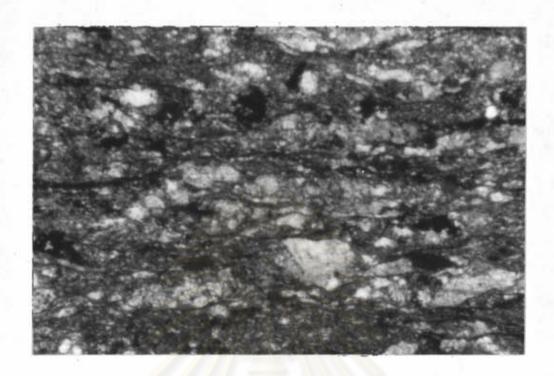


Figure 37 Photomicrograph of calcareous shale of X5.3 member at grid reference 23851779, Khao Mai Nuan (45x, crossed nicols).

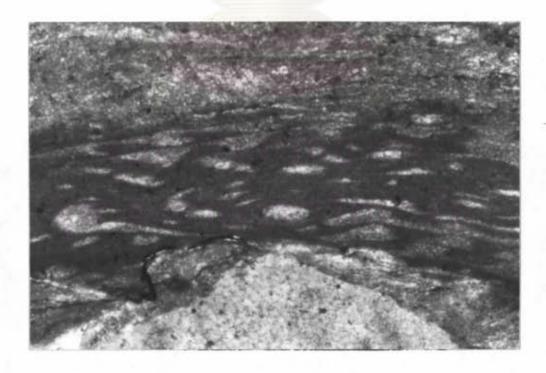


Figure 38 Photomicrograph of biomicrite with the deformed fusulinids of X5.3 member at grid reference 26781850 (45x, uncrossed nicols).

light brown, medium bedded and fine- to medium grained sandstone.

The thicknesss is measured to be approximately 794 meters.

4.2.6 Rock Unit X6

The rock unit is the uppermost unit of the stratigraphic succession in the study area. The topographic feature is
of the rolling hills. The outline of the unit is assumed to be
lense-shaped. The unit locates to the west and east of the area
and was subdivided into X6.1 and X6.2 members based on the lithology
and the separate extent (Figure 39). The bedding planes mostly dip
to the southeast and southwest. The exposures are commonly poor.
However, the section was measured to have a varying thickness of 181
to 474 meters.

4.2.6.1 X6.1 Member

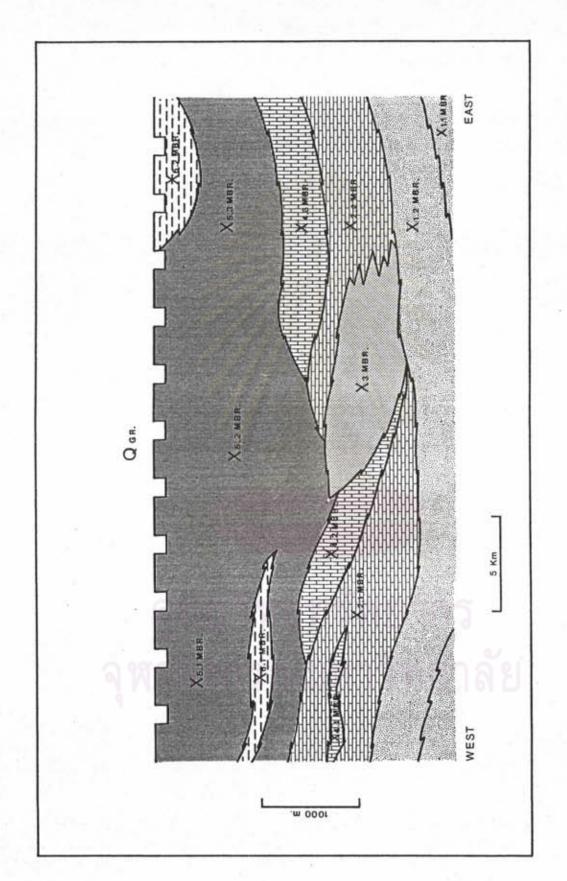
The X6.1 member lies within the X5.1 member with a continuous gradational contact. The lithology of this member is characterized by medium gray to black calcareous shale, brownish gray and dark gray to black silty shale, reddish brown to brownish gray thin bedded siltstone, and gray to black thin bedded chert. The section is measured to be approximately 181 meters thick.

