

## CHAPTER IV

### LITHOSTRATIGRAPHY

#### **Lithological study**

Lithostratigraphy of the rocks at Khao Phu Thok and Phu Wua can be obtained by two well -exposed stratigraphic sections. A complete section of this study is the Phu Thok section (about 139 m long), where approximately more than 98% exposure accounts for this rock sequence. The other is the Phu Wua section (about 205 m), approximately 80% exposures of total rock sequence. The lower part of the composite Phu Thok stratigraphic column is only acquired from the lowermost Phu Wua section. Traverse lines of these subhorizontal bed sections are calculated to obtain appropriate thickness. Most beds of both sections are collected, and the essential lithologic informations are described (see Appendix B ). The detailed stratigraphic columns of both sections are depicted in Fig. 4.1 and Appendix C. However, the description of the members of the Phu Thok sequence is referred from the composite section, which is mainly correlated using polarity of individual strata together with marker beds, lithologies and sedimentary structures of the strata (Fig. 4.1). Petrographic description is very helpful in classifying types of clastic rocks. Classification of the clastic rocks are based principally upon Folk (1968). The detailed explanation of thin-section study is labeled in Appendix I.

#### **Lithostratigraphy of composite section**

Total column of the Phu Thok sandstone sequence (Fig. 4.2) can be separated by the combination of lithologies and sedimentary features into four members as A, B, C, and D.

