# CHAPTER V

# LITHOFACIES

The origin of term "facies" is from the German word meaning "face or aspect". It was firstly used or applied to geology by Steno in 1669 (quoted in Walker, 1984; Selley, 1996). Later, Gressly (1838) developed the term "facies" for unit of rock that shared similar lithological and paleontological features (quoted in Walker, 1984; Reading, 1996; Selley, 1996).

The origin of term "lithofacies" cannot be attributed to any individual. Weller (1958) said that "Sloss (letter, December 24, 1956) stated that it came into informal use in oil-company reported in the 1930s." and it was derived by contraction of the expression "lithologic facies". Krumbein (1948) provided the first definition of lithofacies, "the sum of total of the lithological characteristics of a sedimentary rock". Reading (1978) stated that, "a facies is a body of rock with specified characteristics. In case of sedimentary rocks, it is defined on the basis of color, bedding, composition, texture, fossils and sedimentary structures. 'Lithofacies' should thus refer to an objectively described rock unit". However, this study prefers to combine the definition described by both Krumbein (1948) and Reading (1978) that lithofacies is defined by the lithological characteristics of a sedimentary rock on the basis of rock color, bedding, composition, texture, fossil and sedimentary structures, that are mainly recognized in the field. The lithological terms are described using the classifications of Carozzi (1989), Grabau (1903) and Folk (1959, 1962).

The sedimentary sequences of the Khao Khad Formation appear in the study areas as succession of layers or strata. Firstly the sequences in the fields were mapped as rock units based on the differences in lithological characteristics in three mapping

areas, namely, Khao Khad, Khao Chan and Pak-Chong to Khao Yai areas. In this chapter the lithological characteristics of each rock unit in all three areas will be firstly described in details from both megascopic and microscopic observations. Secondly the correlation of three measured sections will be conducted based on the lithological characteristics of each unit. Thirdly, each lithostratigraphic unit will be established as lithofacies of the Khao Khad Formation including the interpretation on the depositional environment.

## 5.1 Khao Khad Area

The overall rock units of the Khao Khad Formation at Khao Khad area were mapped from eleven measured sections and the traverses are shown in Figure 5.1. The total distance of eleven traverses was 4,500 meters long and 128 rock samples were collected for detailed petrographic study. The graphic representation of sedimentary sequence of each measured section is shown in Figure 5.2. The representative sedimentary sequence of composite sections of the Khao Khad Formation at Khao Khad area is shown in Figure 5.3. From the results of field observation and the graphic representation of all measured sections, it is recognized that there are altogether 9 rock units. The description of each unit is presented in ascending order as follows:

### 5.1.1 Unit KD1

The unit KD1 represents the lowest part of the lithostratigraphic sequence of the Khao Khad Formation at Khao Khad area. It is exposed on a small hill surrounded by flat lowland crop field and cut by the highway no.21 at the km no. 14. The outcrops are exposed along both sides of the road by which those on the western side (about 140 meters long and 6 meters high) is wider than those on the eastern side. It is shown in

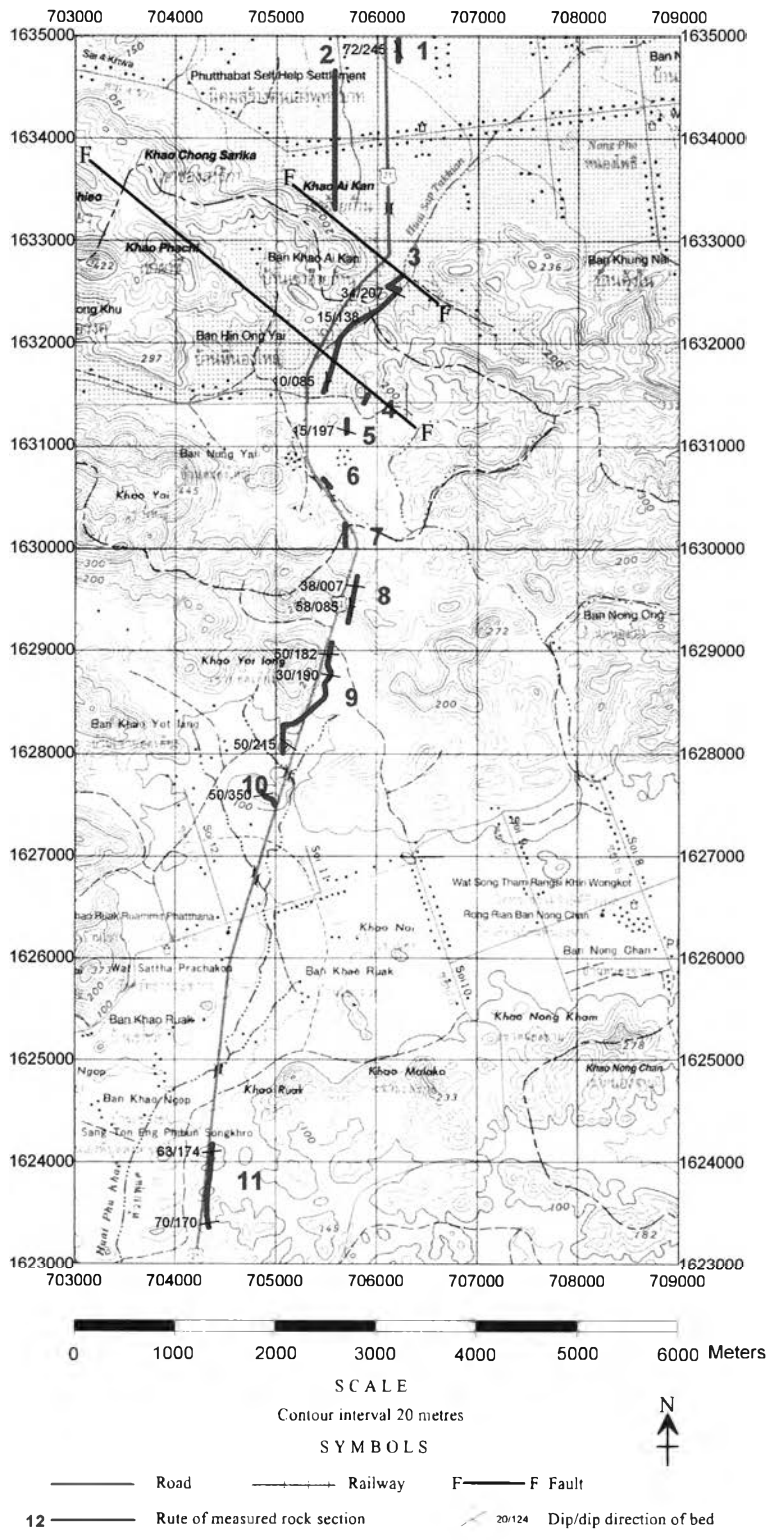


Figure 5.1 Topographic map showing traverses of eleven measured sections along the Khao Khad route (modified from topographic map sheet Amphoe Phatthana Nikhom, 5138I, and Changwat Saraburi, 5138II, Royal Thai survey department).

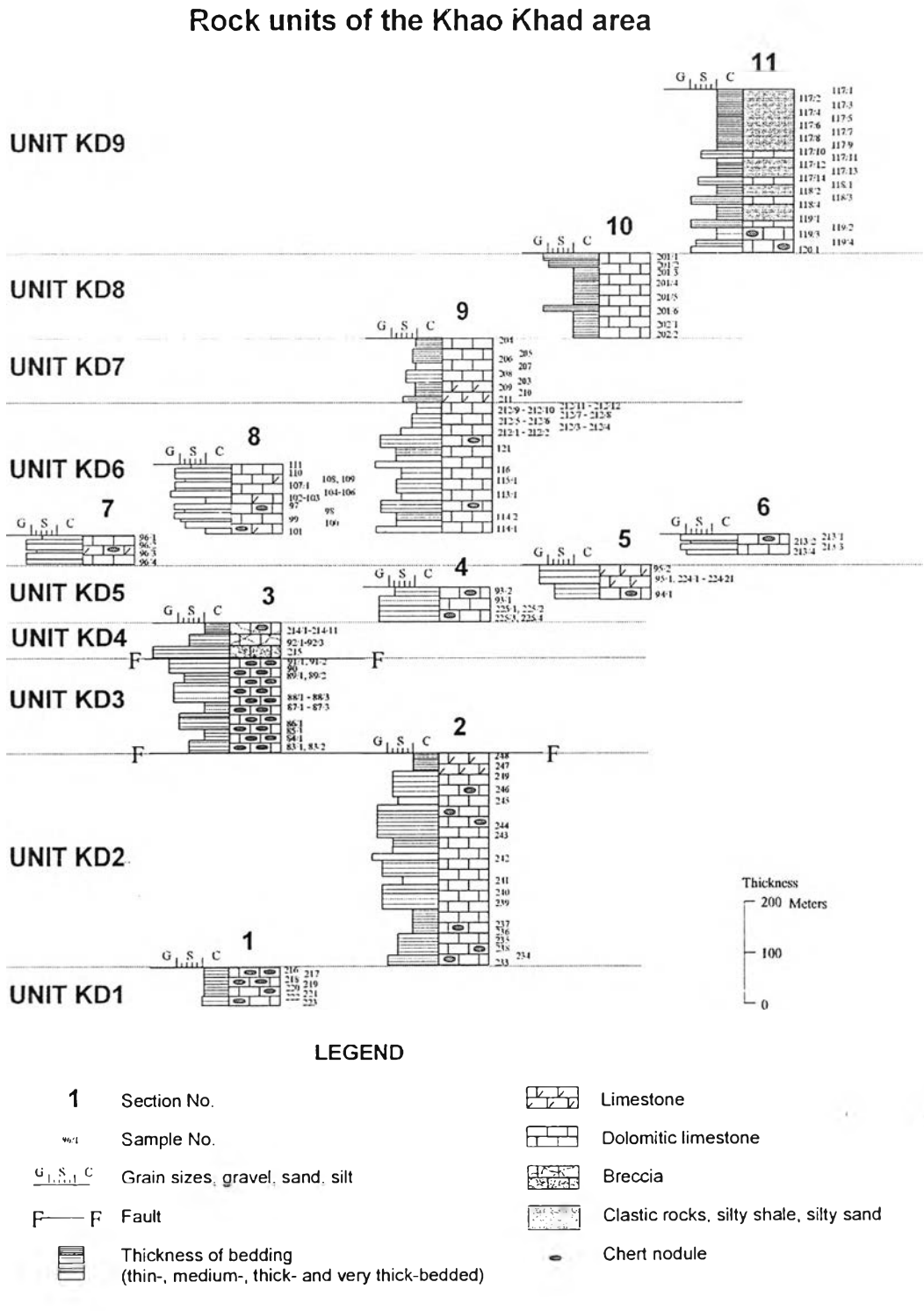


Figure 5.2 The graphic representation of 11 measured sections along Khao Khad route.

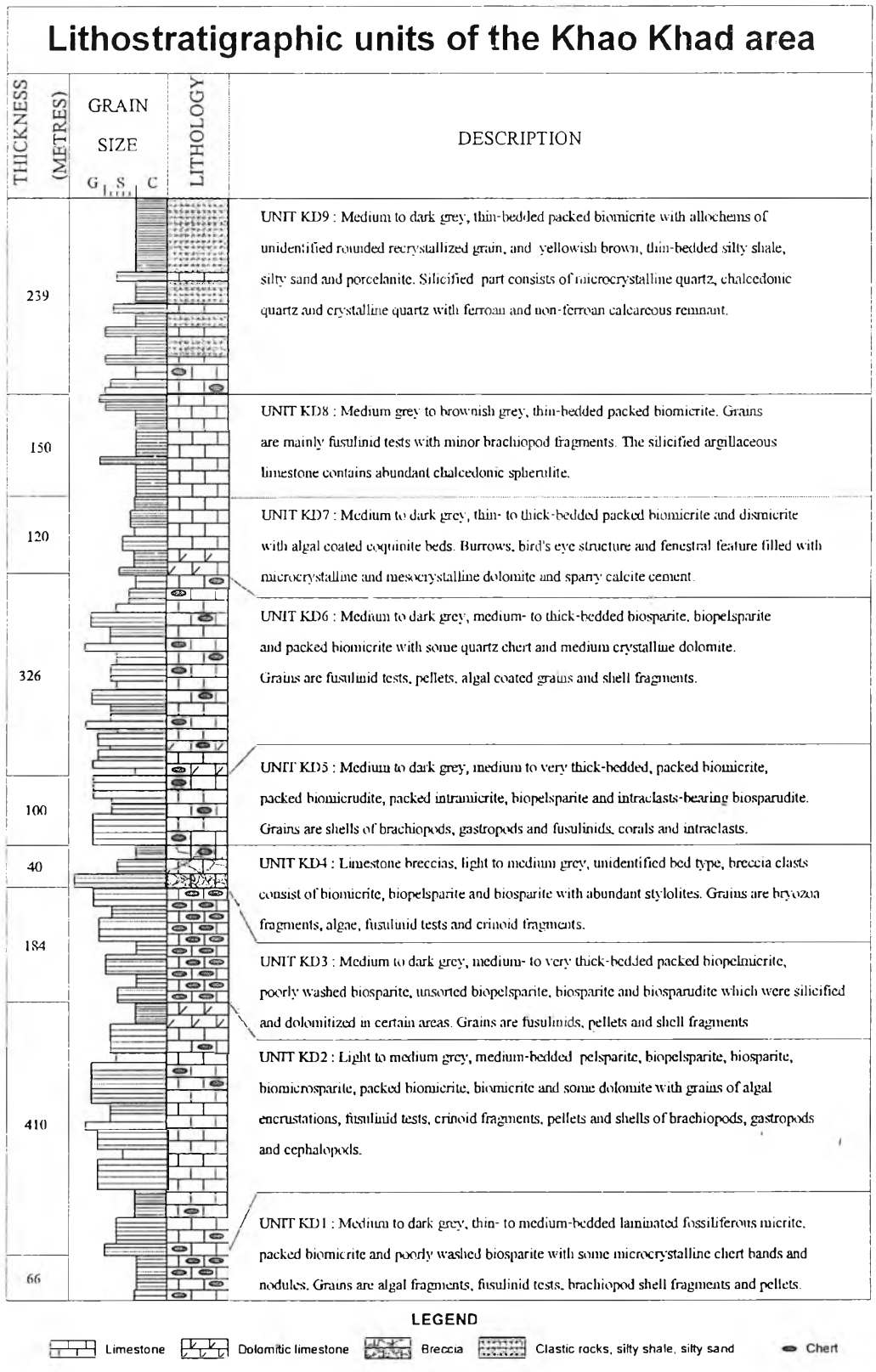


Figure 5.3 The graphic representation of the representative sedimentary sequence of Khao Khad Formation at Khao Khad area.

the map as measured section no.1 (Figure 5.1). The unit KD1 is characterized by parallel and thin- to medium-bedded limestone. The beds trend in the northwest-southeast direction (150 to 155°), and dip 55 to 72° southwestwardly. The thickness of this unit is unknown because its boundary is covered by soils. However, the total thickness should exceed 66 meters as measured from the present exposure.

***Description:*** The unit KD1 is medium light grey to dark grey calcilutite to calcisiltite interbedded with dark grey banded chert, partly nodular chert and siliceous limestone (Figure 5.4A). The lower part of the unit represents by medium light grey, thin-to-medium-bedded calcilutite with minor cherts. It is noted that some banded cherts show irregular boundaries between the chert and limestone (Figure 5.4B). The middle and upper parts consist of thinly bedded limestone which has been subjected to higher degree of silicification than that of the lower part (Figure 5.4C). The weathered surface is usually grey to light grey and smooth on this limestone, but it turns brownish grey to black and rough on the silicified part.

Petrographic studies show that the unit KD1 consists of finely laminated fossiliferous micrite, packed biomicrite and poorly washed biosparite with some microcrystalline chert bands and nodules. The laminated fossiliferous micrite is the most abundance and contains less than 10 % small grains in micrite matrix (Figure 5.4D). The packed biomicrite contains grains of brachiopod shells and small unidentified grains embedded in micrite matrix. Most of grains were completely micritized (Figure 5.4E). The poorly washed biosparite is characterized by grains and some micrite remains which have been cemented by sparry calcite. Grains comprise algal fragments, fusulinid shells, brachiopod shell fragments and pellets. Some fusulinid tests and brachiopod shells show coated micrite. The microcrystalline calcite cement can be recognized around pellet grains (Figure 5.4F) and around contact point

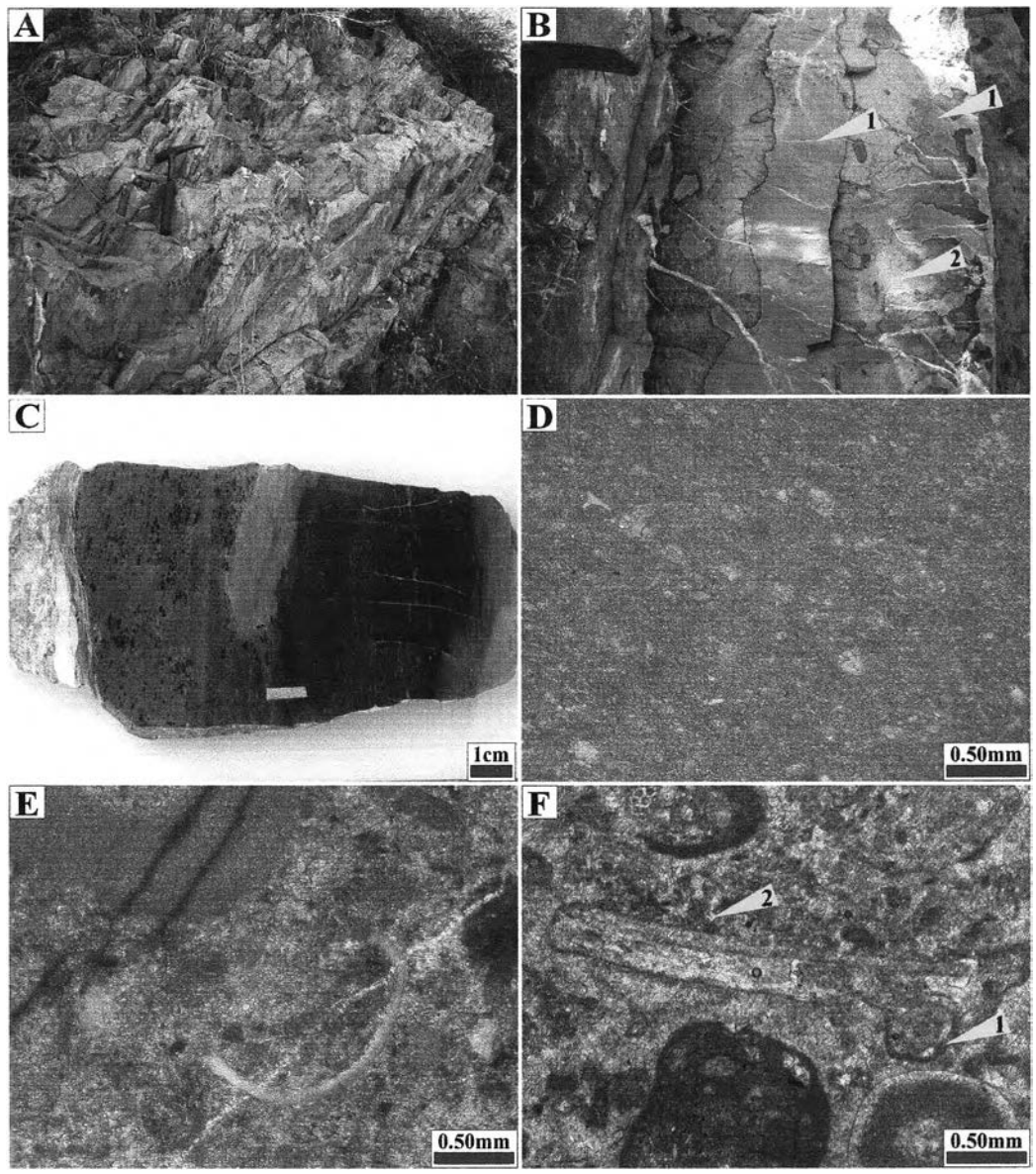


Figure 5.4 **A**: An outcrop of unit KD1showing thin- to medium-bedded, parallel, medium grey to dark grey calcilutite to calcisiltite interbedded with dark grey banded chert, nodular chert and siliceous limestone.; **B**: An outcrop of limestone with banded chert showing irregular boundaries between the chert (1) and limestone (2) of the unit KD1.; **C**: A rock slab of the upper part of the unit KD1 showing medium grey to dark grey calcisiltite with small dots of black calcareous chert.; **D**: Photomicrograph of fossiliferous micrite which is a major rock mass in the upper part of the unit KD1. (PPL); **E**: Photomicrograph of packed biomicrite of the unit KD1 displaying small grains packed in micrite matrix. (XPL); **F**: Photomicrograph of poorly washed biopelsparite of the unit KD1 showing micrite coating around grains (1) and microcrystalline calcite cement (2) around contact points of pellet grains. (PPL)

of brachiopod shells and fusulinid tests (Figure 5.5A). The internal pores of fusulinids are filled with finely crystalline sparry calcite cement. It is noted that some brachiopod shells are filled with micrite which is known as geopetal structures. Nodular chert and silicified limestone are composed mainly of microcrystalline quartz with some calcareous patches (Figure 5.5B).