4.2.6.2 X6.2 Member

The X6.2 member conformably overlies the X5.3 member with a mixed gradational contact. The lithology of rock unit is characterized by brownish gray, medium gray to black calcareous shale, yellowish and redish brown, and light to medium gray shale, pinkish red, reddish brown, light and brownish gray, thin

Description	Calcareous shales interbedded and intercalated with limestones. Calcareous shale:brownish grey,medium grey to black. Limestones:micrite,pseudosparite, biomicrite and biosparite;thin to medium bed,brownish grey end medium to dark grey. Fossile:funulinids and crinoid stoms. Shale interbedded and intercalated with siltstone and chert. Shale:yellowish and reddish brown,light to medium grey. Siltstone:thin bed,pinkich red,reddish brown,light and brownish grey,and splintery. Chert: thin bed,brownish grey and dark grey to black.	X6.2 MBR.
Гіџроюду		
Description	Shales interbedded and intercalated with limestones. Shales: calcareous shale and silt-shale, Calcareous shale:medium grey to black and fissiles. Silt-shale; brownish grey and dark grey to black, Limestones: micrite, pseudosparite, blowiorite and biosparite, and thin to medium bed, Fossils: flusulinids and crinoi stems. Shale and chert intercalated with siltstone. Shale: yellowish and reddish brown, and brownish grey. Chert:thin bed and grey to black, Siltstone:thin bed, reddish brown and brownish grey.	X6.1 M B.R.
Гіґроюду		
Thickness (m)	800 400 800	

Figure 39 Stratigraphic columns of X6.1 and X6.2 members.



Generalized stratigraphic cross section of the study area. Figure 40

bedded siltstone, and brownish gray, medium to dark gray, thin bedded micrite, pseudosparite, biomicrite and biosparite. The thickness was measured to be approximately 474 meters.

A generallized geologic cross-section was drawn (Figure 40) to illustrate the stratigraphic relationship of all 13 rock members. From the present observation the outlines of the rock units and their members are tabular- and lense-shaped, while the contacts between the units, wherever observed, are usually gradational. Since the section is relatively limit compared to the entire regional stratigraphic section, it does not conclusively support the land-side hypotheses of either Tittirananda (1976) - Wielchowsky and Young (1985) or Bunopas and Vella (1983). The succession of the rock units from the northeast (the oldest) to the southwest (the youngest) may neither do this since the arrangement of the succession is, in the most part (?), controlled by the tectonic displacement occurred in the folding/faulting event(s, ?) which followed the genesis of the sedimentary rocks (See further).

4.3 Igneous Rocks

The igneous rocks in the study area and its vicinities fall into two categories, the plutonic and volcanic rocks. The volcanic clastic layers generally found conformably associating the volcanic rocks, are grouped in the "volcanic" rocks also. The volcanic rocks belong to Khao Yai Volcanics and compose mainly of rhyolite, andesite, rhyolitic and andesitic prophyries, tuff, volcanic breccia and agglomerate. The plutonic rock is the diorite of Phra Ngam Diorite. Both igneous rock groups are probably of the Permo-Triasic

age. The plutonic bodies intruded while the volcanic rocks unconformably overlied the Permian sediments (Hinthong, 1981). In Figure 14 the volcanic unit is designated X7.1, and the intrusive, X7.2. Twenty-seven thin-sections of the volcanic rocks and fourteen thin-sections of the intrusive rocks are petrographically classified on the basis of the texture and mineral constituents in according to the IUGS classification. Four types of the X7.1 volcanic rocks are recognized. These are the rhyolitic porphyry, dacitic porphyry, andesitic porphyry and andesitic tuff. These rocks expose in the southern part of the study area and near Khao Sung. The X7.2 intrusive rock, the diorite, occurred as the plugs (perhaps the tops of a single buried batholith ?) at Khao Man, and at an area 2 Kilometers west of Khao Phra Phutthabat Noi. These phugs intruded the Permian carbonate/clastic unit with the thermal-metamorphic phenomena. The petrographic study on both rock groups are as followed.