PHU THOK SECTION

PHU WUA SECTION

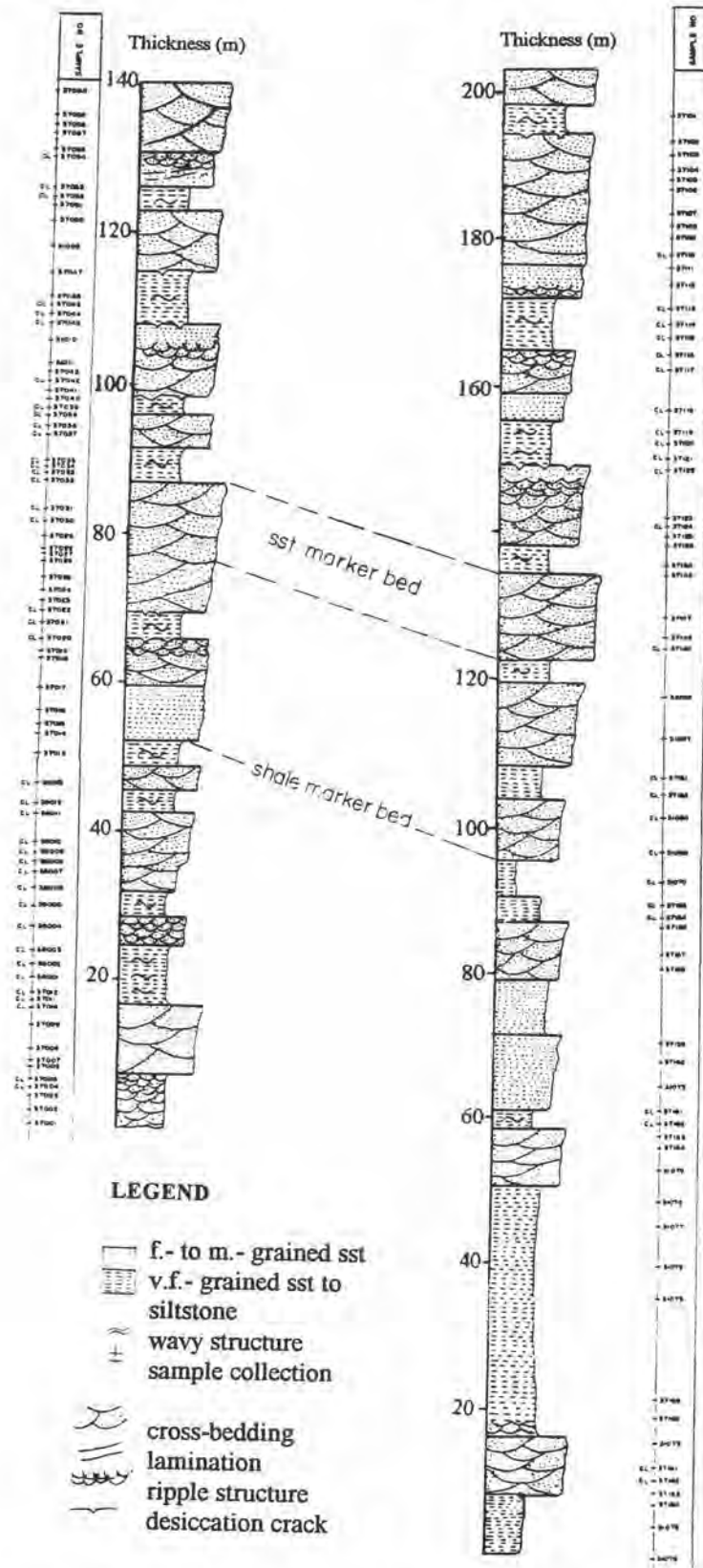


Figure 4.1 Detailed stratigraphic section and sampling site, and two marker beds of Phu Thok and Phu Wua sections.