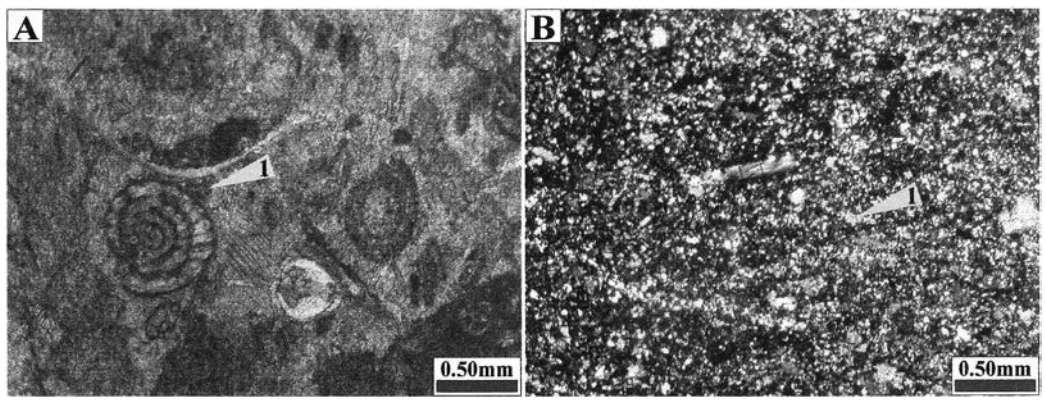


Figure 5.5 **A**: Photomicrograph of poorly washed biosparite of the unit KD1 showing microcrystalline calcite cement (1) around contact point of brachiopod shell and fusulinid test.(PPL); **B**: Photomicrograph of calcareous chert of the unit KD1, consisting mainly of microcrystalline quartz with some calcareous patches (1). (XPL)

### 5.1.2 Unit KD2

The unit KD2 is the second lithostratigraphic unit from the bottom. The outcrops are poorly exposed in the lowland area southward from the small hill of the unit KD1 between km no. 13.5 to no. 12 of the highway no. 21 (Figure 5.6A). The area has been used for agriculture purpose for a long time and most float rocks have been removed out from the field. However, the author had tried to collect some rock samples of this unit in the same area as that reported by Tittirananda (1976) and conducted more detailed survey to the west of Tittirananda's route, as shown in the map as measured section no.2 (Figure 5.1). The rock mass of this unit is characterized by thin- to very thick-bedded limestone. The beds lie in the northwest-southeast direction (120 to 130$^{o}$)

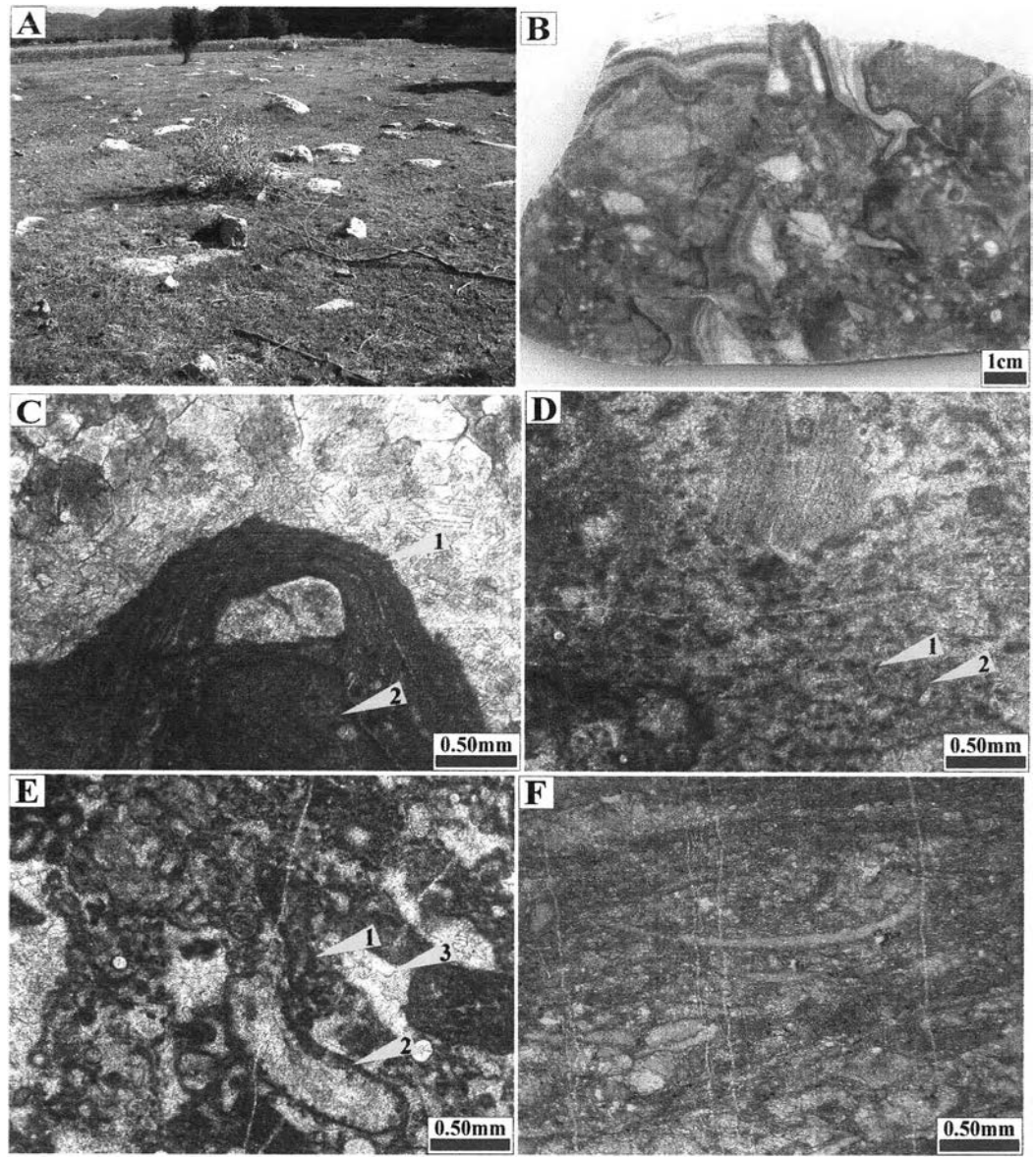


Figure 5.6 **A**: The knotty exposure or low ridge karsts of the unit KD2. **B**: A rock slab of algal stromatolite buildup of the unit KD2.; **C**: Photomicrograph of laminated algal stromatolite (1) accretion from the unidentified micritized grain (2) of the unit KD2. (PPL); **D**: Photomicrograph of pelsparite of the unit KD2. The pellets (1) are initially cemented by microcrystalline calcite cement (2). (PPL); **E**: Photomicrograph of the biopelsparite of the unit KD2, displaying abundant pellets (1) packed together with sparse micritized bioclasts (2) cemented by sparry calcite (3). (PPL); **F**: Photomicrograph of packed biomicrite of the unit KD2 showing grain-supported fabric in micrite matrix. (Stained, PPL)

and dip 30 to 40° southwestwardly. The thickness of this unit and its relation to the rock units above and below are unknown due to the poor exposure and top soil coverage of the lower boundary. However, the calculated thickness exposed across the crop field is approximately 410 meters thick.

***Description:*** The unit KD2 is light to medium grey calcarenite, calcirudite and carbonate buildup. The rock shows a grain-supported fabric of differing types and sizes of grain components. The lower part of the unit is oncolite-algal biolithite and coralline-algal biolithite forming carbonate buildup (Figure 5.6B). The middle part is dominantly a light to medium-grey, medium-bedded calcarenite to fine calcirudite. Distinctive crinoidal limestone beds are present in the middle part of the unit. The upper part consists of coralline-algal biolithite and calcarenite to fine calcirudite with banded dolomite. A coquina bed also appears near the top of the unit. Grains are algal encrustations, fusulinid tests, crinoid fragments, pellets and shells of brachiopods, gastropods and cephalopods. The large gastropod and brachiopod shells are common associated with carbonate buildup. The large *Robustoschwageriga* sp. tests are significantly abundant in the lower middle part associated with algal fragments. It is noted that the rocks have been recrystallized into sparry calcite in the upper part of the unit. The weathered surface of the rock is white to light grey and usually rough due to differential dissolution.

Petrographically the unit KD2 consists of pelsparite, biopelsparite, biosparite, biomicrosparite, packed biomicrite and biomicrite which have been locally dolomitized. Apparently this rock unit was partially metamorphosed into coarsely crystalline marble by which the original textures were mostly obliterated. The pelsparite and biopelsparite are associated with carbonate buildup or algal biolithite (Figure 5.6C). The pelsparite contains abundant fecal pellets cemented earlier by microcrystalline calcite and later by sparry calcite (Figure 5.6D). There are some small

bioclasts,. resembled crinoid fragments deposited together with pellets. The biopelsparite contains many algal encrusted bioclasts, small foraminiferal test, unidentified micritized grains and pellets cemented by sparry calcite (Figure 5.6E). All bioclasts were completely micritized and initially cemented by microcrystalline calcite cement. The biosparite is mostly abundant in the upper part of the unit. The sparry calcite cements various types of grains, such as algal fragments, fusulinid tests and shell fragments of brachiopods, gastropods and cephalopods. The biomicrosparite is probably the recrystallization products of formerly biomicrite. The micrite might have been recrystallized into microspar and usually obscures the original textures. The packed biomicrite is characterized by a grain-supported fabric (up to 50% grain component) of various types of grains (similar to those described above) in the micrite matrix (Figure 5.6F). The shell fragments are usually orientated parallel or sub-parallel to bedding plane. The packed biomicrite is gradually changed into biomicrite as grain components decrease. The detailed petrographic studies of algal stromatolite reveal that many algae are coated on the pre-existing sediments, such as pelsparite, biopelsparite and oncolite (Figure 5.7A). There is some braking period of algal coat which was separated by radiaxial fibrous calcite cement (Figure 5.7B). Many layers of radiaxial fibrous calcite cement are separated by microcrystalline dolomite layers (Figure 3.7C). Some macrocrystalline dolomite rhombs occur in association with sparry calcite cement in the central area of intergranular pores (Figure 5.7D)

### 5.1.3 Unit KD3

The unit KD3 is exposed on the mountains southwardly from the lowland crop field of the unit KD2. The measured section was conducted on the eastern side of road-cut of a small hill, southeastwardly from Khao Ai Kan. It is shown in the measured section no.3 (Figure 5.1). This unit overlies on the rock sequence of the unit KD2 characterized by parallel and medium- to very thick-bedded limestone. The beds trend

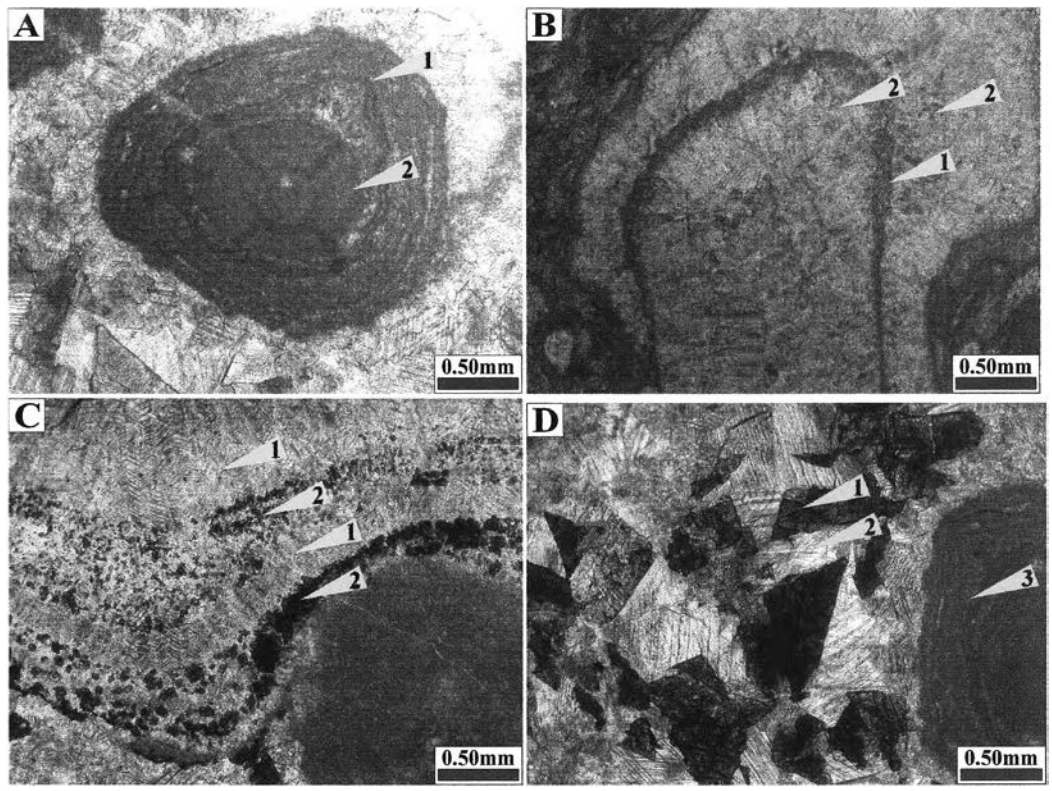


Figure 5.7 **A**: Photomicrograph of oncolite of the unit KD2 illustrating of many layers of algal (1) coating around a micritized host grain (2). (PPL); **B**: Photomicrograph of algal stromatolite of the unit KD2 showing some braking periods of algal coating (1) separated by radiaxial fibrous calcite (2). (PPL); **C**: Photomicrograph showing many layers of radiaxial fibrous calcite cement (1) alternating with microcrystalline dolomite layers (2) of the unit KD2. (Stained, PPL); **D**: Photomicrograph depicting the macrocrystalline dolomite (1) associated with sparry calcite cement (2) in the central area of intergranular pore spaces of the algal stromatolite (3) buildup of the unit KD2. (Stained, PPL)

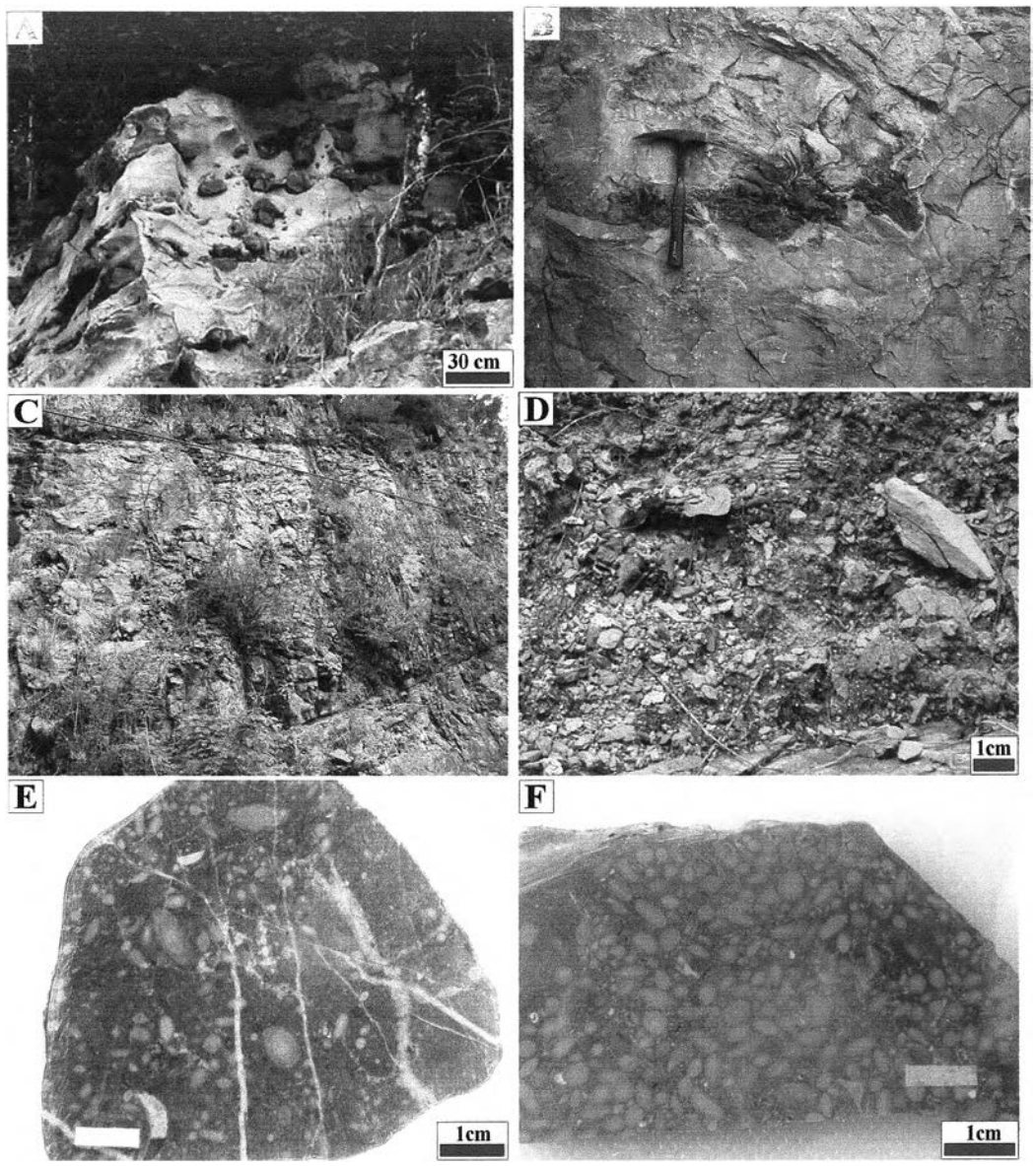


Figure 5.8 **A**: An outcrop of very thick-bedded, medium grey calcarenite with black nodular chert of the unit KD3.; **B**: An outcrop of thick-bedded, medium grey calcarenite to fine calcirudite with black nodular cherts and light color dolomitic limestone of the unit KD3.; **C**: A road-cut section of very thick-bedded medium grey calcarenite to fine calcirudite with less abundant chert nodules of the unit KD3. In this section, there are thin-bedded, yellowish brown to reddish brown silty shale interbedded between very thick-bedded limestones in the lower part.; **D**: Picture of weathered thin-bedded, yellowish brown to reddish brown silty shale between very thick-bedded limestones of the unit KD3.; **E**: A rock slab of matrix-supported fine calcirudite of the unit KD3 showing fusulinid tests of different sizes floating in medium grey micrite matrix.; **F**: A fine calcirudite slab of the unit KD3 showing grain-supported fabrics of mainly fusulinid tests.

in northwest-southeast direction (117 to 132°) and dip 30 to 34° southwestwardly. The thickness of this unit is about 184 meters.

***Description***: The unit KD3 is medium grey to dark grey calcarenite to fine calcirudite with black nodular cherts and dolomite patches (Figures 5.8A and 5.8B). The weathered surface is usually light grey and slightly rough, and occasionally disseminated with protruded chert nodules. Within very thick-beds of this unit, there are at least four layers of silty shale interbedded in this rock (Figure 5.8C). The silty shale is thinly-bedded, yellowish brown to reddish brown, and usually weathered into small pieces or yellowish brown soil (Figure 5.8D). The calcarenite to calcirudite can be sub-divided into two field names, matrix-supported fine calcirudite and grain-supported calcarenite to fine calcirudite. The matrix-supported fine calcirudite is the main rock type of the unit distributed from bottom to top with sparse black chert nodules (Figure 5.8E). The rock is medium- to very thick-bedded, medium grey to dark grey, and has grain sizes from 1 to 12 mms. Some parts show quite contrast in color between very dark grey grains and light grey matrix. Grains are mainly fusulinid tests and the matrix is a mixture of pellet, small shell fragments and cement. The grain-supported calcarenite to fine calcirudite distributed near the top of the unit and is the medium-bedded, medium grey rock in which the grain components show slightly lighter color than matrix (Figure 5.8F). Grains are moderately sorted and composed essentially of small fusulinid tests of 1 to 5 mms in size. The chert nodules 10 to 30 cms in size are found scattered throughout this unit.

Microscopically the unit KD3 consists of packed biopelmicrite, poorly washed biosparite, unsorted biopelsparite, biosparite and biosparudite which were silicified and dolomitized in certain areas. The packed biopelmicrite is the most abundant rock consisting mostly (>50%) of bioclasts and pellets in micrite matrix (Figure 5.9A). Bioclasts are usually coated with micrite suggesting micro-boring on surface. The

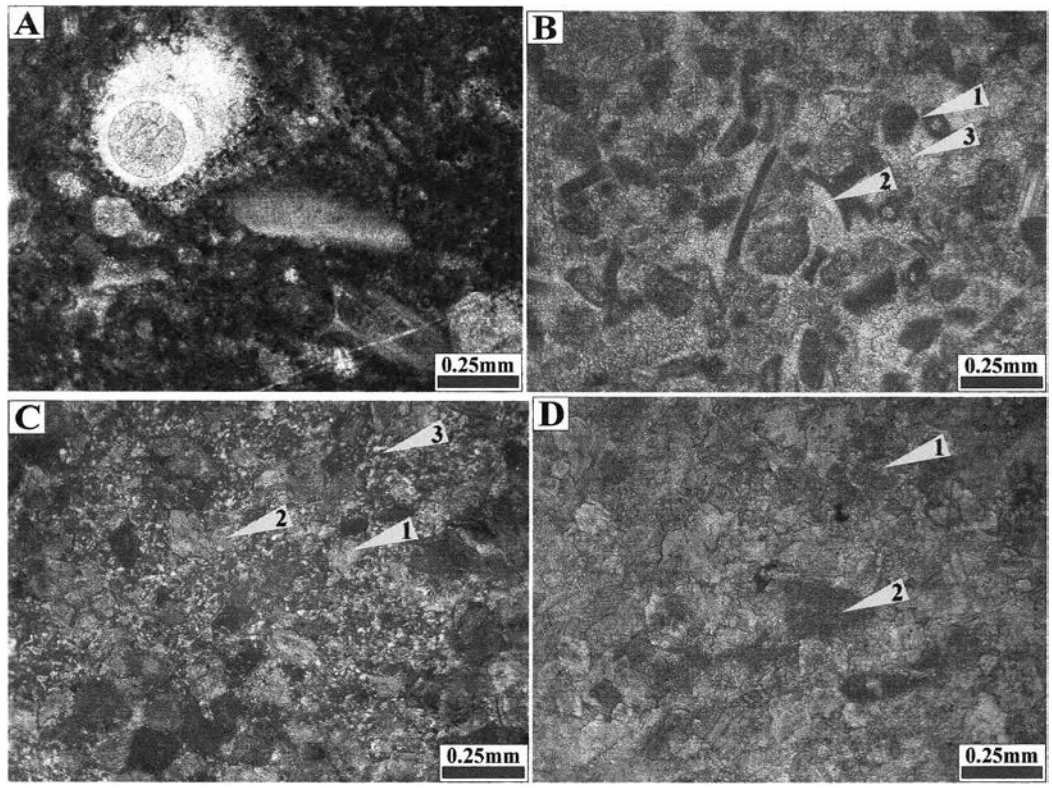


Figure 5.9 **A**: Photomicrograph of packed biopelmicrite of the unit KD3 depicting bioclasts and pellets embedding in the micrite matrix. (PPL); **B**: Photomicrograph of unsorted biopelsparite of the unit KD3 showing grain-supported fabric. Grains were initially cemented by microcrystalline calcite (1), then by isopachous fibrous (2) and finally by sparry calcite (3). (PPL); **C**: Photomicrograph of black nodular chert of the unit KD3 illustrating of dolomite rhombs (1) and calcareous patches (2) scattered in microcrystalline quartz matrix (3). (XPL); **D**: Photomicrograph of dolomitic biosparite of the unit KD3 showing sparsely dolomite rhombs (1) and calcareous grains (2). (Stained, PPL)

isopachous fibrous cement fringes around the surface of internal pores of bioclast. It grows perpendicular to the pore surface and appears as early stage cementation. This fibrous cement might have formerly been acicular aragonite cement. The following stage of cementation was sparry calcite filling the central part of internal pore remains. The poorly washed biosparite is dominant in the middle part of the unit. It contains roughly equal amounts of micrite and sparry calcite cement. The micrite fills in intergranular pores as irregular patches, or fills in fusulinid chambers (known as geopetal feature). The remaining intergranular and intragranular pore spaces were cemented with fine sparry calcite. It appears that the outer surface of shell fragments had been coated with micrite before the fragments were broken. Most of fusulinid internal pores were earlier cemented by small fibrous calcite lining along the surface and followed by coarse sparry calcite in the pore center. Some elongated shell fragments lie parallel or sub-parallel to the bedding plane. In the zone of grain-supported calcarenite to fine calcirudite there is a lack of micrite remains in intergranular pores. The unsorted biopelsparite is abundant in the middle and upper parts of the unit. It is found in the matrix of grain-supported calcarenite to fine calcirudite (Figure 5.9B). The rock contains 10 to 50 percent grains (1 to 2 mms in size) and sparry calcite cement. Grains are composed of randomly oriented fecal pellets and shell fragments. Grains were earlier cemented by thin-layered and light-colored microcrystalline calcite, coating around some pellet grains and around contact point of grains. This cementation probably caused semi-consolidation of the sediment. The later phases of cementation were isopachous fringe of formerly acicular aragonite cement lining the surface of intergranular pores and late sparry calcite cement filling the remaining pore spaces.