4.3.1 Volcanic Rocks

Megascopically, these rocks are slightly porphyritic to porphyritic with the fine-grained groundmass. The rocks are reddish brown, pale green, greenish brown and pale to dark green in fresh color, and grayish brown, light gray, dark gray and dark brown in color on the weathered surface.

Microscopically, the rocks commonly exhibit a hypocrystalline and holocrystalline, and porphyritic texture. They are composed predominantly of plagioclase, orthopyroxene and quartz with subordinate K-feldspars (sanidine, orthoclase and microcline),

epidote, chlorite, sericite and calcite, and opaque minerals. modal percentage of the phenocrysts of plagioclase, K-feldspars, quartz and orthopyroxene are 5 - 40, 15 - 20, 10 - 25 and 5 - 15 respectively. The size of plagioclase phenocrysts commonly ranges from 0.5 to 1.5 mm, and about 0.5 - 0.8 mm. for the orthopyroxene phenocrysts. Texturally, the plagioclase commonly occurs as the anhedral, subhedral and euhedral crystals. Some of the plagioclase grains show a zonation and are partially sericitized. The orthopyroxene is hyperstene and forms the subhedral prismatic grains. The quartz is commonly found as the anhedral grains or as interstitially infilling crystal aggregates, and frequently shows moderately undulatory extinction. Some of the quartz crystals have been resorbed to be embayed quartz. The K-feldspars are occurred as the subhedral to anhedral grains of sanidine, orthoclase and microcline. The most common secondary minerals are chlorite and sericite. The chlorite was noted to be an alteration products of the pyroxene. The fine grained chlorite has a pale green to green pleochroism. The sericite and calcite are associated with plagioclases as their alteration products. The amount of opaque mineral is about 3 - 5%. It occurs as the subhedral and or subhedral grains having an average size of 0.2 mm.

The groundmass of this rock is mostly a mixture of microlite, devitrified glass, glass and plagioclase laths. In places, it displays a well-marked flow structure and spherulitic texture.

The tuff layers found in X2.2 member are not included here under this topic.

4.3.2 Intrusive Rock

Megascopically, this rock has a medium- and coarsegrained porphyritic texture. It is dark green in fresh color and blackish brown, reddish brown on the weathered surface.

Microscopically, it is generally hypautomorphic holocrystalline and medium— to coarse—grained. It is composed essentially of plagioclase (45 - 60%) with An content 35 - 40, hornblende (35 - 55%), diopside (1 - 5%) and augite (1 - 5%). The accessary minerals consist of orthoclase, biotite, muscovite, sphene, epidote and opaque minerals. Some plagioclase is also observed to be spherulitic, zoning and poikilitic. Quartz and pyroxene inclusions in hornblende are commonly recognized. In addition, the pyroxene is partly altered to become chlorite. The opaque minerals are presumably magnetite and other minerals.

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Figure 41 Photomicrograph showing replacing epidote (Ep)
in plagioclase (Plag) in andesitic porphyry of
X7.1 member at Khao Pong, grid reference 21881297.
(45x, crossed nicols)

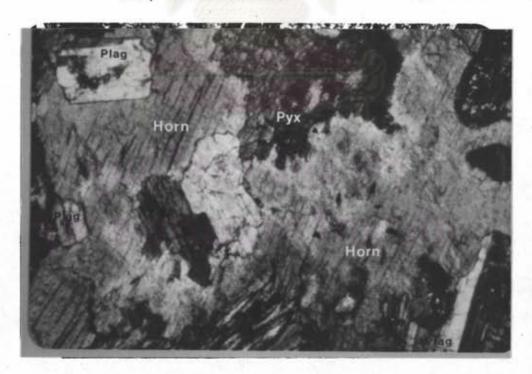


Figure 42 Photomicrograph showing pyroxene (Pyx) inclusions in hornblende (Horn) and plagioclase (Plag) laths of Dîorite of X7.2 member at Khao Man, grid reference 24721423. (45x, crossed nicols)