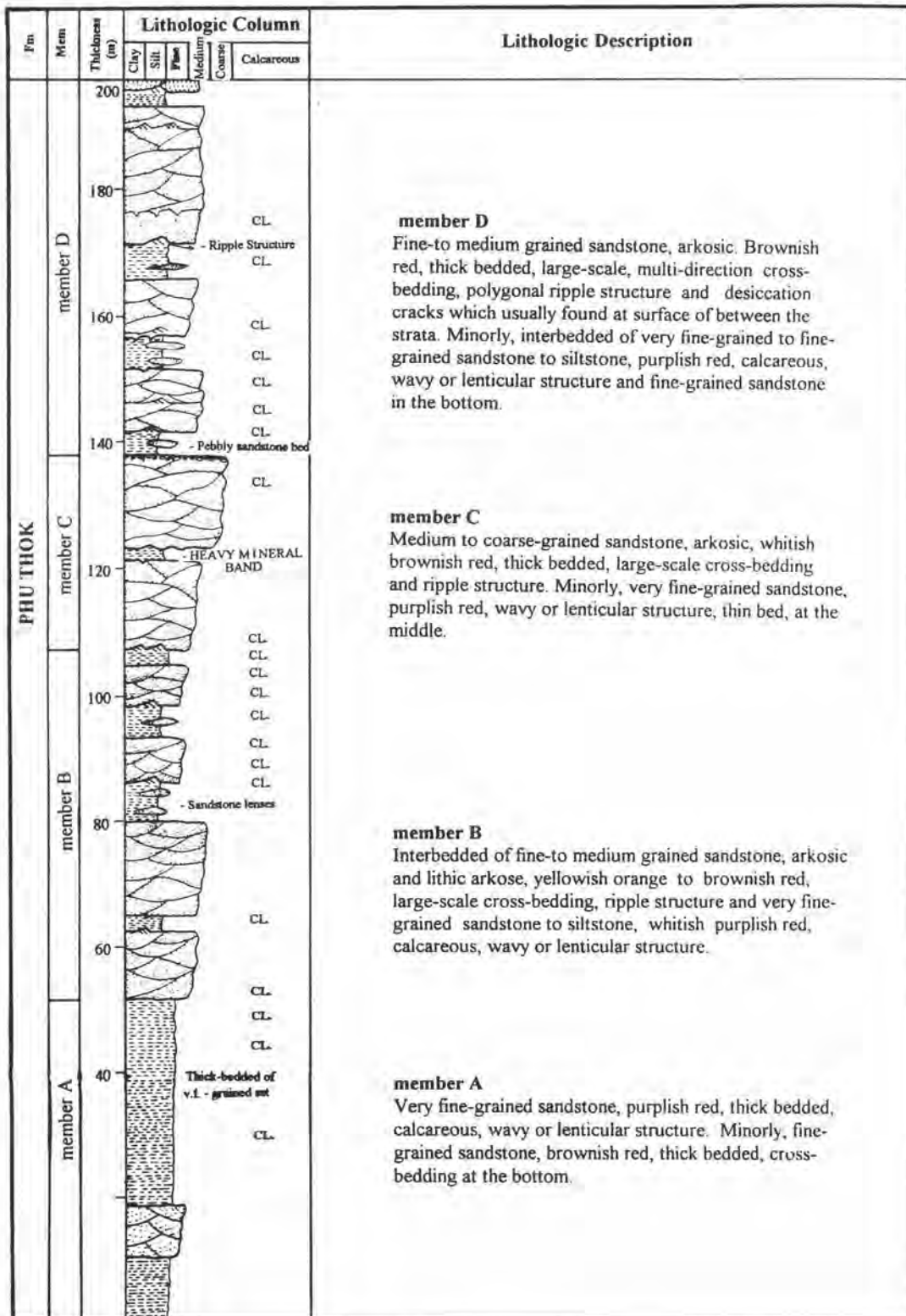


Figure 4.2 Composite stratigraphic column of the Phu Thok in the study area.

## 1. Member A

The lowest stratigraphic unit exposes in the lower part of Phu Wua section. Ten core samples were collected, and mostly they are siltstone to very fine-grained sandstone. The member is conformably overlaid by member B, but the underlain rocks is unclear. Thickness of this member is about 52 m. The member is marked by very thick beds of brownish red, calcareous very fine - grained sandstone ( up to 15 m thick) and some siltstones. It is characterized by interbeds of thickly bedded (up to 1 m thick), very fine-grained sandstone and thinly bedded, fine-grained sandstone in the upper sequence. Sedimentary structures are ripple structures at top surfaces between sandstone and siltstone, and the wavy structures which are normally shown in the very fine-grained sandstone strata. Decreasing in grain size and densely calcareous component in overall rocks at the lower sequence are also noted.

Petrographic study of sandstone samples nos. 31077 and 31086 from Phu Wua section indicates that all sandstone samples are lithic arkose (Folk,1968). The rocks contain the mix of two size-ranged clastic grains. One is subrounded to rounded, high sphericity, normally fine sand size (0.1-0.25 mm in diameter) with some medium sand size, of quartz, chert, and feldspar with minor micas (Fig. 4.4). The other is subangular, low sphericity, normally very fine sand to silt size (0.02-0.05 mm in diameter), of quartz and feldspar with some micas and opaque minerals. These rocks are grain-supported (90 %), well-sorted, and depict textural immaturity. Cementing materials of the samples are usually calcareous and ferruginous. It is also noted that drusy calcite spar or poikilotopic in calcareous cement are recognized.

## 2. Member B

The lower stratigraphic unit exposes in the lower part of Phu Thok and the lower-middle part of Phu Wua sections. Forty-six core samples were collected from both sections and reveal that very fine-grained sandstone are quite dominant in the lower sequence. Thickness of this member is about 62-64 m. This member is

characterized by interbeds of thickly bedded (1-2 m thick in single direction of cross-bedding, but 5-12 m thick in overall continuous strata of sandstone), reddish brown to brownish red, some calcareous, fine-to medium-grained, arkosic sandstone, and purplish brownish red, very fine-grained calcareous sandstone (2-3 m thick). However, dark brownish gray shale and siltstone occasionally take place in the sequence, particularly at the lower part of the Phu Wua section. Major sedimentary structure includes desiccation-crack and ripple structure at top surfaces of between sandstone and the overlying siltstone or the very-fine grained sandstone. Wavy structure is normally shown in the very-fine grained sandstone strata and large-scale, multi-directional, cross-beddings are observed in arkosic rocks.

In the lowest part, the member is marked by interbeds of very thick bed (up to 5-10 m thick), arkosic sandstone and very-fine grained sandstone strata (1-2 m thick). Desiccation cracks and ripple structures are invariably found at the top surface of the very fine-grained sandstone bed (Fig. 4.3). In the upper-middle sequence, interbedded thickly bedded arkosic rocks (1-2 m thick) with strongly multi-directional cross-bedding (Fig. 4.5) and thick bedded, very fine-grained sandstone are recognized. The overall rock sequences in the uppermost part of this member is similar to those of the lower part. Dark brownish gray shale and siltstone, the marker strata, occasionally took place in the sequence, particularly at the uppermost part of the member B (Fig. 4.7). However, decreasing in grain-size and densely calcareous materials in all rock strata of the upper-middle sequence are quite common. Gradational change in grain-size as recorded in the field is decreasing from Phu Thok to Phu Wua sections. The overall pictures of the member is increasing in grain-size at least three cycles of upward sequence.