As mentioned earlier, the unit KD3 is locally silicified as nodular chert scattered throughout the unit. Petrographic study of nodular chert reveals that it is mainly microcrystalline quartz (Figure 5.9C). There are some dolomite rhombs and

calcareous patches scattered in the matrix of the microcrystalline quartz. The dolomite rhombs vary in size from 10 to 300 μms whereas the calcareous patches vary in size from 60 to 100 μms. Some parts of biosparite contain scattered dolomite rhombs and calcareous grains (Figure 5.9D).

### 5.1.4 Unit KD4

The unit KD4 is exposed as a small hill southwest of the Khao Ai Kan near the km no. 11. It is shown in the southern part of the measured section no.3 (Figure 5.1). The thickness of this unit is about 40 meters.

***Description***: This unit is a limestone breccia. The breccia clasts comprise light grey to medium grey calcilutite to calcirudite with scattered nodular chert. The lower part of this unit is easy recognized as small clasts of brecciated limestone with many types of limestone clasts (Figure 5.10A). In the middle and upper parts, the breccia clasts are of different rock types separated by irregular shape of stylolites. The breccia clasts vary in size from one centimeter to two meters (Figure 5.10B) and are cemented by reddish brown, graded calcareous sandstone to siltstone (Figure 5.10C). There are many micro-faults occurring in graded calcareous sandstone to siltstone. The stylolite features are common in this unit which is clearly visible on the weathered surfaces.

Petrographic study reveals that the breccia clasts consist of biomicrite, biopelsparite and biosparite. The biosparite is dominant in the lower part of the unit whereas the biopelsparite and biomicrite are common in the middle and upper parts. Grains are bryozoa fragments, algae, fusulinid tests and crinoid fragments. The Verbeekina is commonly enveloped by micrite. Some grains are also cracked. The crinoid fragments usually show syntaxial overgrowth calcite cement (Figure 5.10D). Some of crinoid fragments were corroded and packed forming micro-stylolite between

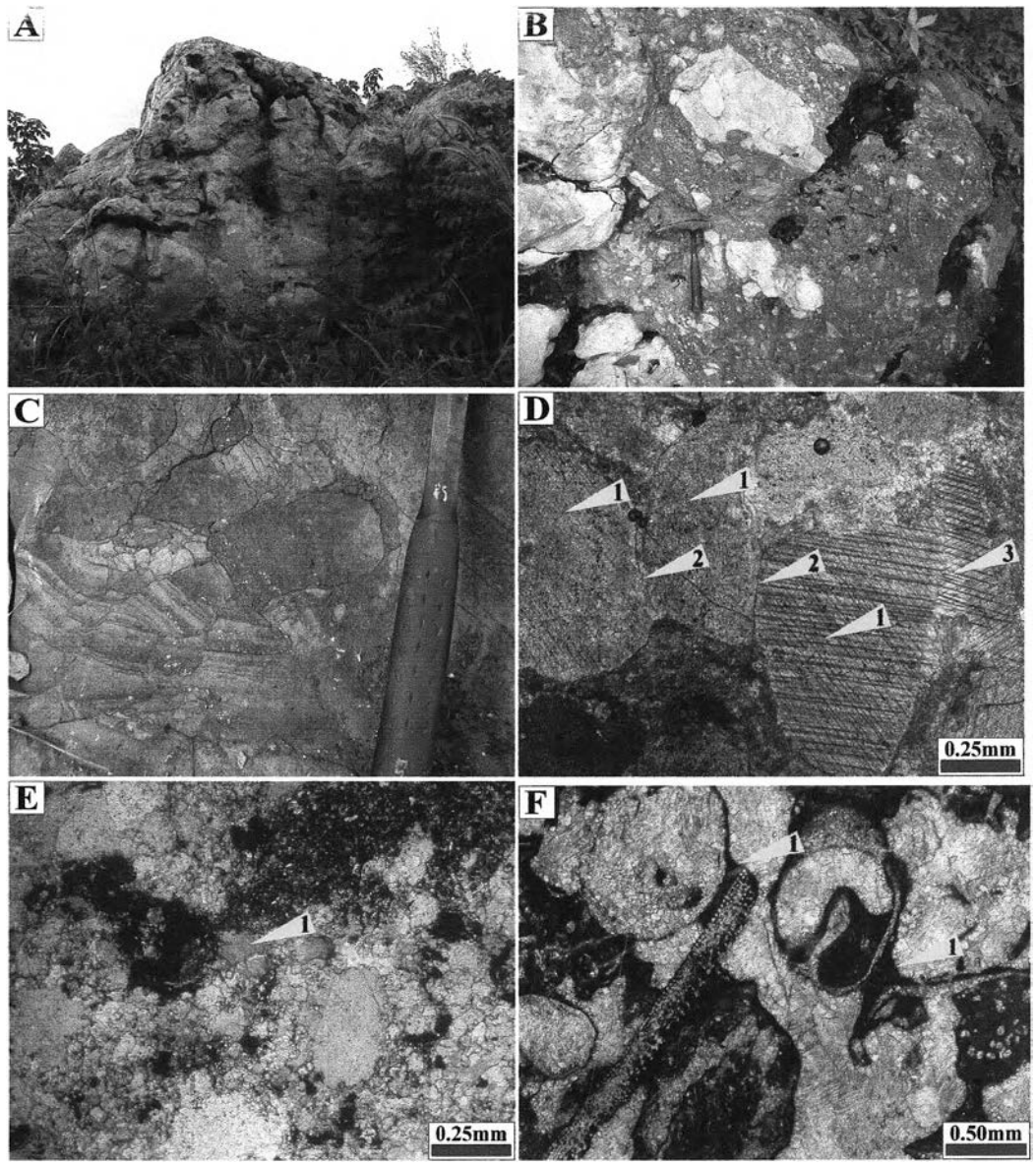


Figure 5.10 **A**: An outcrop of the unit KD4 showing very large breccias cemented by reddish brown, thinly-laminated calcareous silty sandstone.; **B**: A close-up outcrop of limestone breccia of the unit KD4.; **C**: Picture of graded calcareous sandstone to calcareous siltstone which associate with the breccia limestone of the unit KD4.; **D**: Photomicrograph of biosparite of the unit KD4 depicting corroded crinoid grains (1) and micro-stylolite (2) at the grain contact. The syntaxial overgrowth calcite cement also observed on the right of the picture (3). (PPL); E: Photomicrograph of calcareous siltstone of the unit KD4 illustrating ferroan calcite (1) in part of this vadose silt. (Stained, PPL); **F**: Photomicrograph of biosparite of the unit KD4 showing the micrite or meniscus cement (1) at the contact point of grains. (PPL)

grain contacts. Parts of calcareous siltstone contain abundant vadose silt and commonly display micro-solution features. Some parts of grains and cement are transformed into ferroan (purple-stained) calcite (Figure 5.10E). The biomicrite and biopelsparite differ from each others by the variation in the amount of micrite and pellets in the rocks. The meniscus cement is clearly visible in some breccia clasts. It reveals as micrite coated shells cemented by dark grey micrite around grain contact points (Figure 5.10F). Some micrites deposit on the concave side up shell fragments as geopetal structure (Figure 5.11A). There are abundant mesocrystalline dolomite around the micrite cement and shell fragments (Figure 5.11B). The rest of intergranular pore were occluded by sparry calcite cement. It is therefore likely that the unit KD4 is a mixed rock from different depositional environments due to the mechanical weathering, such as talus slope deposits.

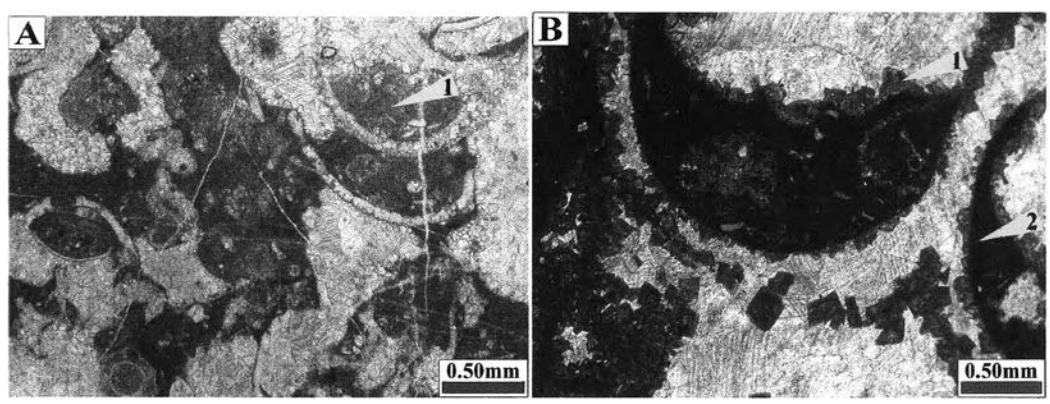


Figure 5.11 **A**: Photomicrograph of biosparite of the unit KD4 showing micrite filled (1) as geopetal structure in the gastropod shell. (PPL); **B**: Photomicrograph of the biosparite of the unit KD4 showing abundant mesocrystalline dolomite (1) around the micrite cement and around micritized grain (2). (Stained, PPL)

### 5.1.5 Unit KD5

The unit KD5 is exposed as isolated two small hills on the eastern side of the highway no.21, near km no.10. It is shown in the measured section nos.4 and 5 (Figure 5.1). There is an old quarry on the eastern side of the southern hill. The rocks are oriented in east-west direction (trending 78 to 107°) and dip southwestwardly with attitude of 15 to 22°. The unit KD5 is exposed in measured section nos. 4 and 5. The total thickness of this unit is more than 100 meters.

***Description***: The unit KD5 comprises calcilutite, calcarenite, calcirudite and biolithite with common chert nodules (Figure 5.12A). The weathered surface of the rocks is slightly rough and clearly reveals diverse types of grains such as brachiopods, gastropods and corals due to differential dissolution (Figure 5.12B). The chert nodules are variable both in shape (mostly elongate) and in size (mostly 10-20 cms in length) as shown in Figure 5.12C. The calcilutite is medium- to very thick-bedded, medium grey to dark grey. The rock is commonly associated with coralline colonies in which their intergranular pores are filled with the dark grey calcilutite (Figure 5.12D). The calcarenite is coarse-grained and displays grain-supported texture. It is a poorly sorted rock with diverse bioclasts, such as fusulinids, algal fragments, brachiopods, gastropods and branching corals (Figure 5.12E). The calcirudite displays matrix-supported texture. The matrix is dark grey, fine-grained and consists of mixed calcilutite to coarse calcarenite. The bioclasts are comparatively large fragments of branching corals, brachiopod shells, gastropods shells and intraclasts (Figure 5.12F). Among those bioclasts, the brachiopods and gastropods are the most abundant and well distributed throughout the unit. The biolithite is algal stromatolite and appears in the lower part of the unit. It is the colonies of coral in growth positions.

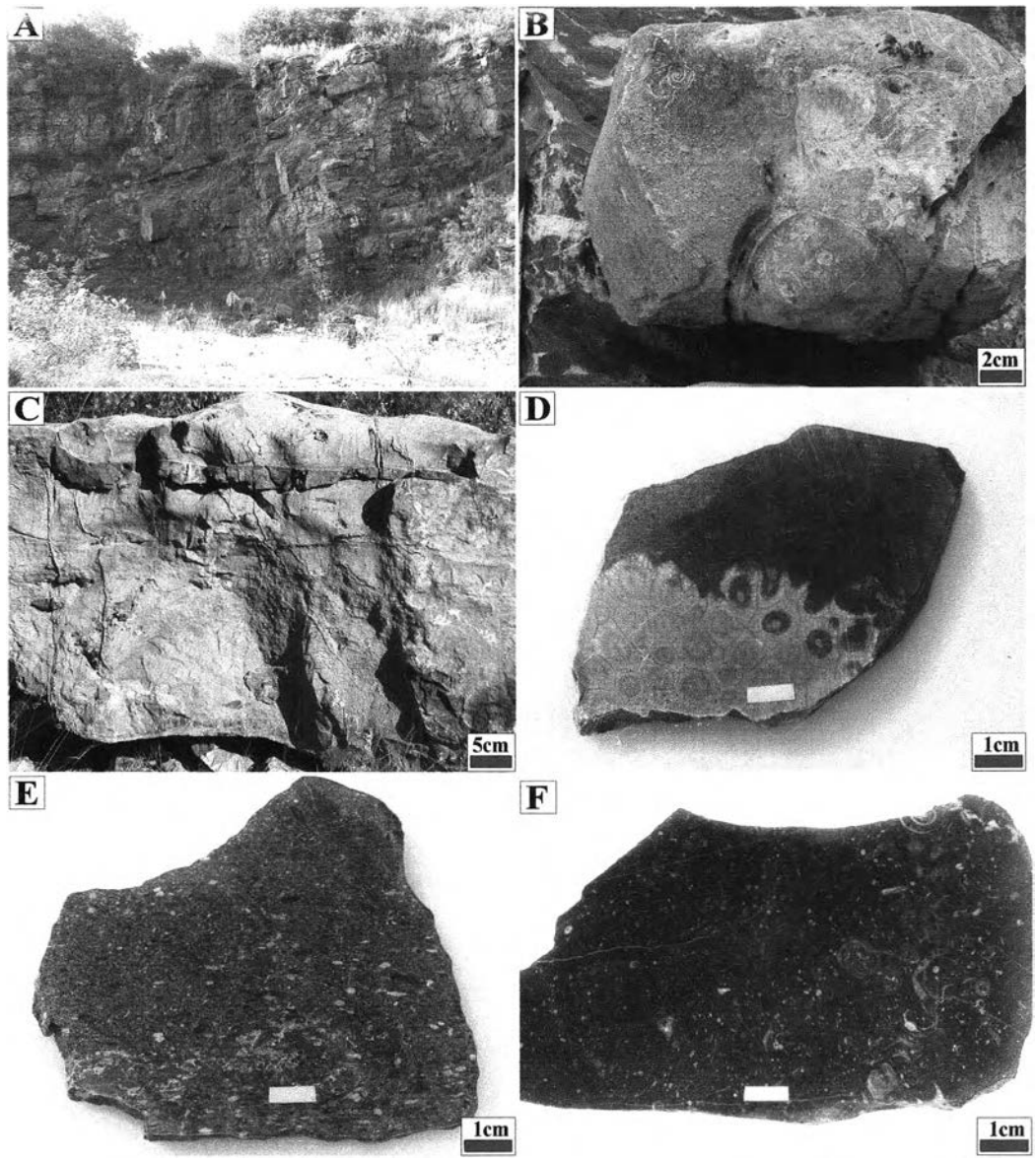


Figure 5.12 **A**: An old quarry on the eastern side of a small hill showing medium- to very thick-bedded strata of medium to dark grey calcilutite to fine calcirudite and biolithite of the unit KD5.; **B**: Weathered surface of fine calcirudite with large brachiopod and gastropod shells, and coral colony.; **C**: Close-up picture of fine calcirudite showing medium- to thick-bedded strata with elongate cherts and small nodular cherts.; **D**: A slab of coral colony associated with dark grey calcilutite of the unit KD5. In this rock slab, there is no bioclast in the dark grey calcilutite.; **E**: A coarse calcarenite slab of the unit KD5 showing medium grey color and grain-supported fabrics.; **F**: A fine calcirudite slab of the unit KD5 showing dark grey color and matrix-supported fabrics. The comparatively large shell fragments are dominant in the lower part of bedding (right) and sparse small shell fragments in the middle and upper parts.

Under a microscope the unit KD5 can be classified as packed biomicrite, packed biomicrudite, packed intramicrite, biopelsparite and intraclasts-bearing biosparudite. The packed biomicrudite is designated as shell fragments larger than 1 mm packed together with smaller unidentified fragments and micrite matrix (Figure 5.13A). The large shell fragments are mainly brachiopods and gastropods. The packed biomicrite is present in part of calcilutite. The packed intramicrite contains abundant small intraclasts of micrite and coral fragments packed with small unidentified fragments and micrite matrix (Figure 5.13B). There are abundant dolomite rhombs disseminated in packed intramicrite and usually show micro-stylolite around grain contact. The biopelsparite contains abundant fecal pellets admixed with bioclasts and cemented by sparry calcite (Figure 5.13C). In part, the intraclast-bearing biosparudite consists of large fusulinids and some intraclasts cemented by sparry calcite (Figure 5.13D). The nodular chert is essentially microcrystalline quartz.

### 5.1.6 Unit KD6

The unit KD6 is exposed at the Khao Yai mountain. The measured section was conducted on the western side of the road cut on the highway no.21 between km nos. 8 to 9 (Figure 5.14A). The rocks trend in the northwest-southeast direction (160 to 173°) and dip northeastwardly with attitude of 40 to 58°. The unit KD6 is shown in the measured section nos. 6, 7, 8 and 9 (Figure 5.1). The total thickness of this unit is more than 321 meters.

***Description***: The unit KD6 is medium to thick-bedded of parallel-bedded type and comprises both grain-supported and matrix-supported calcirudite with some nodular cherts and dolomitic patches (Figure 5.14B). The weathered surface is usually light grey and slightly rough. The chert nodules are usually dark grey and protrude from the surface due to differential weathering.

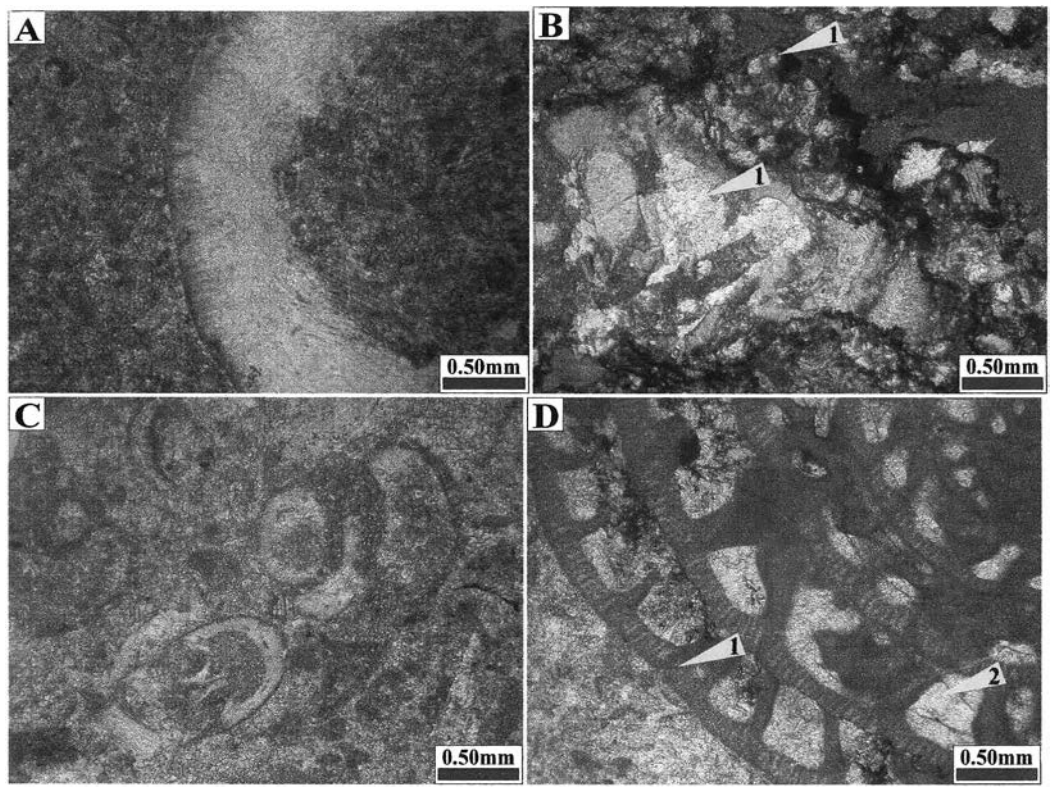


Figure 5.13 **A**: Photomicrograph of packed biomicrudite of the unit KD5 showing a large shell fragments and abundant small unidentified grains closely packed together. (PPL); **B**: Photomicrograph of packed intramicrite with sparse detrital dolomite (1) of the unit KD5. Note also many micro-stylolites developed around grains. (Stained, PPL); **C**: Photomicrograph of biopelsparite of the unit KD5 illustrating the bioclasts are embedded in pelsparite matrix. (Stained, PPL); **D**: Photomicrograph of intraclast-bearing biosparudite of the unit KD5 showing a micritized fusulinid test (1) in which the internal pores has been occluded by radiaxial fibrous calcite cement (2). (PPL)

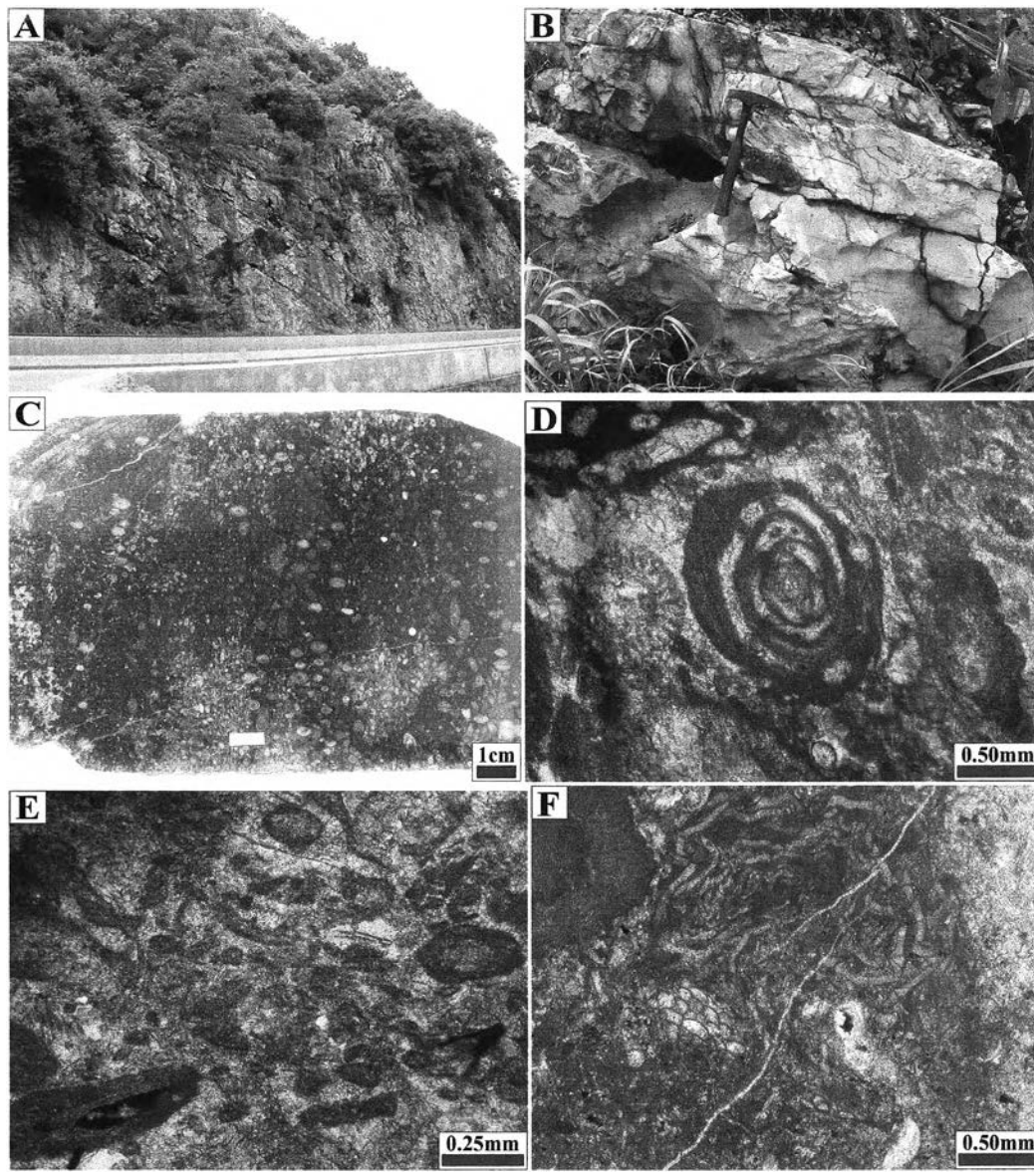


Figure 5.14 **A**: A road cut section of the unit KD6 showing thin- to very thick-bedded strata of medium to dark grey calcilutite to fine calcirudite.; **B**: An outcrop of medium-bedded calcilutite of the unit KD6 showing elongate black nodular chert.; **C**: A fine calcirudite slab of the unit KD6 showing grain-supported fabrics of fusulinid tests.; **D**: The photomicrograph of fusulinid bearing biosparite of the unit KD6 showing completely micritized grains. (Stained, PPL); **E**: Photomicrograph of biopelsparite of the unit KD6 showing diverse micritized grains and some fecal pellets cemented by sparry calcite. (PPL); **F**: Photomicrograph of packed biomicrite of the unit KD6 showing broken unidentified shell fragments closely packed in micrite matrix. There is a coated grain on the upper left of the picture. (Stained, PPL)

The grain-supported calcirudite is fine-grained, medium to dark grey and moderately sorted. It contains grains (1 to 5 mms in size) of mostly fusulinid tests (Figure 5.14C). The matrix-supported calcirudite, the major rock types of this unit, is fine-grained, medium grey and poorly sorted. It contains bioclasts (1 to 10 mms in size) of fusulinid tests). Part of the rock is slightly silicified and appears as yellowish brown patches while the fusulinid tests are dark grey to black.