Petrographic study of sandstone samples from Phu Thok section, nos. 37004, 37005, 37006, 37012 and Phu Wua section, nos. 37161 and 37164 indicate that all the sandstone samples are arkose to subarkose (see Folk, 1968). Clasts are subrounded to rounded with high sphericity and normally fine sand size (0.1-0.25 mm in diameter) of quartz, chert and feldspars with some micas (Fig. 4.6), and rare





Figure 4.3 Outcrop exposure of the lower part of member B showing the non-resistant, very fine-grained sandstone overlaid by resistant strata of cross-bedding, fine-to medium-grained sandstone (photo taking at the type section of Phu Thok).

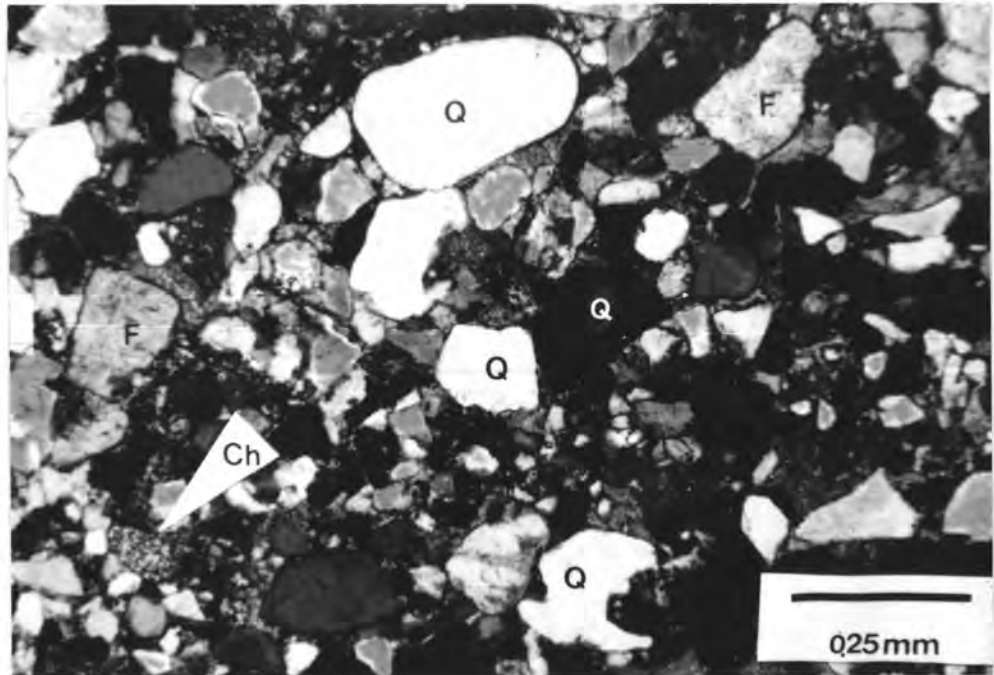


Figure 4.4 Photomicrograph of the very fine - grained sandstone in Member A containing the mixed size-ranged clastic grains. One is subrounded to rounded, high sphericity, normally fine sand size of quartz (Q), chert (Ch), and feldspar (F) with minor micas. The other is subangular, low sphericity, very-fine sand to silt size of quartz and feldspar with opaque minerals, implying rather poor textural maturity. It is noted that the ferruginous cement coated the grains (crossed-nicols).



Figure 4.5 Multi-direction cross-bedding, fine-grained sandstone strata at the middle part of member B (photo taking at the Phu Thok section).