Petrographically, the unit KD6 consists of biosparite, biopelsparite and packed biomicrite with some chert and medium crystalline dolomite. The biosparite contains mainly fusulinid tests and some other grains, commonly cemented by sparry calcite. The bioclasts are completely micritized and the internal pores are occluded by sparry calcite cement (Figure 5.14D). The biopelsparite contains diverse micritized grains and some fecal pellets, usually cemented by sparry calcite (Figure 5.14E). Some grains and pellets show microcrystalline calcite cement near the grain contact. The packed biomicrite consists mostly of closely packed grains embedded in micrite matrix (Figure 5.14F). Grains are unidentified shells, coral fragments and algal coated grains. The broken shells show complete micrite-coating before broken. It is revealed that some fusulinid tests were broken after sediments were indurated. The internal pores of some fusulinid tests were lack of cement before broken then occluded by radiaxial fibrous calcite cement (Figure 5.15A). The nodular chert is mainly microcrystalline quartz with minor chalcedonic quartz (Figure 5.15B). It is noted that there is no silicification in part of dolomite.

### 5.1.7 Unit KD7

The unit KD7 is exposed at two small hills southward from the Khao Yot Iang. It is isolate small hills surrounded by lowland area. The rocks trend northwest-southeast direction (120 to 125°) and dip southwestwardly with attitude of 50 to 53°.

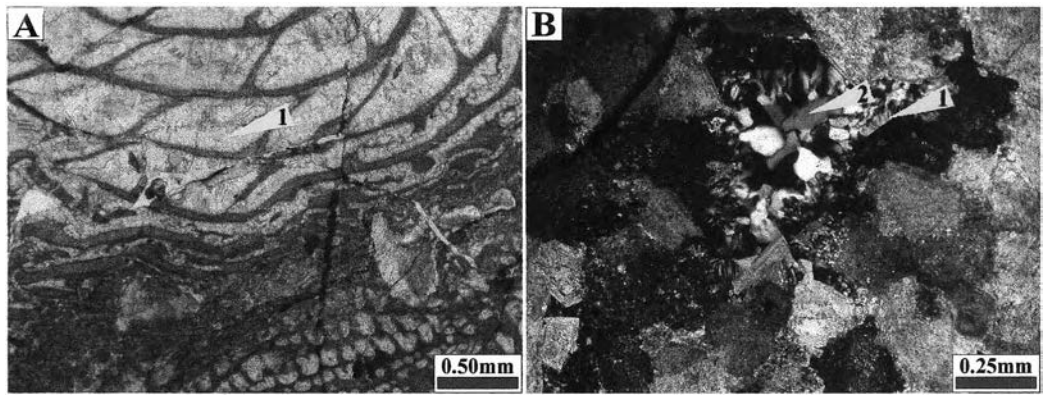


Figure 5.15 **A**: Photomicrograph of packed biomicrite of the unit KD6 showing the broken fusulinid test with radiaxial fibrous calcite cement (1) completely filled in the internal chambers. (PPL); **B**: Photomicrograph of silicified dolomitic limestone of the unit KD6. The chalcedonic quartz (1) fringes around the pore surface and the remaining pores were occluded by megacrystalline quartz (2). (Stained, XPL)

The total thickness of this unit is about 120 meters. The unit KD7 is shown in the southern part of measured section no.9 (Figure 5.1)

***Description***: The unit KD7 is thin-to-thick-bedded and comprises calcilutite to calcarenite with coquinite beds, algal coated coquinite beds and many dolomitic limestone beds (Figures 5.16A and 5.16B). The calcilutite is thin-bedded, medium to dark grey and consists mainly of micrite. It is the major rock mass of this unit. There is some large shell fragments embedded in the calcilutite matrix (Figure 5.16C). Some calcilutite beds were intensely disturbed by burrows (Figure 5.16D). The burrows are generally filled with microcrystalline dolomite. The calcarenite is medium- to thick-bedded, medium grey and contains small shell fragments less than 1 mm in size (Figure 5.16E).

Petrographically, the unit KD7 consists of packed biomicrite and dismicrite. The packed biomicrite is characterized by abundant small grains (a few μms to several hundred μms in size), packed together and embedded in micrite matrix (Figure 5.16F).

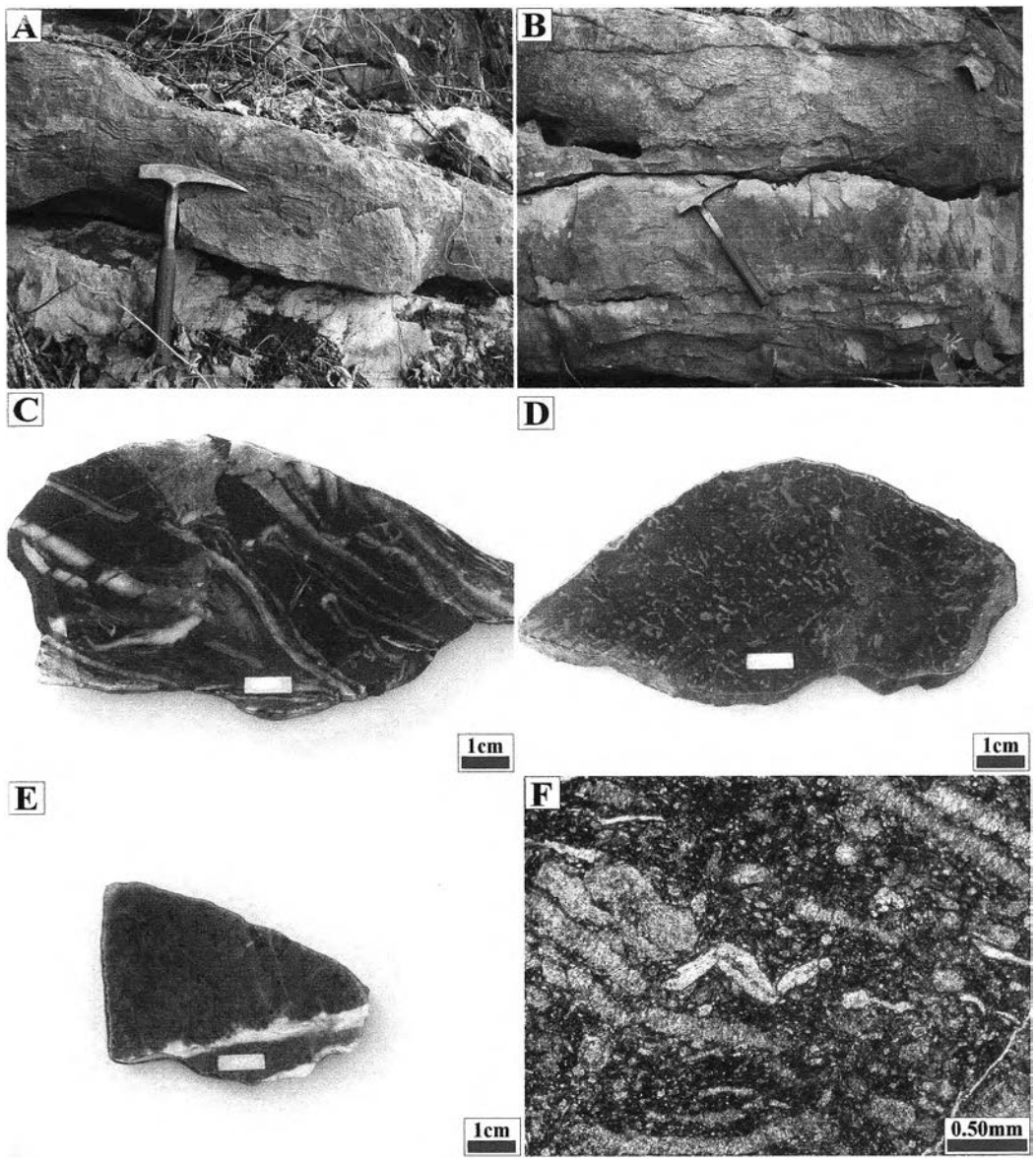


Figure 5.16 **A**: A medium-bed of coquinite in the lower part of the unit KD7.; **B**: An outcrop of medium grey, thick-bedded dolomitic limestone and laminated dolomitic limestone of the unit KD7.; **C**: A coquinite slab of the unit KD7 showing flattened broken shell fragments embedded in the dark grey calcilutite matrix.; **D**: A medium grey calcilutite slab of the unit KD7 showing abundant burrows (white steaks) filled with microcrystalline dolomite rhombs.; **E**: A medium grey calcarenite slab of the unit KD7.; **F**: Photomicrograph of packed biomicrite of the unit KD7 showing abundant unidentified broken shell fragments packed in micrite matrix.

The dismicrite or disturbed micrite is characterized by lesser amount of grains in micrite matrix. Also in the micrite matrix there are abundant burrows (Figure 5.17A), bird's eye structure (Shinn, 1968; Figure 5.17B and 5.17C) and fenestral feature (Choquette and Pray, 1970; Figure 5.17D) which partially filled by microcrystalline and mesocrystalline dolomite and sparry calcite cement.

### 5.1.8 Unit KD8

The unit KD8 is exposed at a small hill near the km no.6 on the western side of highway no.21. It was a small pit quarry. The rocks trend in northwest-southeast direction (100 to 115°) and dip southwestwardly with attitude of 50 to 55°. The total thickness of this unit is more than 150 meters. The unit KD8 is shown in measured rock-section no.10 (Figure 5.1).

***Description***: The unit KD8 is characterized by thin-bedded, medium grey to brownish grey calcarenite (Figure 5.18A). The large grains consist exclusively of fusulinid tests ranging in size from 1 to 2 mms (Figure 5.18B). Much of this unit was weathered into friable siliceous matter.

Petrographically, the unit KD8 consists of packed biomicrite. Grains are mainly fusulinid tests with minor brachiopod fragments (Figure 5.18C). The micritized shells of fusulinid were transformed into microsparite. As such the internal pores were filled with coarse sparry calcite cement. Some part of packed biomicrite contains some spicules embedded in the micrite matrix (Figure 5.18D). The silicified argillaceous limestone contains abundant chalcedonic spherulite (Figure 5.18E).

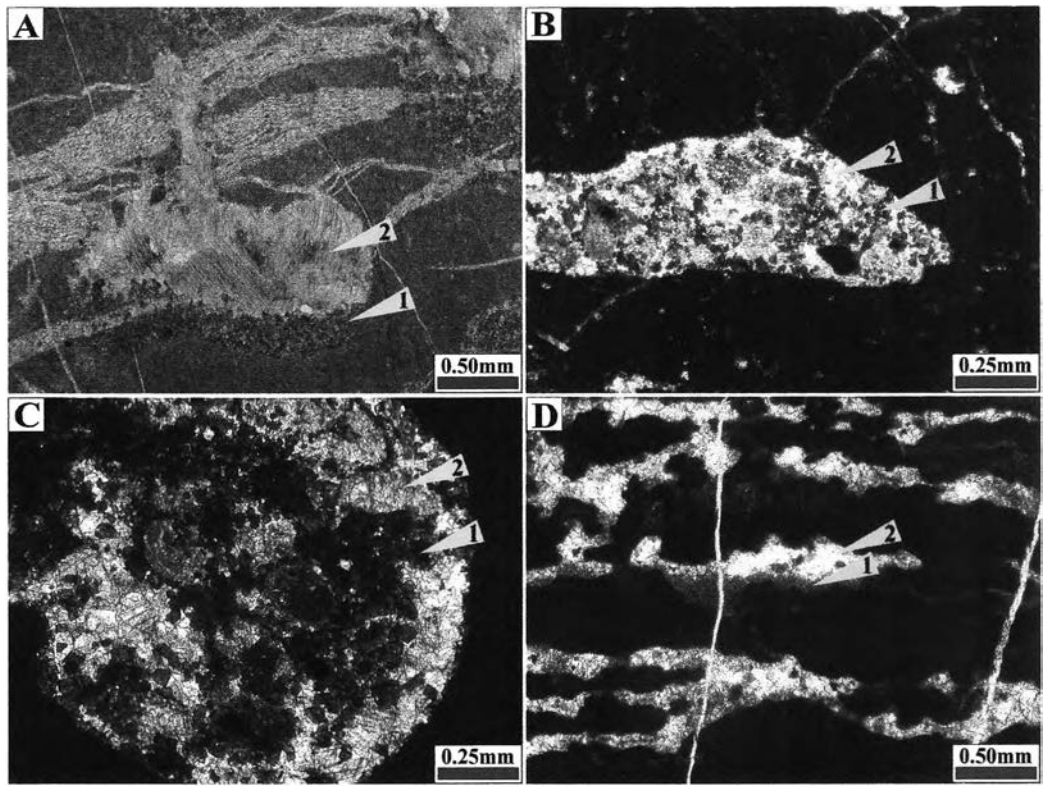


Figure 5.17 **A**: Photomicrograph of disturbed micrite of the unit KD7. The burrows were earlier filled by microcrystalline dolomite (1) and later cemented by sparry calcite (2). (Stained, PPL); **B**: The bird's eye structure in disturbed micrite of the unit KD7. It is filled by microcrystalline dolomite (1) and sparry calcite cement (2). (Stained, PPL)**; C**: The bird's eye structure in disturbed micrite of the unit KD7. It is filled by microcrystalline dolomite (1) and sparry calcite cement (2). (Stained, PPL)**; D**: The fenestral feature in micrite of the unit KD7. It was initially filled by microcrystalline dolomite (1) and finally by sparry calcite cement (2). (PPL)

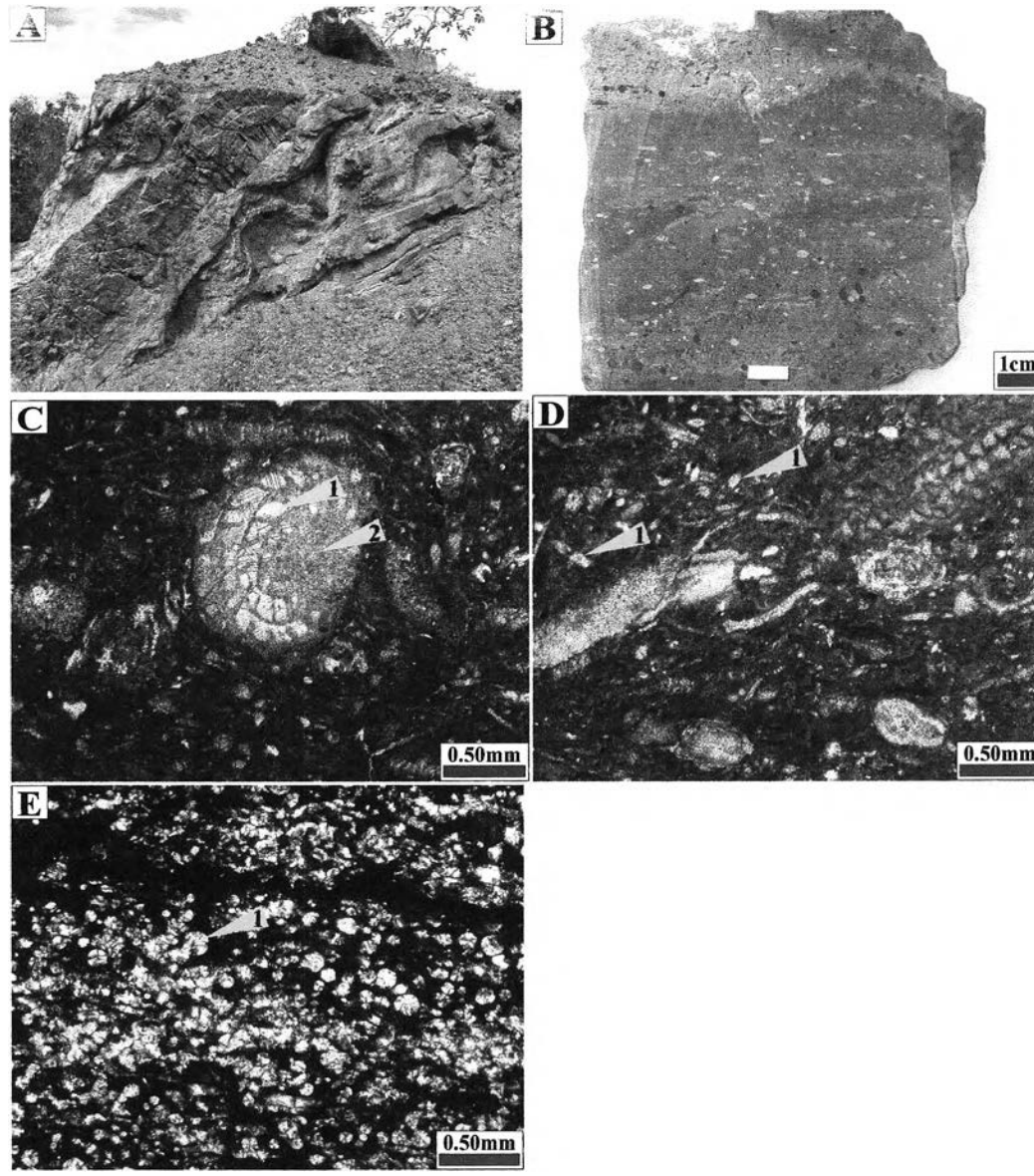


Figure 5.18 **A**: An outcrop of weathered calcarenite interbedded with silicified argillaceous limestone of the unit KD8.; **B**: A calcarenite slab of the unit KD8 showing matrix-supported fabric of fusulinid test.; **C**: Photomicrograph of packed biomicrite of the unit KD8. All internal pores were filled by sparry calcite cement (1) and micritized grains (2) were transformed into microsparite. (PPL); **D**: Photomicrograph of packed biomicrite of the unit KD8 illustrating some spicules (1) packed in micrite matrix. (PPL); **E**: Photomicrograph of silicified carbonate of the unit KD8 showing abundant chalcedonic spherulite (1) in argillaceous matrix. (XPL)

### 5.1.9 Unit KD9

The unit KD9 is exposed at a small hill near km no.3, on the highway no.21. The rocks lie in northeast-southwest direction (75 to 85°) and dip southwestwardly with attitude of 60 to 72°. The unit KD9 is shown in the measured section no.11 (Figure 5.1). The total thickness of this unit is less than 239 meters.

***Description***: The unit KD9 is a sequence of thinly-bedded, medium grey to dark grey calcilutite in the lower part and gradually passing upward into clastic associations of yellowish brown, thin-bedded silty shale, silty sandstone and porcelanite (Figure 5.19A). The silicified calcilutite usually appears as dark grey to black colored rock on fresh surface or as yellowish brown colored rock on the weathered surface (Figure 5.19B).

Petrographically, the unit KD9 consists of packed biomicrite and microcrystalline quartz chert. The packed biomicrite consists of closely packed grains in micrite matrix. Grains are rounded to sub-rounded and appear as micrite-coated or completely micritized grains (hence unable to identify) (Figure 5.19C). In addition there are some small quartz grains (10 to 20 μms in size) of probably detrital origin disseminated throughout the unit. Some calcareous grains are however completely filled by coarse sparry (partly ferroan) calcite cement (Figure 5.19D). In part the carbonate has been silicified which appears as crypto to microcrystalline quartz and minor chalcedonic quartz. Also in the fine grain chert matrix there are some non-ferroan calcareous remnants (red-stained in Figure 5.19E) as well as ferroan calcareous remnants (purple-stained in Figure 5.19F). There are also some ferroan microcrystalline dolomites disseminated in the fine grain chert matrix.

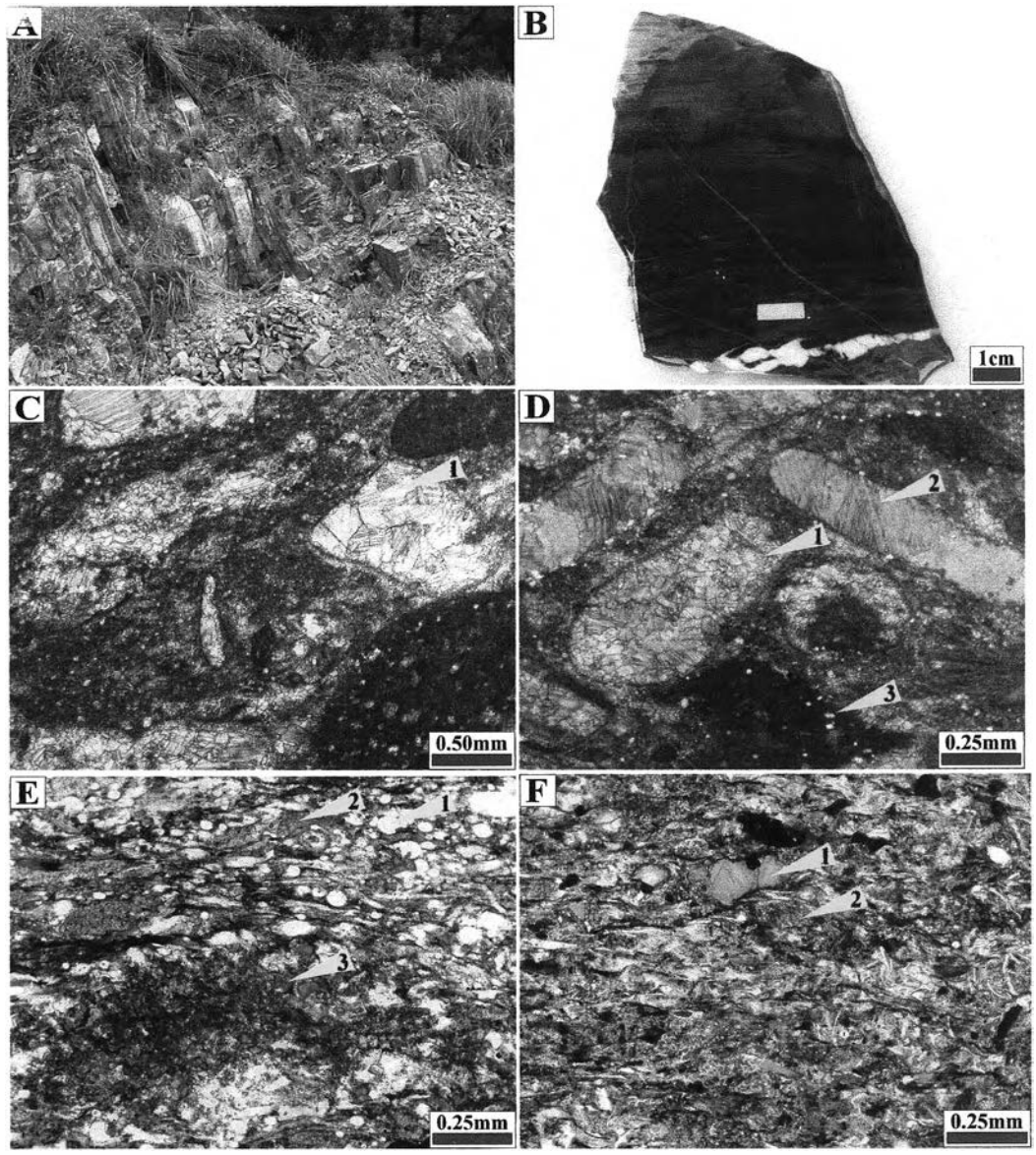


Figure 5.19 **A**: An outcrop of the unit KD9 consisting of thin-bedded calcilutite and silicified argillaceous limestone.; **B**: A silicified argillaceous limestone slab of the unit KD9.; **C**: Photomicrograph of rounded packed biomicrite of the unit KD9 showing micrite coated grains with rounded rims. Grains were completely replaced by sparry calcite.; **D**: Photomicrograph of rounded packed biomicrite of the unit KD9. The rounded grains were completely replaced by sparry calcite (1), partially ferroan calcite (2). There is some small detrital quartz grains (3) sparsely distributed in the micrite matrix. (Stained, PPL); **E**: Photomicrograph of silicified limestone of the unit KD9 showing abundant chalcedonic spherulite (1) embedded in silicified argillaceous matrix (2) with some calcareous remnant (3). (Stained, XPL); **F**: Photomicrograph of silicified limestone of the unit KD9 showing calcareous remnants (1) that are made up partially of ferroan calcite (2). (Stained, PPL)

## 5.2 Khao Chan Area

The overall rock units of the Khao Khad Formation in the Khao Chan area can be best represented in the western part of the area. Totally five measured sections were conducted in order to define the characteristics of sedimentary sequence in the Khao Chan area. The locations of these measured sections are shown in Figure 5.20. Most traverse lines were made in the north-south direction roughly perpendicular to the regional strike. The total thickness of the measured sections was 6,603 meters long in which 269 rock samples were collected from those sections. The graphic representation of sedimentary sequence of each measured section is shown in Figure 5.21.

The representative sedimentary sequence of composite section of the Khao Khad Formation at Khao Chan area is shown in Figure 5.22. From the results of direct field observation and the graphic representation of all measured rock sections, it is recognized that there are altogether 9 units. The description of each unit is presented in ascending order as follows:

### 5.2.1 Unit KC1

The unit KC1 is the lowest rock unit of the Khao Khad Formation at Khao Chan area. It is exposed as on a gentle slope, north of the Khao Chan. It overlies on the uppermost unit of the Pang Asok Formation. The rocks trend in the northwest-southeast direction (100 to 115°) and dip southwestwardly with attitude of 50 to 53°. The unit KC1 is exposed in the measured section nos. 3, 4 and 5 with thicknesses of 294, 283 and 233 meters, respectively (Figure 5.22). The total thickness of this unit ranges from 233 to 294 meters.

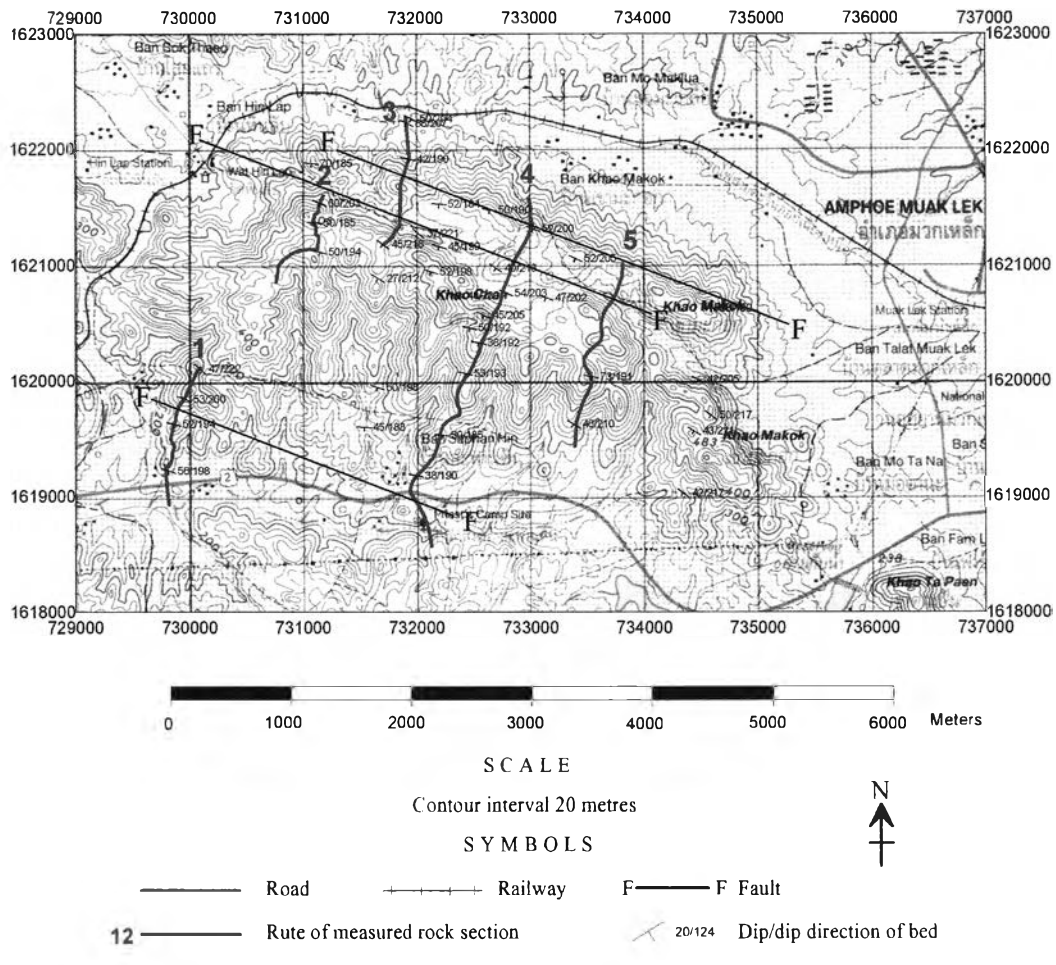


Figure 5.20 Topographic map showing traverses of five measured sections along the Khao Chan route (modified from topographic map sheet Amphoe Kaeng Khoi, 5238III, Royal Thai survey department).

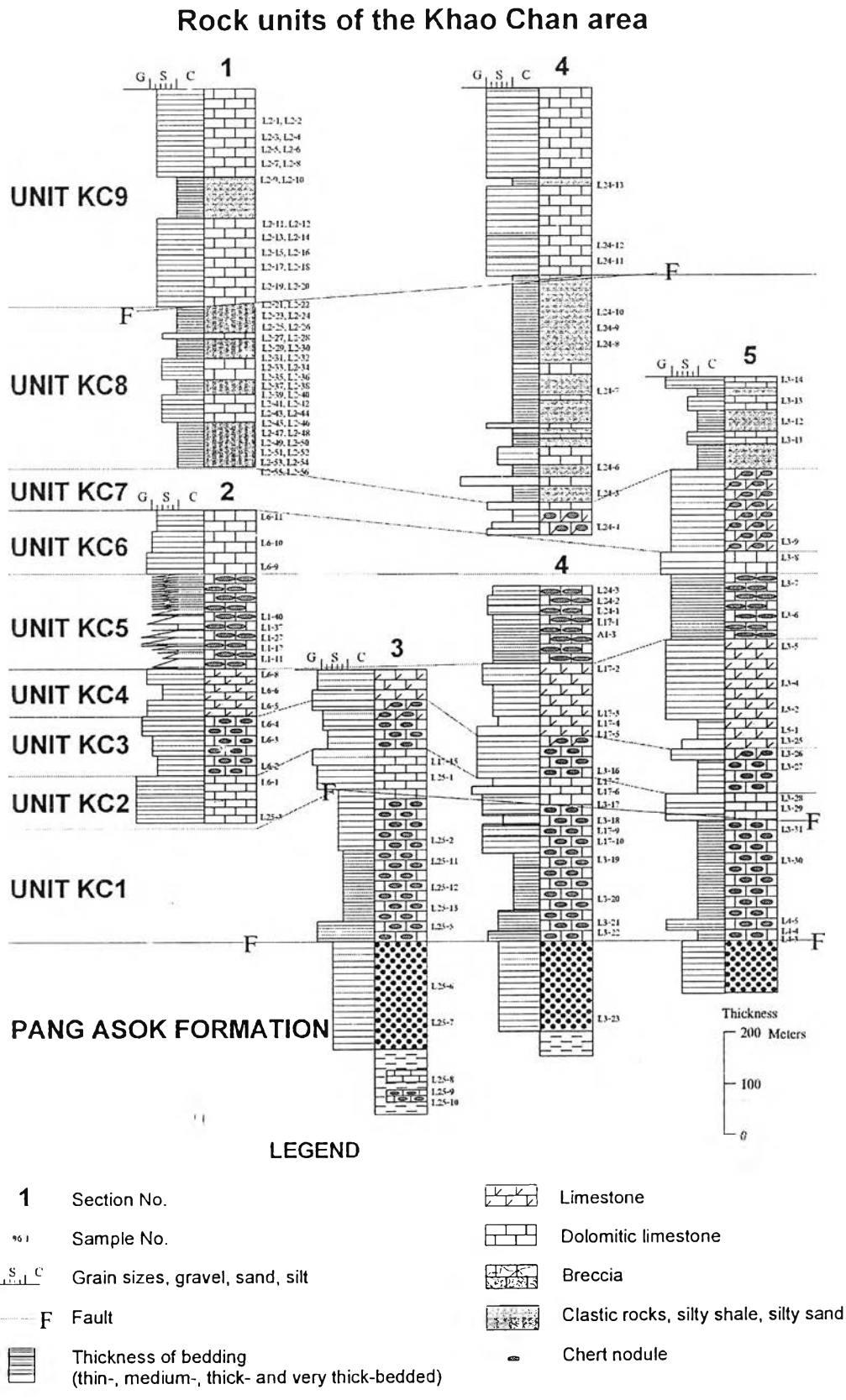


Figure 5.21 The graphic representation of 5 measured sections along Khao Chan route.

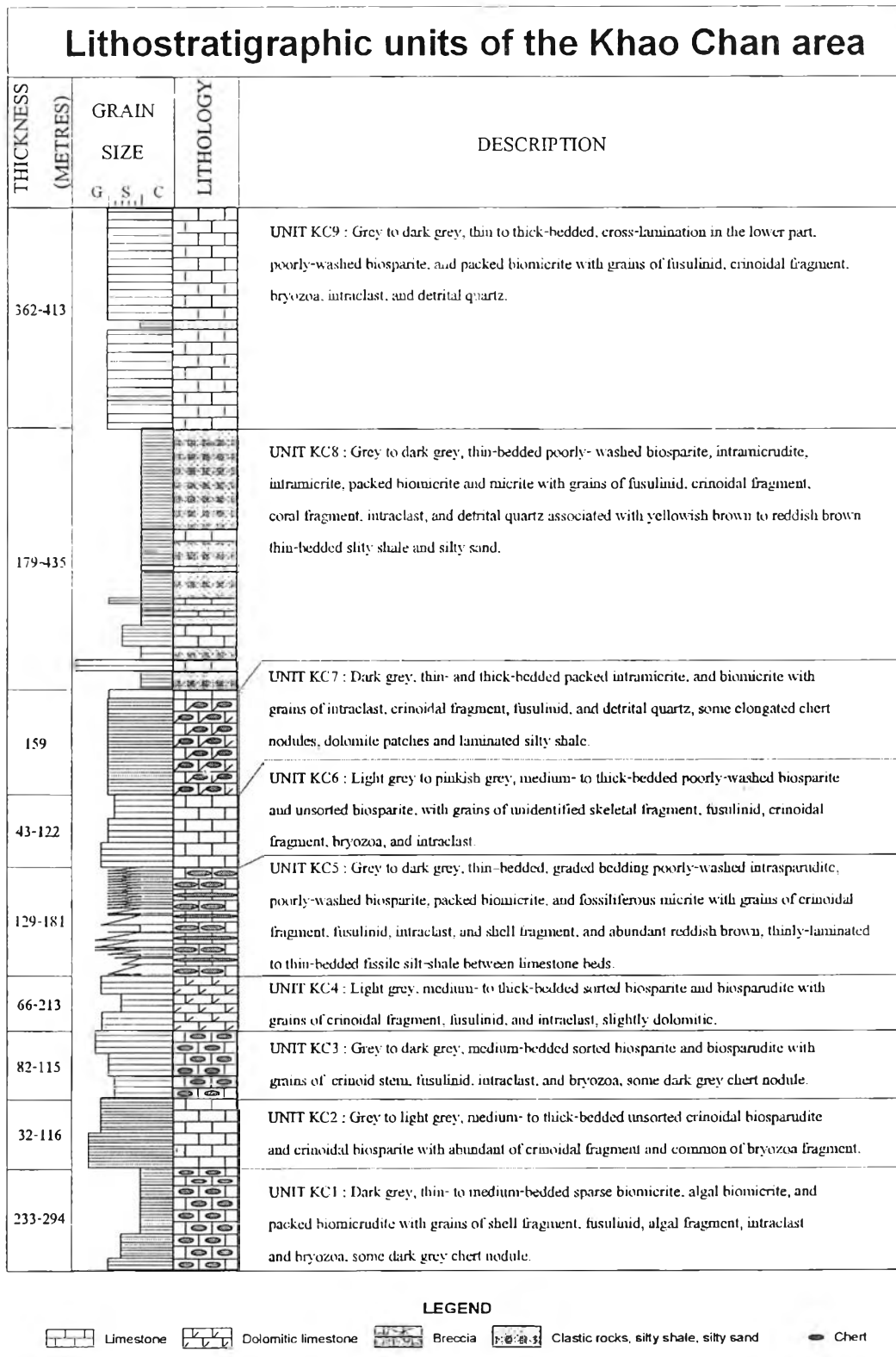


Figure 5.22 The graphic representation of the representative sedimentary sequence of the Khao Khad Formation at Khao Chan area.

***Description***: The unit KC1 is thin-to medium-bedded, medium grey to dark grey and comprises calcilutite to fine calcirudite with dark grey chert nodules. The bedding is mostly wavy-and-nonparallel to locally wavy-and-parallel bed type (Figure 5.23A). The lower part of the unit is dominated by thinly-to-thickly-laminated calcilutite and fine calcirudite containing abundant algal mats, brachiopod shell fragments and fusulinid tests of mainly *Robustoschwagerina* sp. (Figure 5.23B). In contrast, the middle and upper parts are represented by medium-bedded calcilutite with relatively rare shell fragments and sparse fusulinid tests.

Petrographic studies show that the unit KC1 is biomicrite, algal biomicrite, packed biomicrudite, poorly washed biosparite, poorly washed biosparudite, poorly washed biopelsparite and poorly washed biopelsparudite with some cryptocrystalline dolomite and microcrystalline chert. The biomicrite (Figure 5.23C) consists of complete or broken skeletons in a fine-grained micrite matrix. The skeletons, such as brachiopod shells and foraminiferal tests are sharply marked off by a sparry calcite cement of 20 to 100 μms in size. Some internal pores of fusulinid tests and gastropod shells are partly or completely filled with micrite matrix or pelmicrite and mark geopetal like structure. In some cases, the internal spaces or chambers of shells are wholly filled with coarse sparry calcite. The algal biomicrite is exclusively recognized in the lower part of the unit. It comprises unidentified algal fragments closely packed with calcareous intraclasts and/or bioclasts ranging in size from a few to hundred μms. The packed biomicrudite is also exclusively abundant in the lower part of the unit. Thus, this rock is found closely associate with algal biomicrite. It consists mainly of complete foraminiferal tests (mostly *Robustoschwagerina* sp., 2 to 7 mms in size) closely packed in micrite matrix. The poorly washed biosparite is characterized by closely packed grains of micritized and/or dolomitized shell fragments of both fusulinids and brachiopods. Micrite matrix is locally observed between the packed grains. The micritized grains show complete micritization as revealed by dark color in

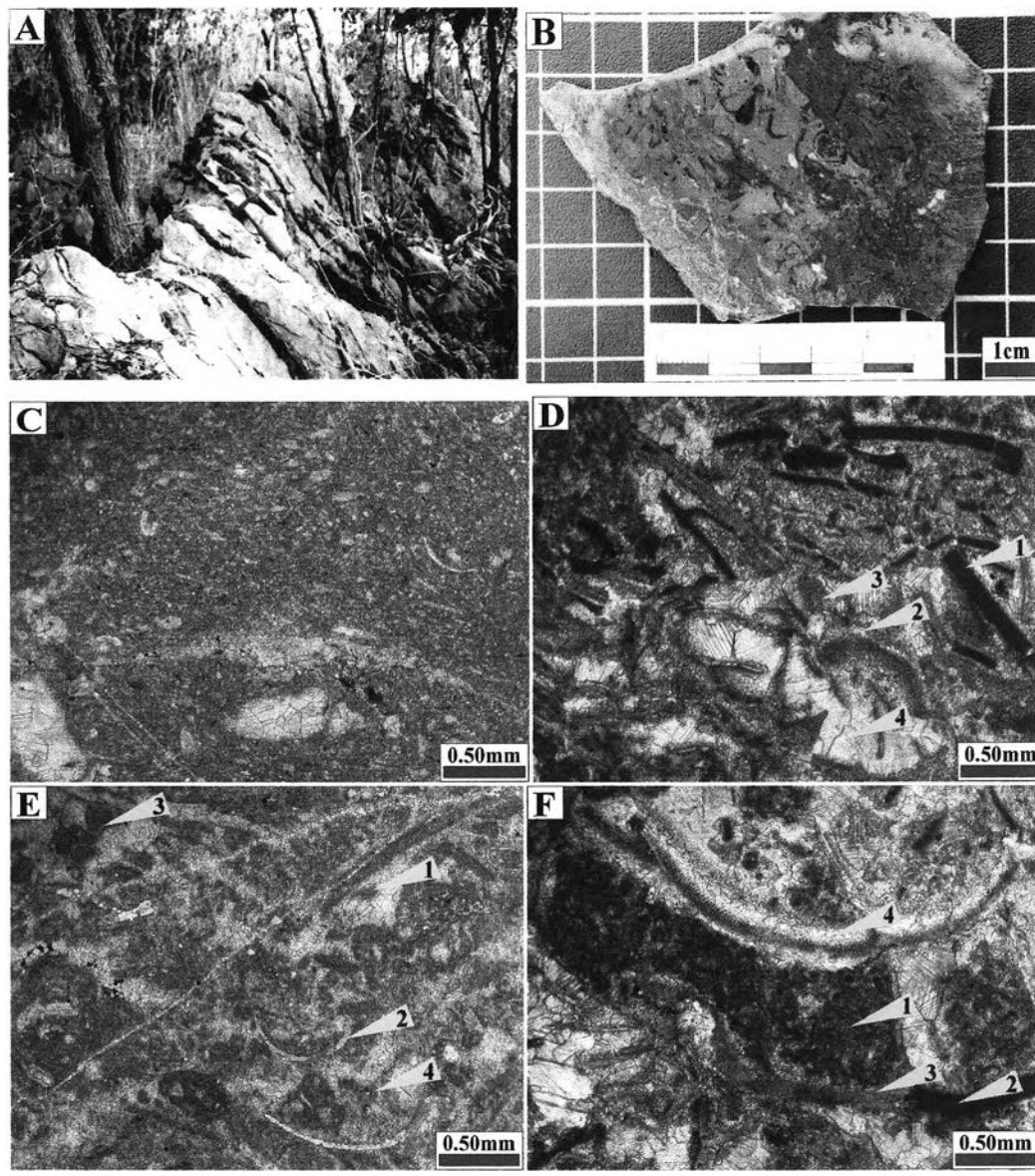


Figure 5.23 **A**: An outcrop of the lower part of unit KC1showing thin- to medium-bedded, dark grey calcilutite with dark grey chert nodules.; **B**: A greenish grey to dark grey calcilutite slab of unit KC1 showing shell fragments with sparse foraminiferal tests.; **C**: Photomicrograph of packed biomicrite of the unit KC1. (Stained, PPL); **D**: Photomicrograph of poorly washed biosparite of the unit KC1 showing abundant micritized (1) and dolomitized (2) shell fragments cemented by microcrystalline calcite (3) and coarse crystalline (4) sparry calcite. (Stained, PPL); **E**: Photomicrograph of poorly washed biopelsparite of the unit KC1 showing abundant fecal pellets (1) deposited together with bioclasts (2) and micrite remains (3). Some pellets were initially cemented by microcrystalline calcite (4). (Stained, PPL); **F**: Photomicrograph of poorly washed biosparudite of the unit KC1 showing some fecal pellets (1) filling in fusulinid chambers. Parts of shells were micritized (2) or dolomitized (3) or locally silicified (4). (Stained, PPL)

plane polarized light. Textural evidences also revealed that the fragments were initially cemented by microcrystalline calcite in the form of thin layer before they were completely micritized. The fragments were later cemented by coarse sparry calcite (Figure 5.23D). As for the poorly washed biosparudite, the rock largely resembles the poorly washed biosparite except that there are a number of large skeleton fragments (up to 7 mms). The poorly washed biopelsparite and poorly washed biopelsparudite consist of abundant fecal pellets together with bioclasts and micrite remains (Figures 5.23E and 5.23F). The sizes of grains vary from a few μms to several mms. The grains are cemented by sparry calcite. Some pellets were initially coated and cemented by microcrystalline calcite. In this rock there is also cryptocrystalline dolomite (take no stain) partially replace fusulinid tests (Figure 5.23F). Minor amount of microcrystalline quartz was also found to partially replace fusulinid tests which were not dolomitized and micritized. Chert nodules of varying size and shape regularly disseminate throughout the unit (Figure 5.23A). The chert is essentially microcrystalline quartz with occasionally some tiny calcareous patches.