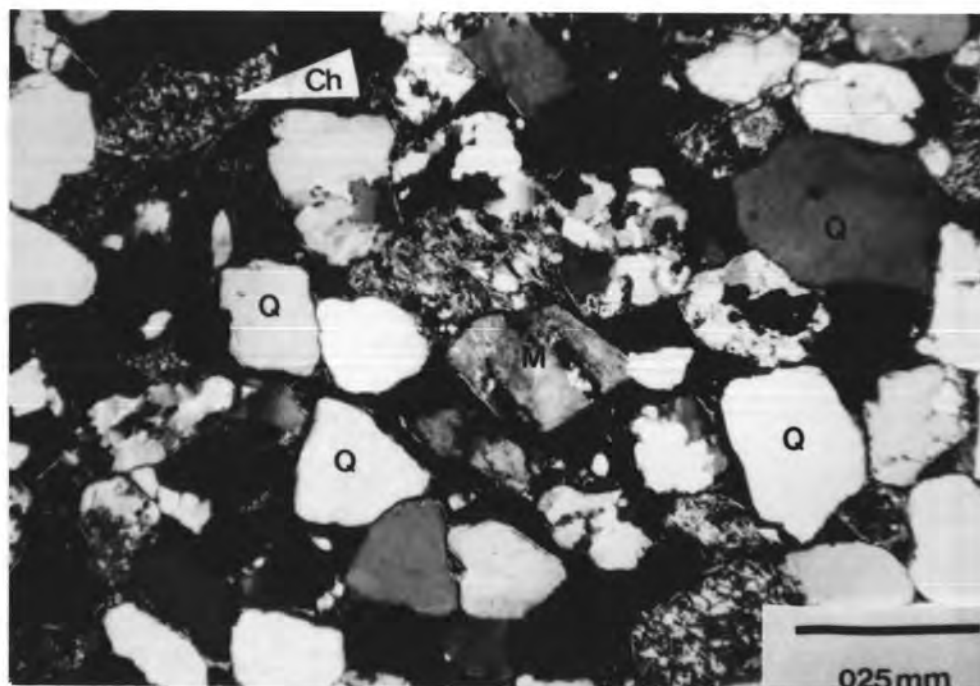


Figure 4.6 Photomicrograph of fine-to medium-grained arkose showing the grain-supported (>95 %), moderately-to well-sorted, and fairly good textural maturity. Clasts are subrounded to rounded with high sphericity of quartz (Q) , chert (Ch) and microcline (M) with some micas. (crossed-nicols).

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fragments of volcanic rocks. These rocks are grain-supported (>95 %), moderately- to well-sorted, and mature in textural. It is noted, from some samples, that the precipitated calcite and iron-dots are relatively common in the porous samples. The boundary between detrital core and overgrowth becomes very distinct by extremely coating of iron oxides on the original detrital grains.

The very fine-grained sandstones are determined to be lithic arkose (Folk, 1968). The rocks contain mixtures of two unequal sizes of clastic grains (see Fig.4.4). These characters are similar with those of the very fine-grained sandstone in the lowest member.

### 3. Member C

This member exposes in the middle part of Phu Thok and Phu Wua sections. 21 core samples were collected in both sections, revealing that the medium-grained sandstones are dominant. Thickness of this member varies from 25 to 39 m. It is characterized by two thickly-bedded (ranging from 12 to 20 m thick), light reddish brown to reddish brown, fine-to coarse-grained sandstone, intercalated by some pebble or coarse-grained sandstone layers in the middle-upper part of the member. A single bed of purplish brownish red, calcareous, very fine-grained sandstone to siltstone (2 m thick) is regarded as a lens between two, more resistant, gigantic sandstone strata (Fig.4.8). Polygonal desiccation cracks and ripple structures at top surface of sandstones are also common, and wavy structures in the strata are frequently present. Arkosic sandstones have large-scale, multi-directional, cross-beddings whereas the wavy structures are typically found in the very-fined grained sandstone strata (Figs. 4.9 and 4.10). Mostly gigantic strata are marked by very thick single-cross bedding (up to 6-8 m thick) at the bottom of individual beds. It is noted that the coarser-grained sandstone reveal quite more resistant strata than the finer-grained sandstone of this member (Fig. 4.11). Furthermore, the polygonal fracture cracks are usually found in the finer-grained. Maranate (per.com) suggested that this





Figure 4.7 The typically siltstone marker bed (near the hammer) at the junction between of member B and C at Phu Thok section. It is noted that the thicker strata of siltstone is yielded in Phu Wua section.