### 5.2.2 Unit KC2

The unit KC2 overlies the unit KC1 with sharp contact. They are well exposed as light grey outcrop on weathered surface. This unit trends northwest-southeast direction (100 to 120°) and dips southwestwardly with attitude of 50 to 60°. It is exposed in the measured section nos. 2, 3, 4 and 5 (Figure 5.22) with the thicknesses of 116, 77, 32 and 52 meters, respectively. The total thickness of this unit varies from 32 to 116 meters with a tendency to be thickened westwardly.

***Description***: The unit KC2 is medium- to thick-bedded, light grey to medium grey and comprises crinoidal calcarenite to fine calcirudite (Figure 5.24A). With un-aid eyes, the rocks contain more than 50 % fragments of large crinoid stems, between

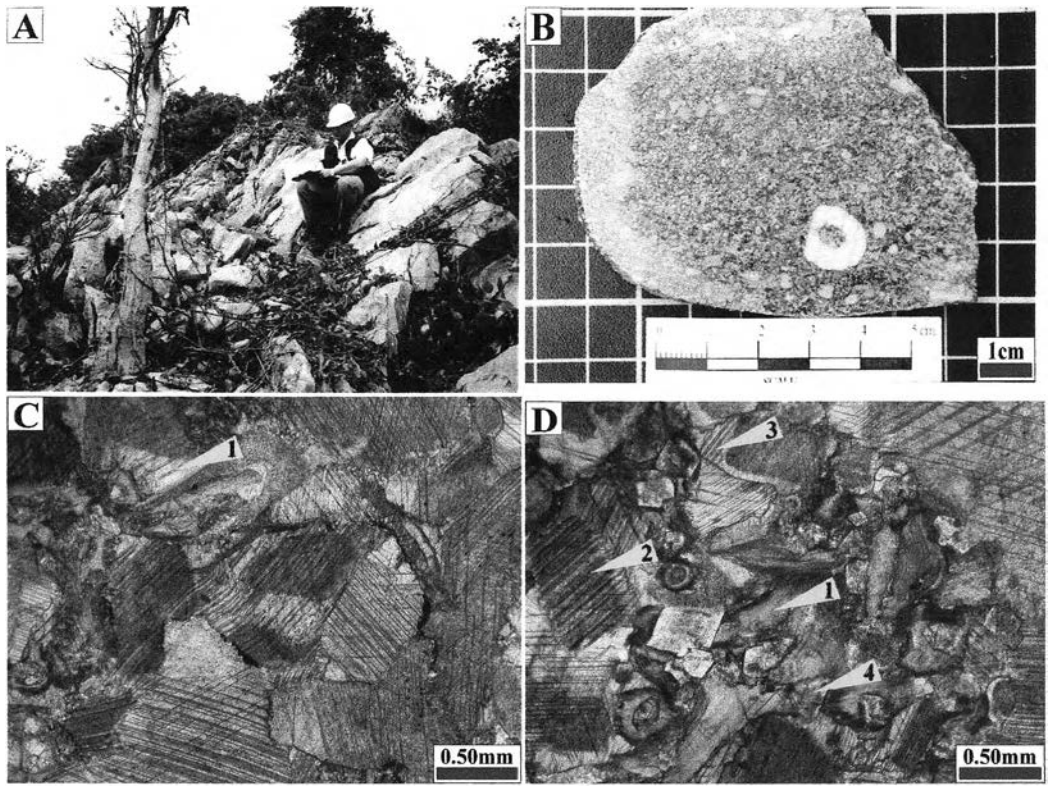


Figure 5.24 **A**: An exposure of medium- to thick-bedded encrinite of unit KC2.; **B**: An encrinite slab of the unit KC2 showing poorly sorted crinoidal fragments.; **C**: Photomicrograph of crinoidal biosparite of the unit KC2 showing overgrowth calcite cement on crinoid ossicles (1). (Stained, PPL); **D**: Photomicrograph of crinoidal biosparite of the unit KC2 showing fragments of bryozoa (1) and crinoid fragments (2) cemented by overgrowth calcite cement (3). Note also the replacement of mesocrystalline dolomite rhombs (4). (Stained, PPL)

0.5 and 2 cms in diameter (Figures 5.24B). The bedding is parallel-bedded type with very thin bands of grayish black to reddish silty shale in each crinoidal limestone beds.

Petrographically this unit is unsorted crinoidal biosparudite and crinoidal biosparite which contain mainly (more than 50 %) crinoidal and bryozoan fragments. They are cemented together by coarsely crystalline and relatively clean sparry calcite. The fine-grained matrix is rarely recognized as micrite and pseudosparite with sparse dolomite rhombs in some parts. The crinoidal fragments are essentially ossicles of crinoid stems. Each ossicle is made up of a single calcite crystal in which its crystallographic C-axis is parallel to the central canal. Most crinoid fragments were over-grown by syntaxial calcite cement (Figure 5.24C). It can be recognized that all grains were corroded before deposition. The dolomite rhombs are commonly associated with fine-grained matrix as well as replace the bryozoan fragments. The rhombs are subhedral to euhedral crystals of various sizes (50 to 300 μms) and some are corroded (Figure 5.24D).

### 5.2.3 Unit KC3

Overlying the unit KC2 with gradational contact is the calcarenite with chert nodules of the unit KC3. This unit trends in northwest-southeast direction (90 to 109°) and dips southwestwardly with attitude of 50 to 63°. This unit is present in the measured section nos. 2, 3, 4 and 5 (Figure 5.22) with the thicknesses of 115, 100, 82 and 87meters, respectively. The total thickness of this unit varies from 82 to 115 meters with the tendency to be thickened westwardly.

***Description***: The unit KC3 is medium- to thick-bedded, grey to dark grey and comprises coarse calcarenite and fine calcirudite with scattered dark grey chert nodules (Figures 5.25A). The nodules vary in size from a few cms to a few ten cms and partly

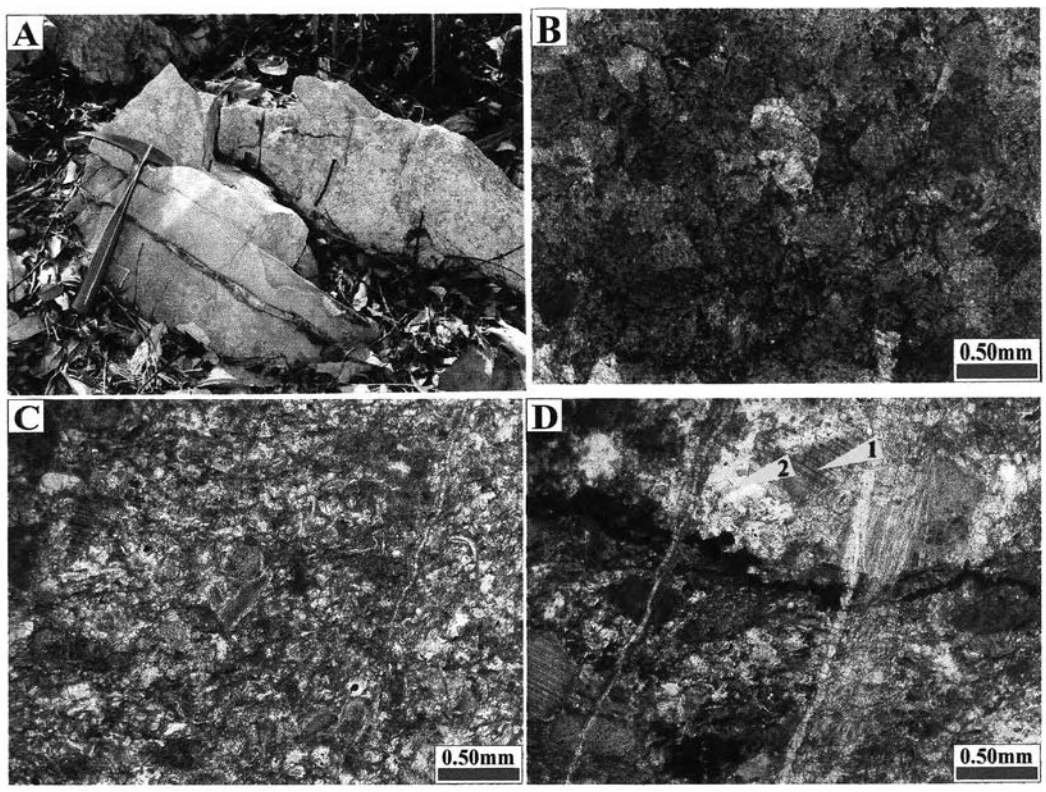


Figure 5.25 **A**: An exposure of fine calcirudite with chert nodules of unit KC3 showing an elongated nodular chert.; **B**: Photomicrograph of sorted biosparite of the unit KC3 showing closely packed grains cemented by sparry calcite in filled by some micrite. (PPL); **C**: Photomicrograph of poorly washed biosparite of the unit KC3 depicting dark brown and dull microcrystalline dolomite can be recognized locally at the boundaries of carbonate grains. (Stained, PPL); **D**: Photomicrograph of the poorly washed biosparite of the unit KD3 that is slightly silicified with remnant of calcareous grains (1) and calcite rhombs (2). (Stained, PPL)

elongated. The upper part of the unit is slightly dolomitic. With un-aid eyes the major grain components are crinoid stems, foraminifera, intraclasts and bryozoans, respectively in decreasing order of abundance. It is noted that the skeletal remains of crinoids and foraminifera are also present in chert nodules.

Microscopically, the unit KC3 is designated as sorted biosparite and biosparudite with some microcrystalline chert. The biosparite and biosparudite (Figures 5.25B) consist of broken fragments of crinoids, bryozoans and unidentified calcareous skeletons, mixed in various proportions with intraclasts and complete foraminifera shells .The well sorted grains are cemented together by relatively clear calcite. However, the dark brown and dull microcrystalline dolomite can be recognized locally at the boundaries of carbonate grains (Figures 5.25C and 5.25D). The crinoid fragments show syntaxial overgrowth calcite cement and corrosion. In addition, the dark grey microcrystalline chert appears as lenses and elongated nodular shape embedded in the carbonate rocks. The nodular chert is mainly microcrystalline quartz, locally with some disseminated calcite rhombs. It is also noticed that the degree of silicification was more intense in the calcareous matrix than in the calcareous grains. The calcareous skeletons however have been silicified locally.

### 5.2.4 Unit KC4

Unit KC4 overlies conformably on unit KC3 with gradational contact. Most weathered surface shows 'elephant skin' texture. Beds lie in northwest-southeast trend (103 to 110°) and dip southwestwardly with attitude of 51 to 59°. It is exposed in the measured section nos. 2, 3, 4 and 5 (Figure 5.26A) with the thicknesses of 92, 66, 135 and 213 meters, respectively. The total thickness of this unit varies from 66 to 213 meters with a tendency to be thickened westwardly.

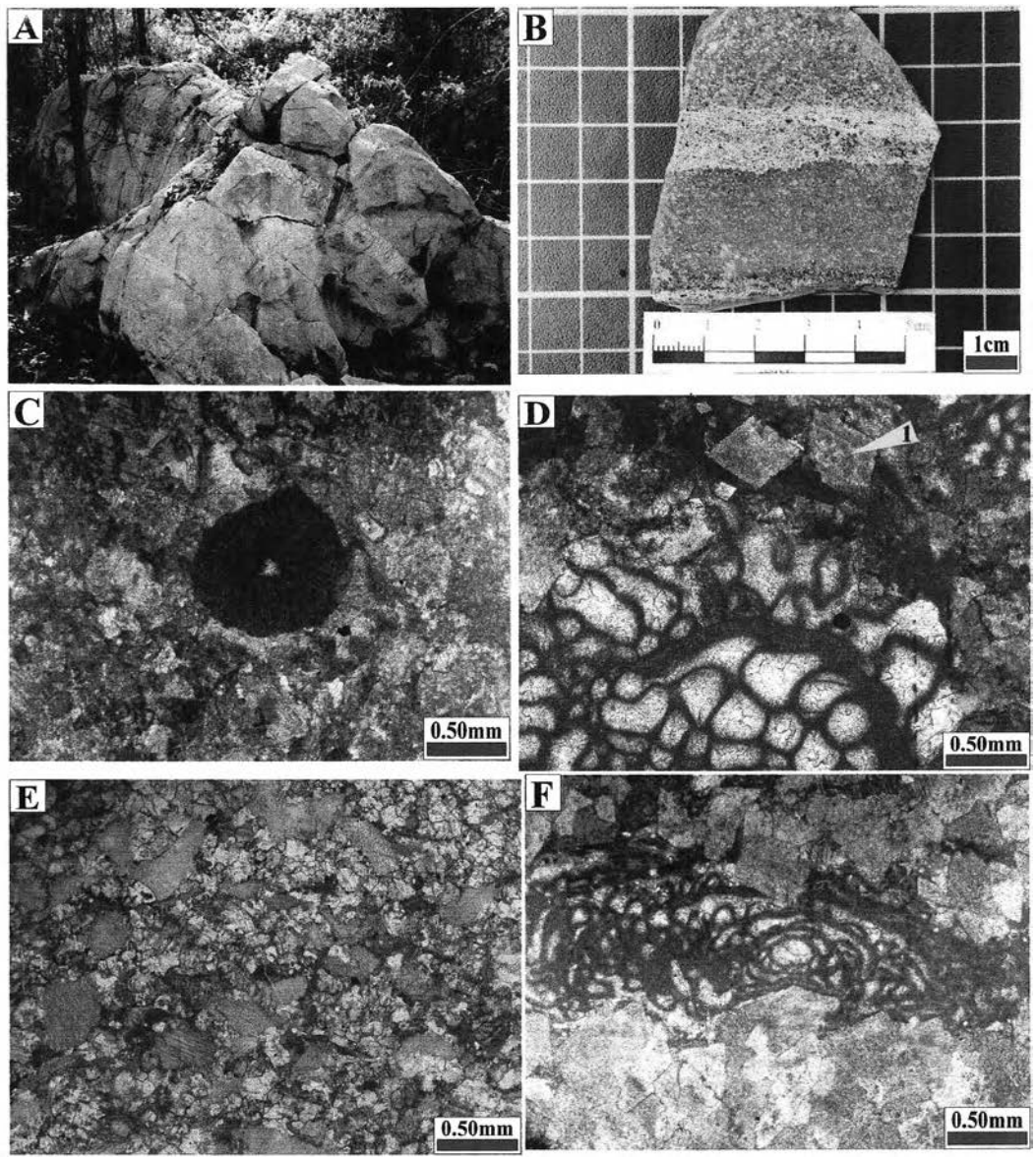


Figure 5.26 **A**: An outcrop of medium-bedded calcarenite interbedded with medium-bedded calcirudite with thin-bedded dolomitic calcarenite of the unit KC4.; **B**: A rock slab of the unit KC4 showing the light grey, thin-bedded dolomitic calcarenite (middle) between fine calcirudite and calcarenite.; **C**: Photomicrograph of poorly-washed biosparite of the unit KC4 displaying grains are closely packed in the form of grain-supported. (PPL); **D**: Photomicrograph of the dolomitic biomicrite of the unit KC4 showing the macrocrystalline dolomite rhombs (1) dominant in the micritic part. (PPL); **E**: Photomicrograph of the dolomitic limestone of the unit KC4 showing nearly complete dolomitized rock. (Stained, PPL); **F**: Photomicrograph of dolomitic calcarenite of the unit KC4 showing the dolomite rhombs replacing the foraminiferal test. (PPL)

***Description***: The unit KC4 is medium-to thick-bedded, light grey and comprises coarse calcarenite to fine calcirudite with dolomitic limestone alternating with thin bedded dolomite (Figures 5.26B). The skeletal grain components of this unit are similar to those of the underlying unit KC3.

The petrographic studies of the unit KC4 reveal that the characteristic of this unit is quite similar to those of the unit KC3 but with higher degree of dolomitization. The unit KC4 comprises mostly sorted biosparite, biosparudite and fine to coarse crystalline dolomite. Grains are essentially crinoidal fragments, foraminiferal tests and intraclasts. These grains are closely packed in the form of grain-supported fabric with sparse micrite, and cemented by sparry calcite. Some parts of this unit are poorly-washed biosparite (Figure 5.26C). The sparry calcite cements of 10 to 100 μms in size are usually recognized in the chambers of foraminiferal tests (Figure 5.26D). Many parts of the rocks are thinly-bedded, and composed essentially of fine to coarse crystalline dolomite. This bedded dolomite might have been formed by selective dolomitization in a rather uniform and extensive fashion along the bedding planes (Figure 5.26E). The bed with relatively finer-grained size usually exhibits the higher degree of dolomitization. Dolomite usually has a very strong tendency to form idiomorphic rhombohedral crystals cut across the primary structures or pre-existing carbonate grains (Figure 5.26F).

### 5.2.5 Unit KC5

Conformably upward from the unit KC4 is the grade-bedded calcarenite with chert bands of unit KC5. The outcrop of this unit is poorly exposed and mostly covered with vegetations and soils. The bedding characteristic shows the gradual change upwardly from medium-beds of the underlying unit KC4 to thin-beds of the unit KC5. Beds lie in northwest-southeast trend (100 to 115°) and dip southwestwardly with

attitude of 50 to 60°. It is exposed as a thick sequence in the measured section no.2, and also recognized in the measured section nos. 4 and 5 (Figure 5.22) with the thicknesses of 181, >149, and 129 meters, respectively. The total thickness of this unit varies from 129 to 181 meters and thickened westwardly.

***Description***: The unit KC5 is thin- to medium-bedded, grey to dark grey and comprises graded calcarenite to calcilutite with dark grey chert bands. There is abundant reddish brown fissile silty shale thinly-laminated to thinly-bedded between limestone beds (Figure 5.27A). It is noted that four calcirudite beds of 9-13 meters thick are present in the middle part of this unit (Figures 5.27B). These four calcirudite beds are characterized by the remarkably large grain components or intraclasts. With un-aid eyes, the grain components of this unit can be recognized as intraclasts, crinoidal fragments, fusulinid tests and shell fragments, respectively in decreasing order of abundance.

Microscopically the rock comprises poorly-washed intrasparudite and a series of thinly-laminated and grade-bedded sequences of poorly-washed intrasparite, packed biomicrite and fossiliferous micrite, with microcrystalline banded cherts and very finely crystalline dolomite. The poorly-washed intrasparudite, which is present exclusively in the calcirudite beds, consists of very large grain components of angular boulders, cobbles, pebbles and sands of intraclasts derived from erosion of the pene-contemporaneous deposits within the sedimentary basin adjacent to the depositional area (Figure 5.27C). The rest of grains in the intrasparudite are subordinate calcareous skeletons, mostly crinoid ossicles, foraminiferal tests and other skeletons fragments with micrite and sparry calcite cement. The poorly-washed intrasparite consists of intraclasts and carbonate skeletal fragments with some micrite remains cemented by sparry calcite (Figure 5.27D). The packed biomicrite (Figure 5.27E) and fossiliferous micrite (Figure 5.27F) are present in the upper part of grade-bedded calcarenite.

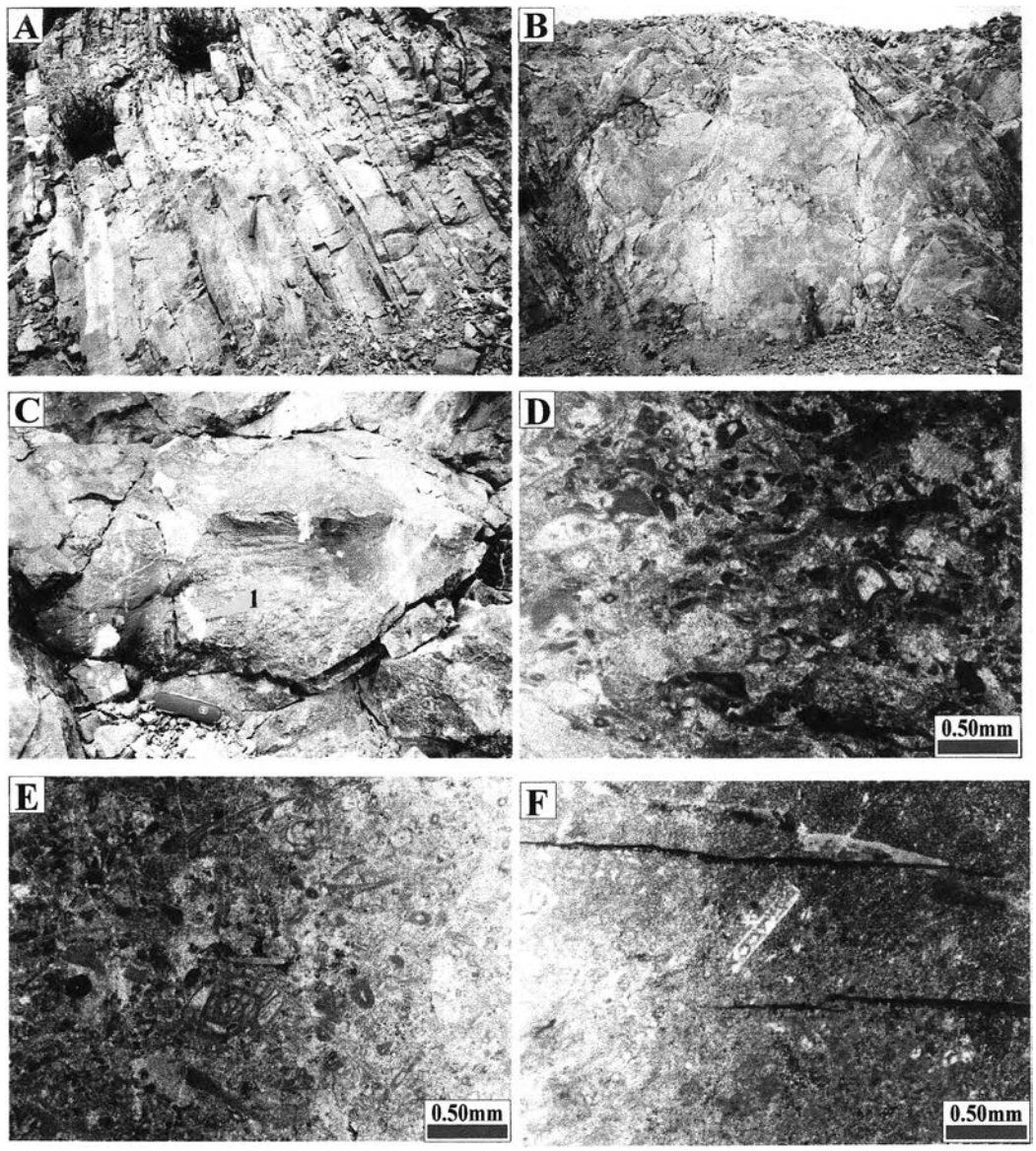


Figure 5.27 **A**: An exposure of thin-bedded, grey to dark grey of a series of graded bedding calcarenite to calcilutite with banded chert and thinly-laminated to thin-bedded, reddish brown, fissile silty shale between limestone beds of the unit KC5.; **B**: An exposure of very thick-bedded calcirudite, 13 meters thick, between a series of graded bedding of thin-bedded calcarenite to calcilutite, in the middle part of the unit KC5.; **C**: An exposure of calcirudite in the middle part of the unit KC5 showing the abundant intraclasts (1) with the size varying from millimeters to decimeters.; **D**: The photomicrograph of poorly-washed intrasparite of the unit KC5 showing moderately sorted of calcareous skeletons. (XPL); **E**: The photomicrograph of packed biomicrite of the unit KC5. (XPL); **F**: Photomicrograph of fossiliferous micrite in the lower part of picture, and microcrystalline quartz in the middle and upper parts of picture, of the unit KC5. (XPL)

The lithological boundary between the packed biomicrite and fossiliferous micrite is apparently transitional by which there is a progressive decrease of grain abundance in proportion to the increase of calcareous matrix. The banded cherts, occasionally associated with packed biomicrite and fossiliferous micrite, consist of microcrystalline quartz replacing carbonate matrix with sparse carbonate remnants. The carbonate remnants are both calcareous patches and dolomite patches. The latter are mostly very finely crystalline dolomite and common microcrystalline dolomite. It is noted that there are very finely crystalline dolomite around calcareous remnants and some microcrystalline dolomites were replaced by ferroan calcite.