Figure 4.8 Outcrop showing the thickly bedded, very fine-grained sandstone (reddish-brown color) is located between the giant cross-bedding, fine-to medium-grained sandstone strata. (photo taking at the Phu Thok section).



Figure 4.9 Multi-direction cross-bedding of very thick bedded (up to 10 m thick), medium-grained arkose, the lower part of member C, at the Phu Thok section.



Figure 4.10 Closed-up view of the very fine-grained sandstone showing the wavy structure, which is the typical feature of the rock strata, member C (photo taking at the Phu Thok section).

feature is caused by dehydration of the rocks. The heavy mineral beds are usually found in the bottom of each stratum. Petrographic study of sandstone samples collected along Phu Thok section, including nos. 37014, 37018, 37020, 37025, and 37029 and Phu Wua section, no. 37148, indicate that all of sandstone samples are lithic arkose to arkose (Folk, 1968). Clasts are variably from subangular to well-rounded, with high sphericity, and normally medium-coarse sand size (0.4-0.8 mm in diameter) of quartz, chert, and feldspars, with some micas and rare volcanic rock fragments. All grains are extremely coated by ferruginous cementing materials. However, an arkosic sample (no. 37148) indicates that grains of these clasts are coarse-grained sand size. Like those of the Member B, these rocks are grain-supported (>85 %), but become perfectly oriented, and moderately- to well-sorted, and show good textural maturity. However, the rocks in the Phu Wua section display relatively poorer textural maturity than the other section, implying more proximity to provenance.

The very fine-grained sandstones are examined petrographically to be lithic arkose (Folk, 1968). In general, the rocks, e.g. sample rock no. 37020, shows similar lithology to that of the Phu Wua Lang member. It is noted that drusy calcite spar and poikilotopic in calcareous cement are recognized.

#### **4. Member D**

The member is referred to the sandstone strata which are exposed in the upper part of Phu Thok and Phu Wua sections. A total of 59 samples, collected from both sections, suggest that the rocks are frequently similar in sandstone type to the member B, but dissimilar in detailed sedimentology. The thickness of this member ranges from 60 to 80 m. The member is characterized by interbedded thickly bedded (2-10 m thick), reddish brown, fine-to medium-grained arkosic sandstone with purplish brownish red, very fine-grained calcareous sandstone (2 m thick).

In the lowest part, the member is marked by thick beds of calcareous, very fine-grained sandstone (4-10 m thick). Some strata of arkosic sandstone (less than 2-3 m thick) are intercalated at the middle of the former beds (Figs. 4.12 and 4.13). Sedimentary structures in the arkosic rocks certainly consists of strongly, multi-

directional cross-bedding and reveals desiccation cracks and ripple structures between these beds. This sequence is characterized at the top part by one very thick bedded, fine-to medium-grained, arkosic sandstone (up to 10 m) with outstanding large-scale, single-directional, cross-bedding (Fig. 4.14). The top of this bed normally is coarse-grained sandstone layer. Then, the sequence is followed by interbedded series of thick bedded, fine-grained arkosic sandstone (2-5 m thick) and very fine-grained calcareous sandstone (up to 2 m thick) (Fig 4.15). Strongly multi-directional cross-beddings are recognized in the arkosic rocks. Densely calcareous precipitates in overall rocks at the lower-middle sequence are also noted. In the upper part, a sequence of very thick bedded, fine-medium grained sandstone (up to 10 m) which have large-scale, cross-bedding were observed. It is noted that the polygonal desiccation cracks are densely shown at top surfaces of each bed (Fig. 4.16). Hard pan of the formation is characterized by medium-grained, arkosic sandstone whose strongly desiccation cracks and ripple structures are encountered. Stratigraphically, the very fine-grained sandstone (2m thick) reveals that the rock is in the uppermost part of the sequence. The overall picture of the member is an increase in grain-size of at least 3 cycles in the upward sequence.