### 5.2.6 Unit KC6

Overlying conformably on the unit KC5 is calcarenite to fine calcirudite of unit KC6. Bedding lies in northwest-southeast trend (94 to 100°) and dips southwestwardly with attitude of 47 to 65°. It is well exposed in the measured section no.2, and also recognized in the measured section nos. 5 (Figure 5.22) with the thicknesses of 122 and 43 meters, respectively. The total thickness of this unit varies from 43 to 122 meters with a tendency to be thickened westwardly.

***Description***: The unit KC6 is medium- to thick-bedded, light grey to pinkish grey, moderately sorted and comprises calcarenite to fine calcirudite (Figures 5.28A and 5.28B). The skeletal grain components are fusulinids, crinoid stems, intraclasts, bryozoans and unidentified skeletal fragments. It is noted that there is reddish brown silty shale thinly-laminated between limestone beds, especially, in the upper part of the unit. The banded argillaceous calcilutite with laminated silty shale has the thickness varying from a few cms to a few ten cms.

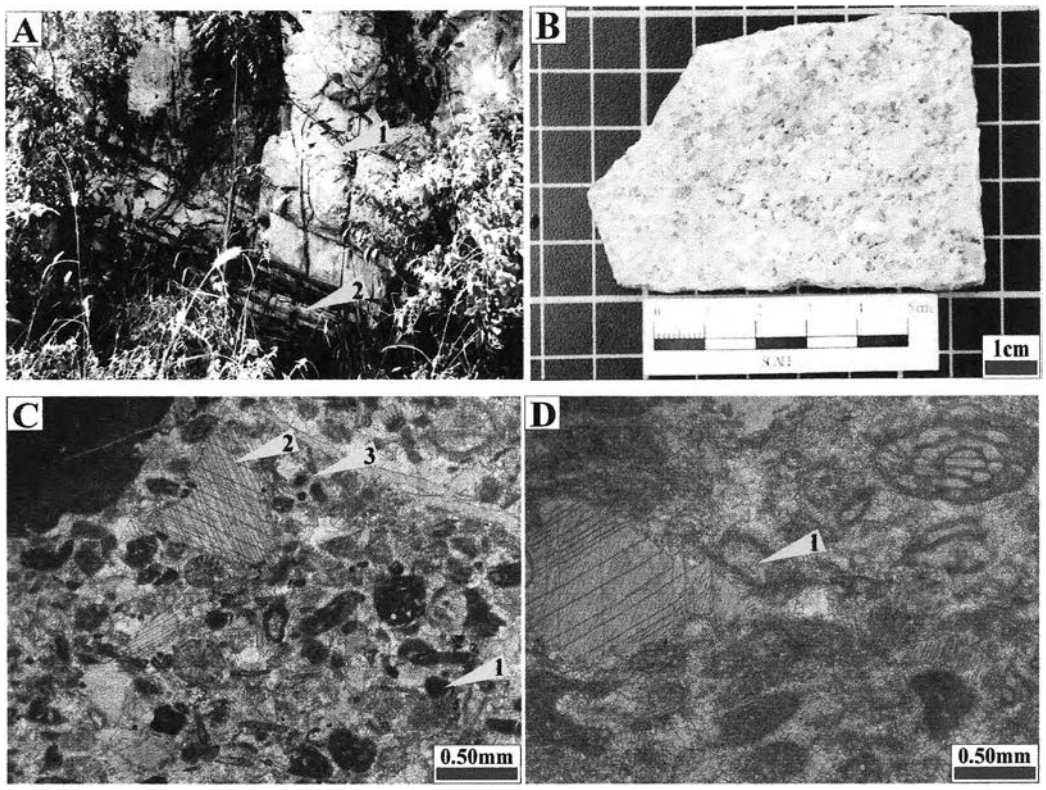


Figure 5.28 **A**: An exposure of medium- to thick-bedded, pinkish grey calcarenite of the unit KC6 (1) contact with thin-bedded, graded-bedding calcarenite of the unit KC5 (2).; **B**: A rock slab of light grey, moderately sorted, slightly metamorphosed calcarenite of the unit KC6.; **C**: Photomicrograph of the unsorted biosparite of the unit KC6. Most of grains were completely micritized (1), except crinoid fragments (2), and initially cemented by microcrystalline calcite (3). The sparry calcite cements all intergranular pores. (Stained, PPL); **D**: Photomicrograph of unsorted biosparite of the unit KC6. Some small grains in the center were coated (1) and initially cemented by microcrystalline calcite. (Stained, PPL)

Petrographically the unit KC6 comprises unsorted biosparite, unsorted biosparudite and poorly-washed biosparite. The unsorted biosparite and unsorted biosparudite contains micritized shell fragments, corroded crinoid stems and intraclasts of various sizes (50 to 1000 μms) cemented by sparry calcite (Figures 5.28C and 5.28D). The poorly-washed biosparite contains abundant grains of fusulinids, crinoidal stems, intraclasts, bryozoans and unidentified skeletal fragments with some micrite remains. These were cemented by sparry calcite. It is noted that most grains, except crinoid fragments, were completely micritized, and then were corroded before deposition. The microcrystalline calcite cement can be recognized in the unsorted biosparite.

### 5.2.7 Unit KC7

The unit KC7 overlies conformably on the unit KC6. It is exposed as ridge of the Khao Chan. The outcrop of this unit is poorly exposed due to dense vegetation, especially, bamboo forest. The succession of this unit has been intensively folded so that the various shapes of tight isoclinal and parasitic folds are recognized in the middle of the unit (Figure 5.29A). Bedding lies in the northwest-southeast trend of 90 to 118°. The broad structure of this unit dips southwestwardly with attitude of 47 to 83°. It is well exposed in the measured section nos. 4 and 5 with the thicknesses of >67 and 159 meters, respectively. The thickness of the unit is about 159 meters with a tendency to be thickened westwardly.

***Description***: The unit KC7 is an alternating sequence of calcarenite (partly calcilutite) and silty shale. The calcarenite is dark grey and thin- to thick-bedded. The silty shale is thinly-laminated between limestone beds. The middle and upper parts of this unit were patchily dolomitized. The elongate nodular cherts of a few cms in size

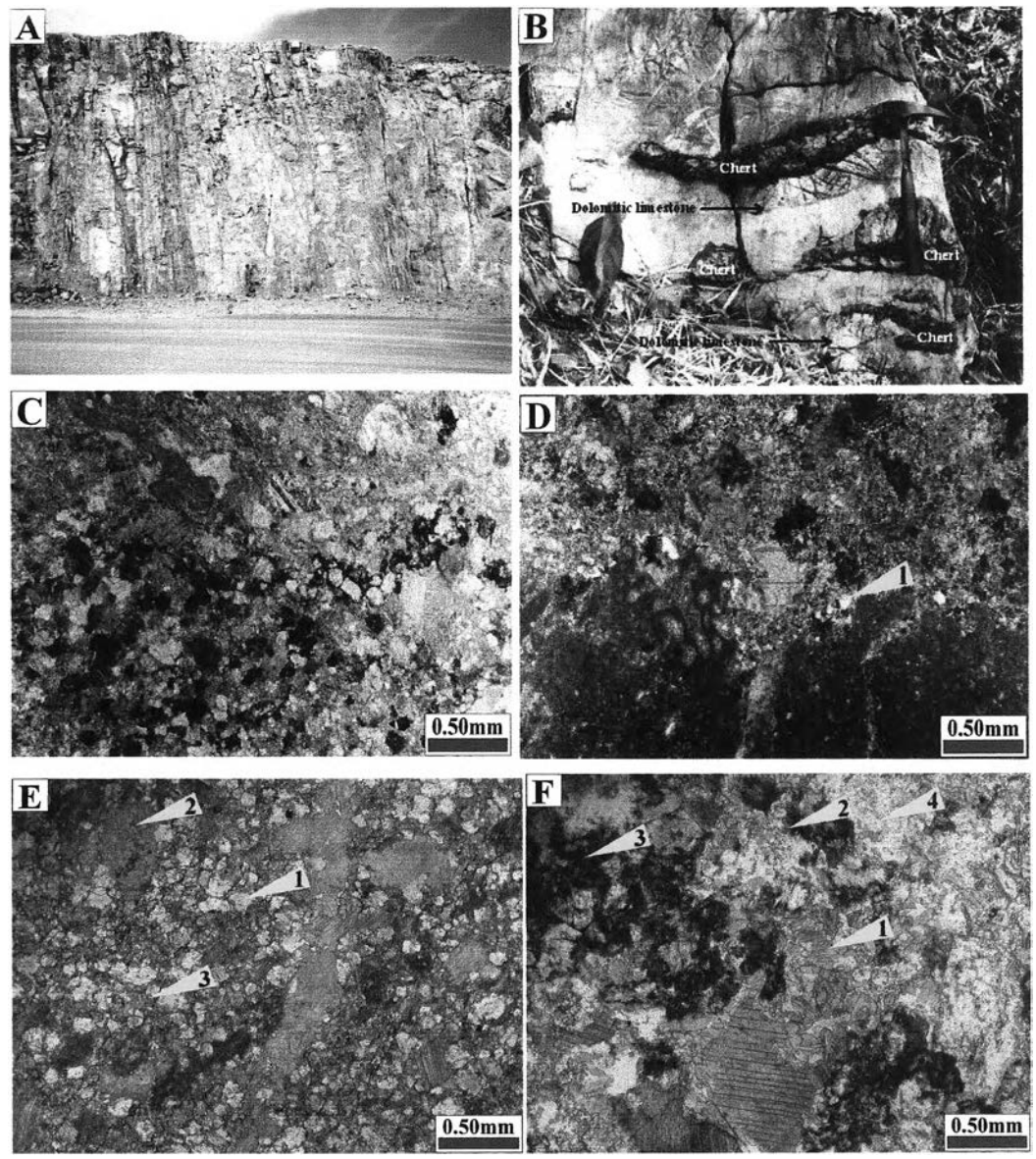


Figure 5.29 **A**: An exposure of thin- to medium-bedded, dark grey, calcarenite of the unit KC7 showing strongly folding.; **B**: An exposure of medium-bedded, dark grey calcarenite of the unit KC7 showing elongate chert nodules and dolomitic limestone patches embedded in limestone beds.; **C**: Photomicrograph of packed intramicrite of the unit KC7 showing more than 50 per cent of sand size intraclasts with fine-grained carbonate matrix. (XPL); **D**: Photomicrograph of biomicrite and microcrystalline chert of the unit KC7 showing some detrital quartz (1) scattered between contact zones. (XPL); **E**: Photomicrograph of dolomitic intrasparite of the unit KC7 showing abundant dolomite grains (1) packed with calcareous grains (2) and cemented by ferroan calcite (3). Note the late ferroan calcite vein. (Stained, PPL); **F**: Photomicrograph of silicified limestone of the unit KC7. There are abundant calcareous patches (1) and microcrystalline dolomite (2) together with some vadose silt (3) embedded in the microcrystalline quartz chert (4). (Stained, PPL)

are scattered throughout the succession. In addition, the nodular cherts are also associated with some dolomitic limestone (Figure 5.29B).

Microscopically the unit KC7 consists of packed intramicrite and biomicrite. The packed intramicrite is composed dominantly (> 50%) of fine-grained carbonate intraclasts and minor skeletal fragments packed in fine-grained micrite matrix (Figure 5.29C). The biomicrite contains predominantly of broken crinoid ossicles and foraminiferal tests, with some intraclasts and detrital quartz packed in micrite matrix (Figure 5.29D). The detrital quartz grains (10 to 100 μms in sizes) probably laid on formerly hardground surface of biomicrite. The dolomite patches consist of abundant small dolomite grains deposited together with calcareous grains. They are packed together and cemented by ferroan sparry calcite (Figure 5.29E). The petrographic study of chert nodules reveals abundant calcareous remnants disseminated throughout the chert body. There are many microcrystalline dolomite scattered in the microcrystalline quartz chert. Some part of chert nodule contains carbonate silts, or vadose silts (Figure 5.29F).

### 5.2.8 Unit KC8

Conformably overlying the unit KC7 is limestone interbedded with silty shale of unit KC8. It is associated with the unit KC7. Bedding lies in northwest-southeast trend of 95 to 118°. The broad structure of this unit dips southwestwardly with attitude of 40 to 53°. It is well exposed in the measured section nos. 1, 4 and 5 (Figure 5.22) with the thicknesses of 300, 435 and 179 meters, respectively. The overall thickness of this unit varies from 179 to 435 meters.

***Description***: The unit KC8 is a sequence of medium grey to dark grey, thin-bedded calcarenite in the lower part. The unit is gradually passing upward into clastic

associations of thin-bedded silty shale, silty sandstone and porcelanite with very thick-bedded calcirudite in the uppermost part (Figures 5.30A). The cumulative thickness ratio of carbonates/clastics of this unit is approximately 4:1. The uppermost calcirudite beds are 1 to 2 meters thick and comprise essentially compacted intraclasts (1 to 10 cms in size) which are significant feature of limeclast conglomerate (Figure 5.30B).

Petrographically the unit KC8 consists of poorly-washed biosparite, intramicrudite, intramicrite, packed biomicrite and dismicrite. The poorly-washed biosparite is characterized by abundant skeletal fragments of crinoid, foraminifera, coral, algae and unidentified fragments with some intraclasts, detrital quartz, fine-grained matrix and sparry ferroan calcite cement (Figure 5.30C). The intramicrudite and intramicrite contain abundant intraclasts with the size varying from a few mms to a few cms and the shape varying from elongate, angular to subrounded (Figure 5.30D). The packed biomicrite contains skeletal fragments similar to those found in the poorly washed biosparite, embedded in fine-grained matrix. The foraminiferal tests and crinoidal fragments are also found embedded in micrite matrix. The elongate grains are usually oriented subparallel to the bedding plane. Dismicrite is composed wholly of a micrite without grains (Figure 5.30E). The poorly-washed biosparite, intramicrite, packed biomicrite and dismicrite are present throughout the unit whereas the intramicrudite appears only in the upper part of the unit. The porcelanite contains abundant sponge spicules of 10 to 100 μm in sizes mixed with silicified argillaceous matter (Figure 5.30F).

### 5.2.9 Unit KC9

The uppermost unit of the sedimentary sequence at Khao Chan area is unit KC9 (Figure 5.31A). It lies on the unit KC8 with fault contact. The unit KC9 marks the termination of Khao Khad Formation in the Khao Chan area with abrupt

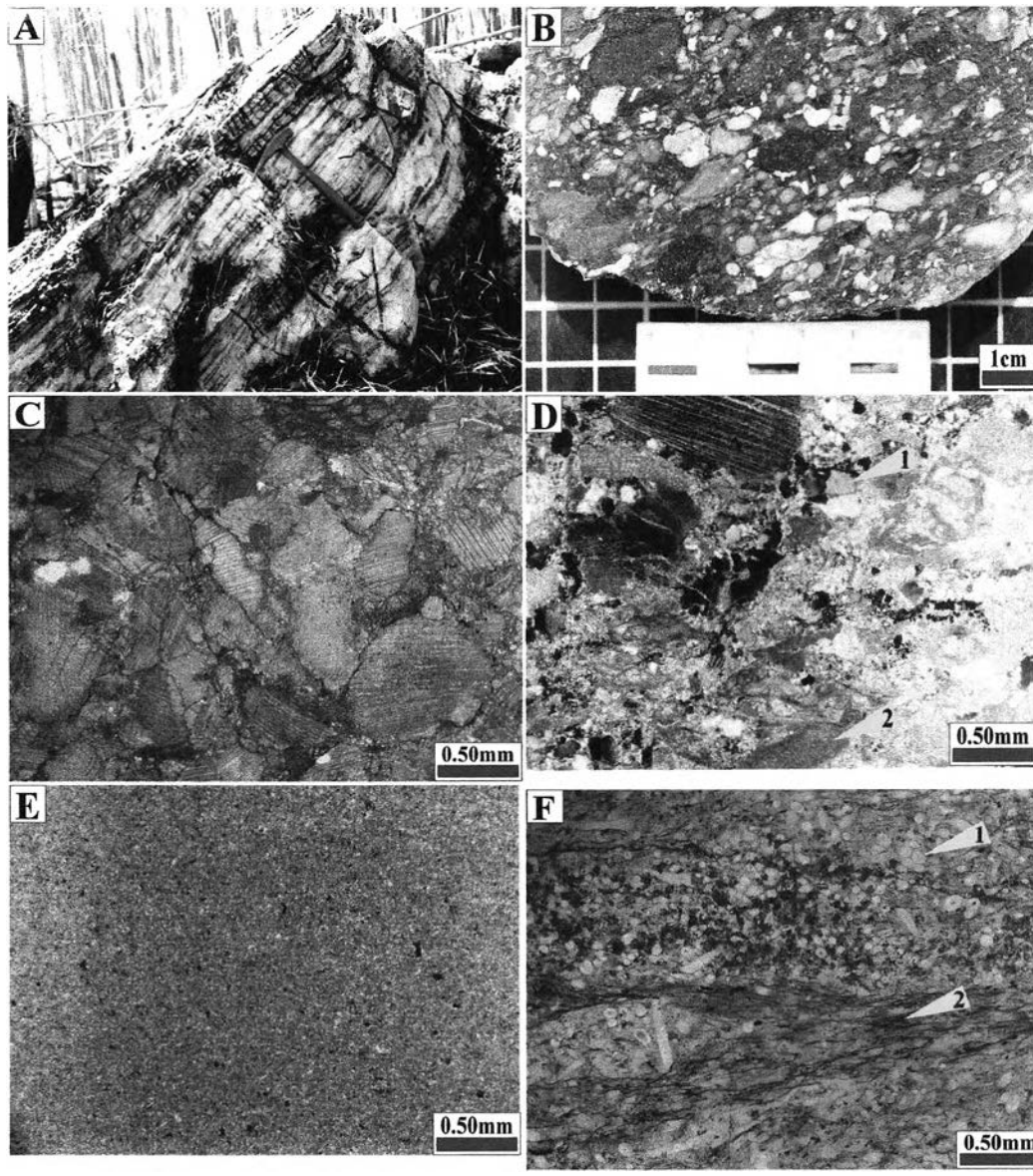


Figure 5.30 **A**: An outcrop of thin-bedded, dark grey mixed calcarenite and sandy calcarenite of the unit KC8.; **B**: An rock slab of calcirudite of the uppermost part of the unit KC8 showing abundant intraclasts packed with foraminiferal tests and crinoidal fragments.; **C**: Photomicrograph of poorly washed biosparite of the unit KC8 consists of corroded crinoid fragments and fusulinid tests packed together and cemented by ferroan calcite. (Stained, PPL); **D**: Photomicrograph of intramicrite of the unit KC8 showing abundant detrital quartz (1) and intraclasts (2). (XPL); **E**: Photomicrograph of micrite without grains of the unit KC8. (XPL); **F**: Photomicrograph of porcelanite of the unit KC8 showing abundant sponge spicules (1) with silicified argillaceous matter (2). (Stained, PPL)

lithological change upwardly into the fine-grained clastic sequence of the Sab Bon Formation. Bedding trends in northwest-southeast direction (92 to 106°) and dips southwestwardly with 53 to 63°. It is well exposed in the measured section no.1, and also recognized in the measured section nos. 4 with the thicknesses of 413 and 362 meters, respectively. The total thickness of this unit varies from 362 to 413 meters with a tendency to be thickened westwardly.

***Description***: This unit is thin- to thick-bedded, medium grey to dark grey and comprises calcarenite rarely with small chert nodules. Cross-lamination can be recognized in the lower part of the unit.

Petrographically, the unit consists of poorly-washed biosparite, packed biomicrite, and sparse biomicrite with microcrystalline quartz chert. The poorly washed biosparite contains bioclasts of foraminiferal tests, crinoids, unidentified skeletal fragments and bryozoa, together with intraclasts, detrital quartz, micrite remains and sparry calcite cement (Figure 5.31B). The packed biomicrite is characterized by over 50 % of relatively large, both complete to broken bioclasts and intraclasts embedded in the micrite matrix (Figure 5.31C). The bioclasts of packed biomicrite are mostly unidentified skeletal fragments, foraminiferal tests, crinoids and bryozoa. The sparse biomicrite contains small unidentified bioclasts (< 50 %) in micrite matrix. The small chert nodule is made up essentially of microcrystalline quartz with some calcareous patches (Figure 5.31D).