Sandstone samples collected at the Phu Thok section, including nos. 37032, 37035, and 37042 and the Phu Wua section, nos. 37105, 37115, 37126, and 37132, indicate that all studied sandstone samples are arkose to lithic arkose (Folk, 1968). More frequently petrographic study indicates subangular to subrounded clasts. Moderate to high sphericity and normally fine to medium sand size (0.25-0.5 mm in diameter) of quartz, chert, and feldspar with some micas are predominated features. It is noted that some sandstones (e.g. sample no. 37042) is admixed by the coarse-grained sand size (0.8-1 mm in diameter). These rocks are grain-supported (>85%), moderately sorted, and immature to submature in textural maturity. The Phu Wua samples therefore become less maturity and contain more volcanic fragments than the Phu Thok section. The very fine-grained sandstones are assigned to be lithic arkose (Folk, 1968). Again the rocks contain the mixtures of two different sizes of clasts. These characters are quite similar to those of the very fine-grained sandstone in the other members. The thickness of the overall Phu Thok formation is approximately 205 m.



Figure 4.11 The non-resistant strata of very fine-grained sandstone (light reddish-brown color) overlaid by a resistant bed of fine-to medium-grained sandstone (dark reddish-brown) at the middle part of member C (photo taking at the Phu Thok section).



Figure 4.12 Interbeds of very fine-grained (soft beds) and fine-to medium-grained sandstone (resistant beds) at the lower of member D. It is noted that the multi-directional, cross-bedding is usually found in resistant sandstone beds (photo taking at the Phu Thok section).





Figure 4.13 Strongly multi - directional cross-bedding sandstone strata at the middle part of member D. The underlain part is the soft bed of very fine-grained sandstone (photo taking at the Phu Thok section).



Figure 4.14 The very thick bedded fine-to medium-grained sandstone which has large-scale cross-bedding at the upper part of member D (photo taking at the escarpment of Phu Wua section).



Figure 4.15 The erosional surface of thick-bedded, very fine-grained sandstone at the upper part of member D (photo taking at the escarpment of Phu Wua section).

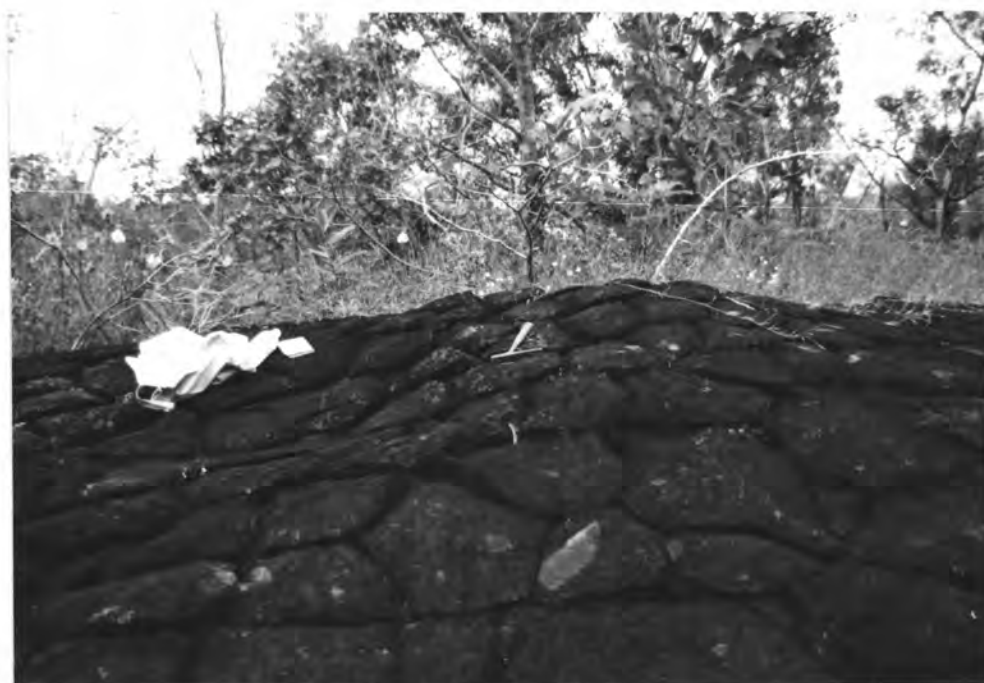


Figure 4.16 Desiccation crack is the typical characterized of the uppermost part of fine-to medium-grained sandstone of the Phu Thok Formation, member D (photo taking at the Phu Wua section).