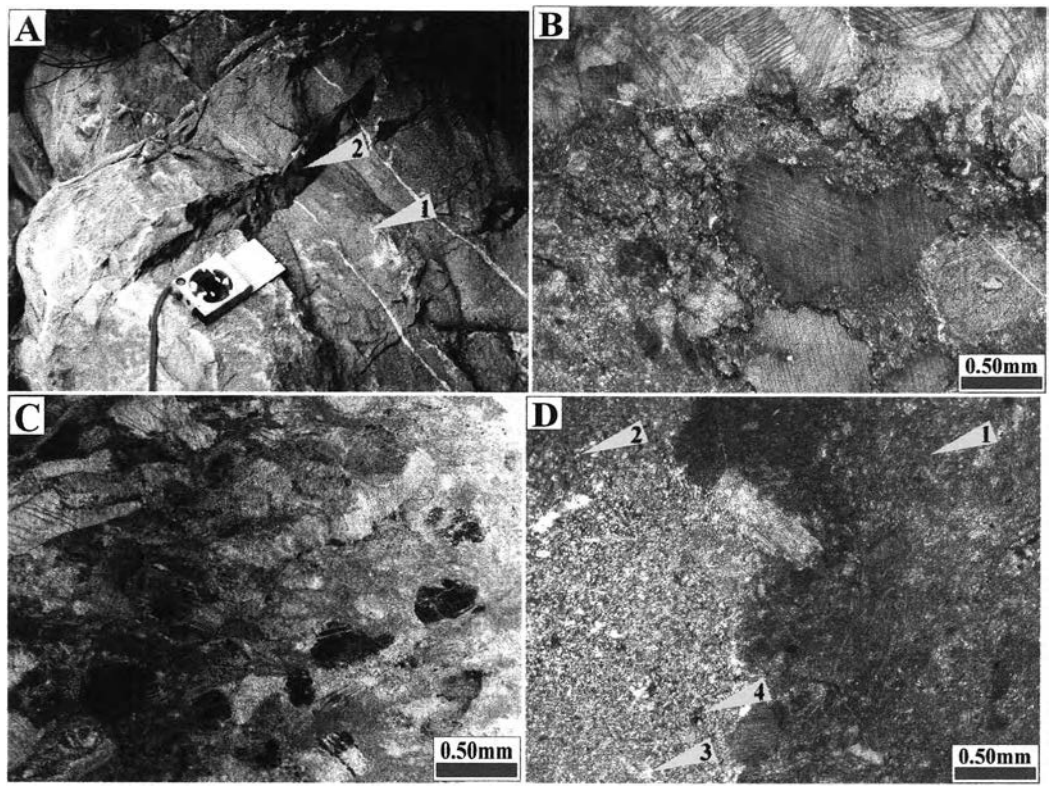


Figure 5.31 **A**: An exposure of medium grey calcarenite (1) of the unit KC9 showing inclusion of dark grey calcilutite (2) indicating reverse movement of micro fault.; **B**: Photomicrograph of poorly washed biosparite of the unit KC9 depicting corroded crinoid fragments and unidentified small fragments packed together and cemented by ferroan calcite. (Stained, PPL); **C**: Photomicrograph of packed biomicrite of the unit KC9 showing unidentified skeletal fragments packed with fine-grained matrix. (Stained, XPL); **D**: Photomicrograph of sparse biomicrite (1) and microcrystalline quartz chert (2) of the unit KC9. There are small calcareous remnants (3) in microcrystalline chert matrix. Some parts of calcareous grains are ferroan calcite (4). (Stained, XPL)

## 5.3 Pak Chong to Khao Yai Area

The Khao Khad Formation in the Pak Chong to Khao Yai area is exposed as many isolate hills. Totally thirteen measured sections were conducted in order to define the characteristics of sedimentary sequence in this area. The locations of these measured sections are shown in Figure 5.32. Most traverse lines were made in the north-south direction roughly perpendicular to the regional strike. The total thickness of the measured sections was 8,000 meters long in which 113 rock samples were collected from all sections. There are some igneous intrusions in this area so that many parts of the rocks were metamorphosed. The graphic representation of sedimentary sequence of each measured section is shown in Figure 5.33.

The representative sedimentary sequence of composite section of the Khao Khad Formation at Pak Chong to Kao Yai area is shown in Figure 5.34. From the results of direct field observation and the graphic representation of all measured rock sections, it is recognized that there are altogether 3 units. The description of each unit is presented in ascending order as follows:

### 5.3.1 Unit PK1

The unit PK1 is the lowest unit of the Khao Khad formation at Pak Chong to Khao Yai area. Bedding lies in east-west trend (80 to 96°) and dips toward both north and south directions, depending on the folding structure, with attitude of 33 to 90°. It is exposed as a thick sequence in the measured section nos. 4, 6, 9 and 10, and also recognized in the measured section nos. 3, 5, 7, 11 and 12 (Figure 5.32) with the thicknesses of 333, >99, >135, 215, >40, >32, >40, >76 and >20 meters, respectively. The total thickness of this unit is not less than 333 meters.

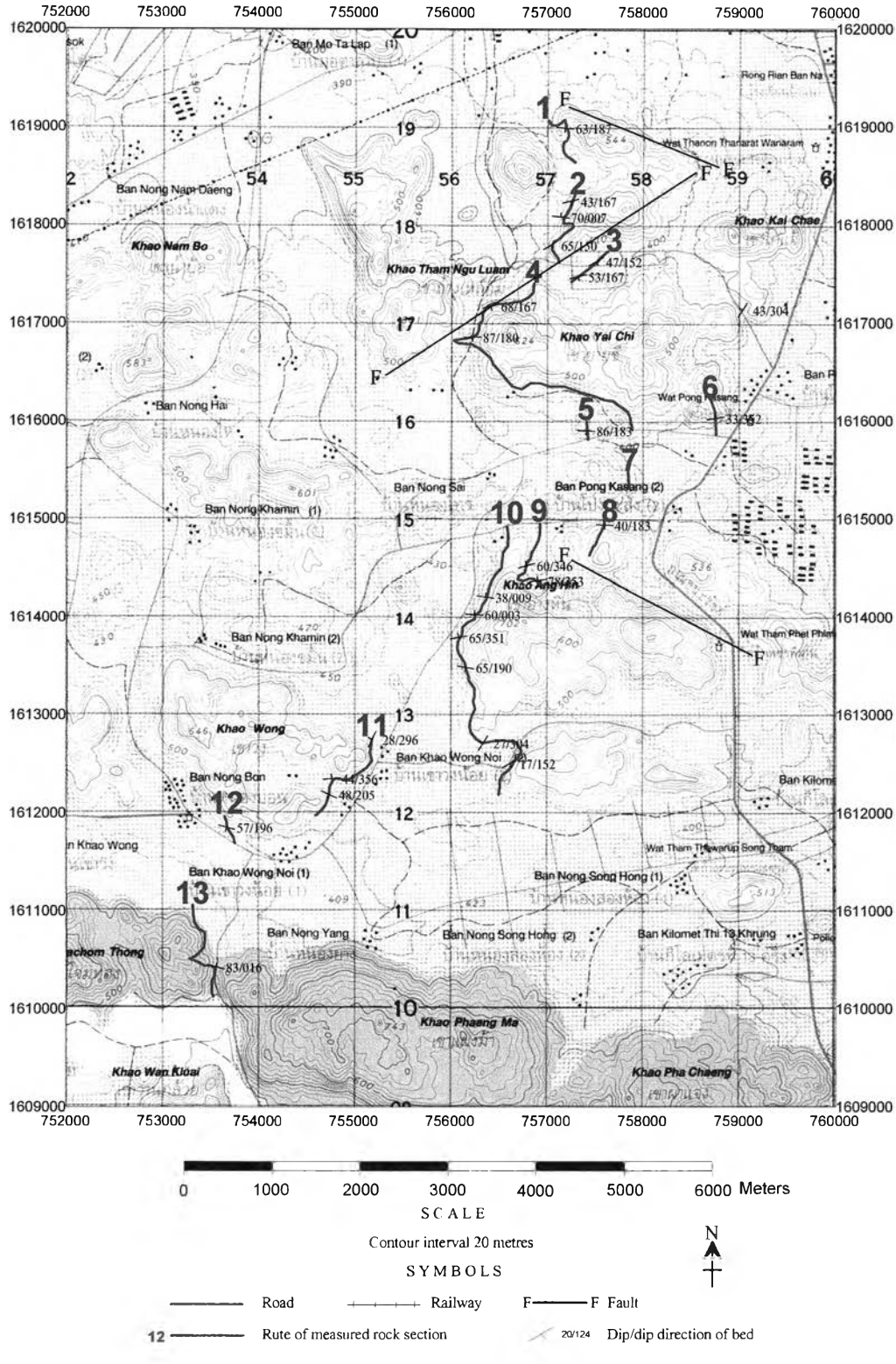


Figure 5.32 Topographic map showing traverses of thirteen measured sections along the route Pak Chong to Khao Yai (modified from topographic map sheet Amphoe Pak Chong, 5238II, Royal Thai survey department).

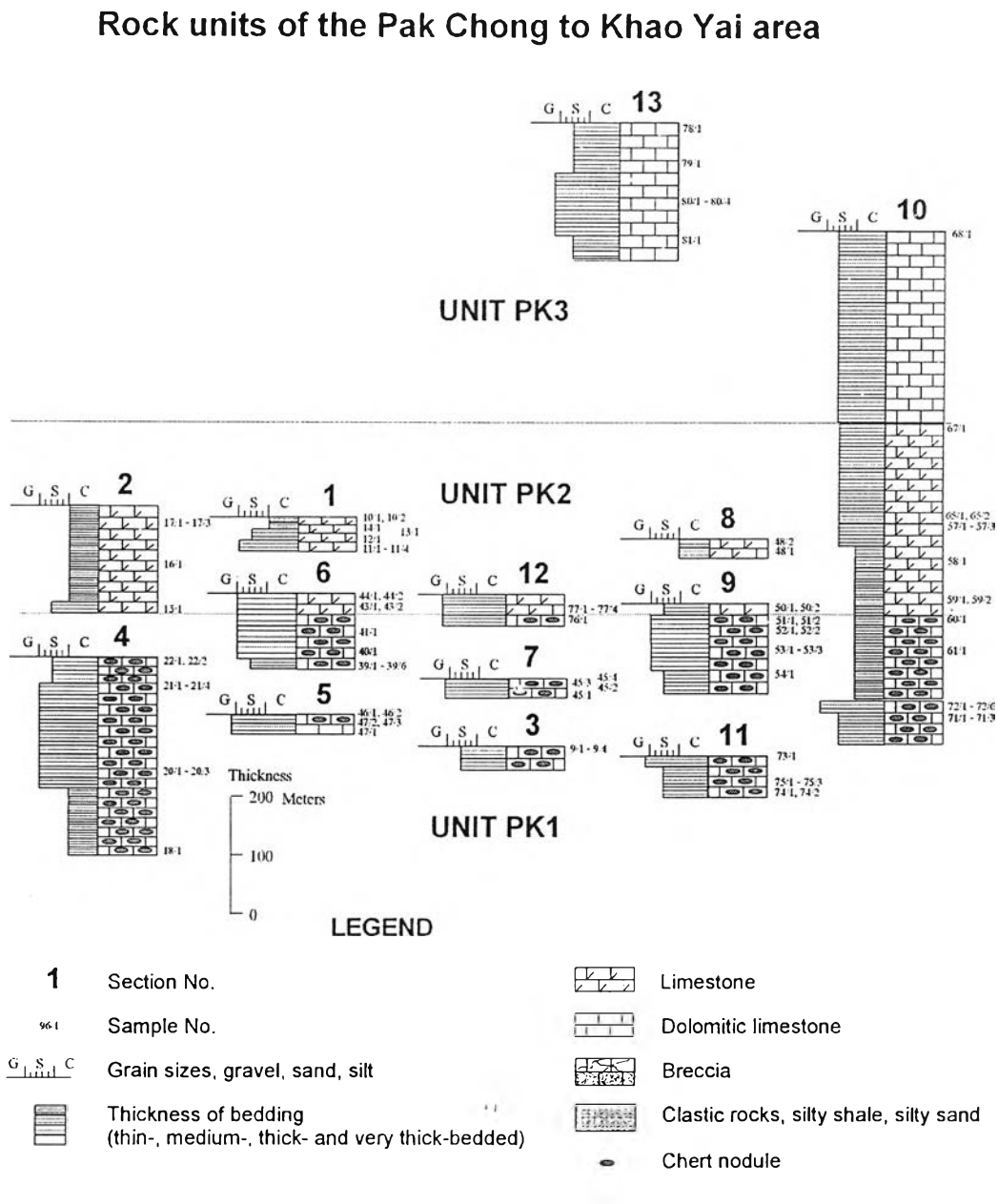


Figure 5.33 The graphic representation of 13 measured sections at Pak Chong to Khao Yai route.

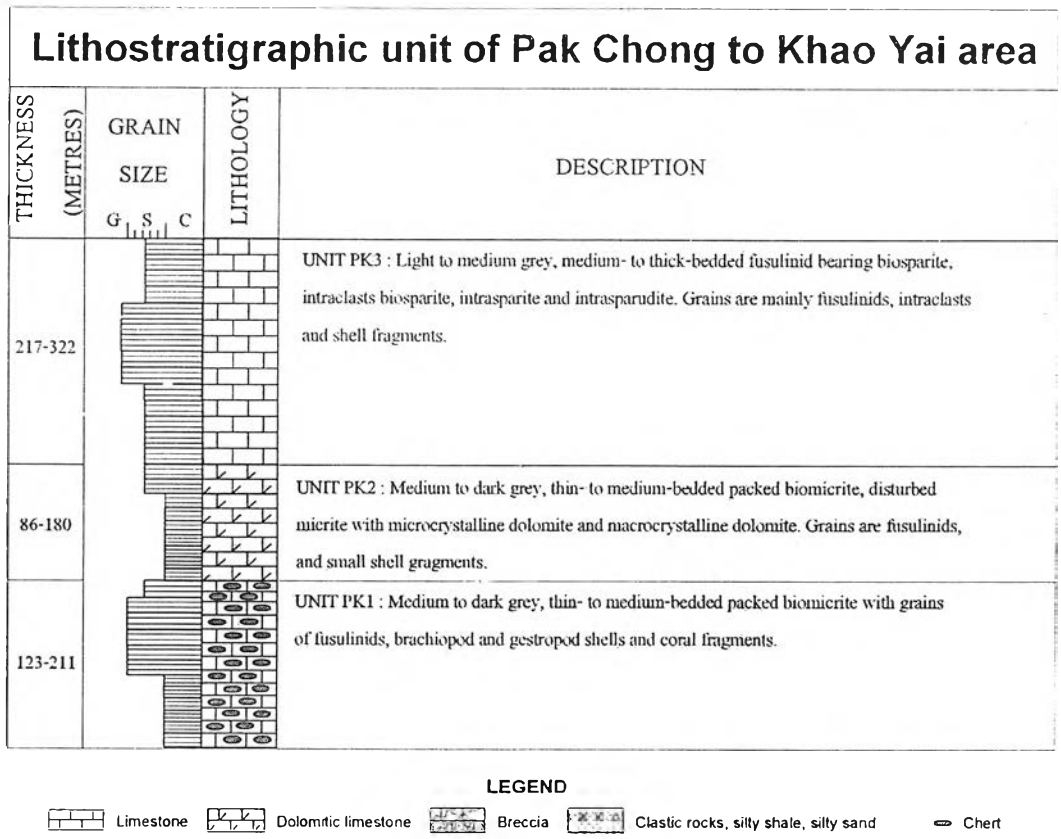


Figure 5.34 The graphic representation of the representative sedimentary sequence of Khao Khad Formation at Pak Chong to Khao Yai area.

***Description***: The unit PK1 is thin- to medium-bedded, medium to dark grey and comprises calcisiltite to calcarenite with black chert nodules (Figure 5.35A). The calcisiltite is dominant in the lower part of the units and the calcarenite is major rock mass in the middle and upper parts of the unit (Figure 5.35B). In hand-specimen, the rock contains many small elongate white spots (< 0.5 to 1 mm in size), and black fusulinids (1 to 1.5 mms in size) embedded in fine-grained micrite matrix. The white spots are uniformly scattered in the rock mass and orientated parallel or sub-parallel to the bedding plane. In the upper most part of the unit, some calcarenite beds contain brachiopod and gastropod shells (Figure 5.35C).

Petrographically, the unit PK1 is a packed biomicrite. The rock contains grains of complete fusulinid tests, brachiopod and gastropod shells with some dolomite rhombs embedded in micrite matrix. Many shell fragments are broken (Figure 5.35D). Much of the rock was subjected to certain degree of neomorphism (Figure 5.35E). As a result the micrite was recrystallized into pseudospar (5 to 20 μms in size) and much of grains were transformed into sparry calcite (10 to 100 μms in size). Some detrital dolomite rhombs (10 to 100 μms in size) were also found to embed in pseudosparite. In part of the nodular chert, it consists mainly of microcrystalline quartz and locally crystalline (10 to 70 μms in size) quartz as well as calcareous remnants, such as calcareous patches and rhombic dolomite (Figure 5.35F).

### 5.3.2 Unit PK2

The unit PK2 is the second unit of the Khao Khad Formation at Pak Chong to Khao Yai area. It is exposed conformably overlying on the unit PK1. Bedding trends in northwest-southeast direction (97 to 106°) and dips toward both north and south

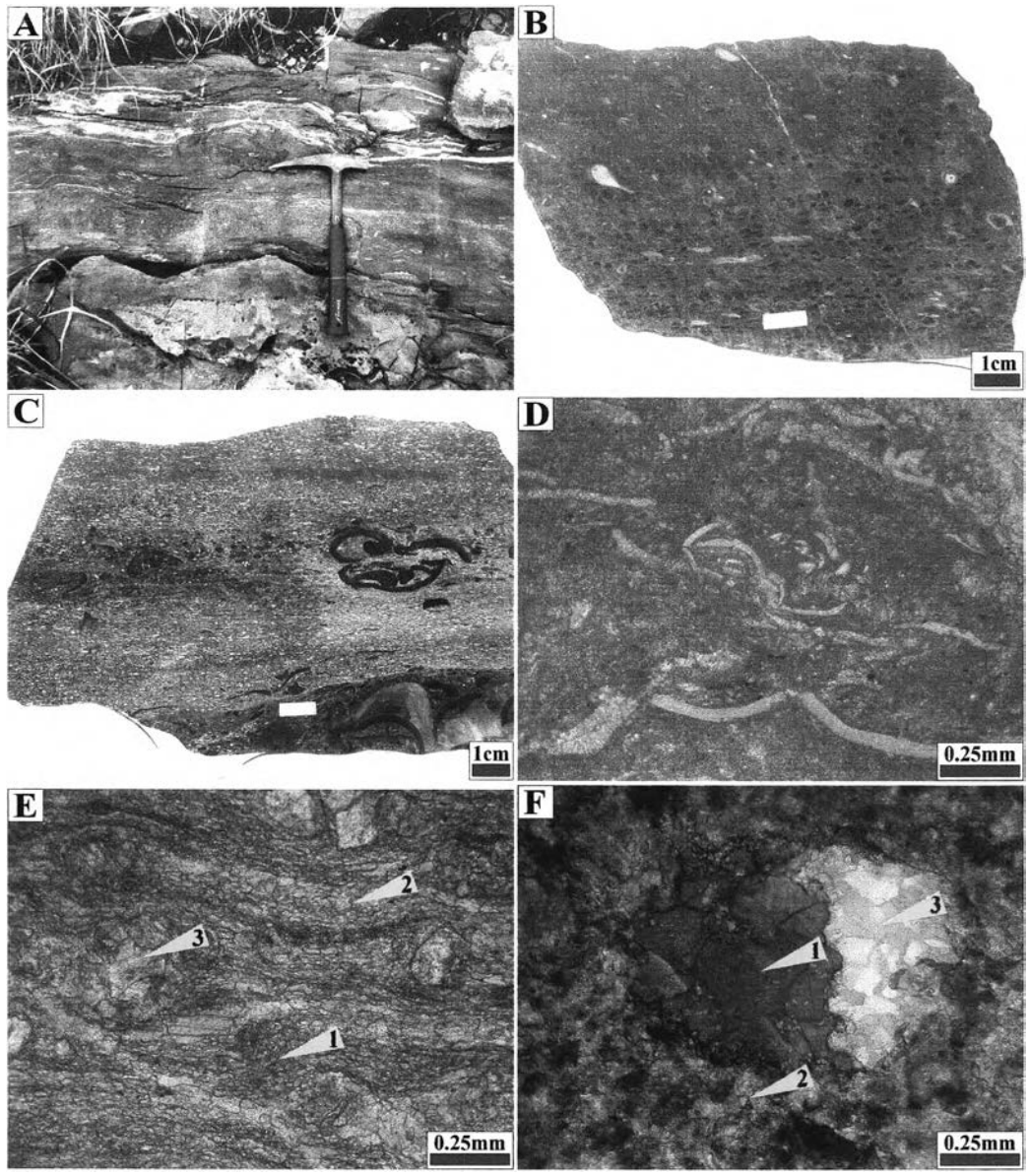


Figure 5.35 **A**: An outcrop of medium grey calcarenite with white banded of shell fragments of the unit PK1.; **B**: A medium grey calcarenite slab of the unit PK1 showing abundant fusulinid tests (black) embedded in micrite matrix.; **C**: A rock slab of medium grey calcarenite of the upper most part of the unit PK1. There are many brachiopod and gastropod shells locally presented in calcarenite beds.; **D**: Photomicrograph of packed biomicrite of the unit PK1 showing some broken shells in micrite matrix. (Stained, PPL); **E**: Photomicrograph of aggrading neomorphic pseudosparite of the unit PK1 in which micrite was transformed into pseudospar (1) and grains were transformed into coarse sparry calcite (2). Note also some dolomites (3) embedded in the pseudosparite. (Stained, PPL); **F**: Photomicrograph of quartz chert of the unit PK1 showing calcareous patches (1) and microcrystalline dolomite rhombs (2) in microcrystalline quartz matrix. Parts of quartz chert are megacrystalline quartz (3). (Stained, PPL)

directions, depending on the folding structure with attitude of 57 to 80°. It is exposed in measured rock section nos. 1, 2, 6, 8, 9, 10 and 12 (Figure 5.32) with the thicknesses of >60, 180, >35, >35, >20, 322 and >40 meters, respectively. The total thickness of this unit varies from 180 to 322 meters.

***Description***: The unit PK2 is thin- to medium-bedded, medium grey to dark grey and comprises coarse calcilutite interbedded with thin-bedded dolomitic limestone and thinly-laminated dolomite. It appears in the fields as bands of white to light grey 'elephant skin' texture on the weathered surface that marks the difference from the other rock units (Figure 5.36A). In the hand specimen the dolomitic limestone is white, thinly-bedded to thinly-laminated without significant grains. This is quite in contrast to medium grey to dark grey coarse calcilutite (Figure 5.34C). The cross lamination is also present in the dolomitic limestone (Figure 5.36B).

Petrographically, the unit PK2 is packed biomicrite, disturbed micrite with microcrystalline dolomite and macrocrystalline dolomite. The packed biomicrite consists of diverse small bioclasts (10 to 500 μms in size) embedded in micrite matrix (Figure 5.36C). The disturbed micrite is characterized by abundant bioturbations, probably burrow in micrite matrix (Figure 5.36D). There are many phases of burrows and burrow filling. Burrows are filled with micrite, finely crystalline dolomite and sparry calcite cement (Figures 5.36E). The dolomite beds are essentially medium crystalline dolomite replacing the pre-existing calcareous parts (Figure 5.36F). In some parts of the rock, micrite was neomorphosed into pseudospars.

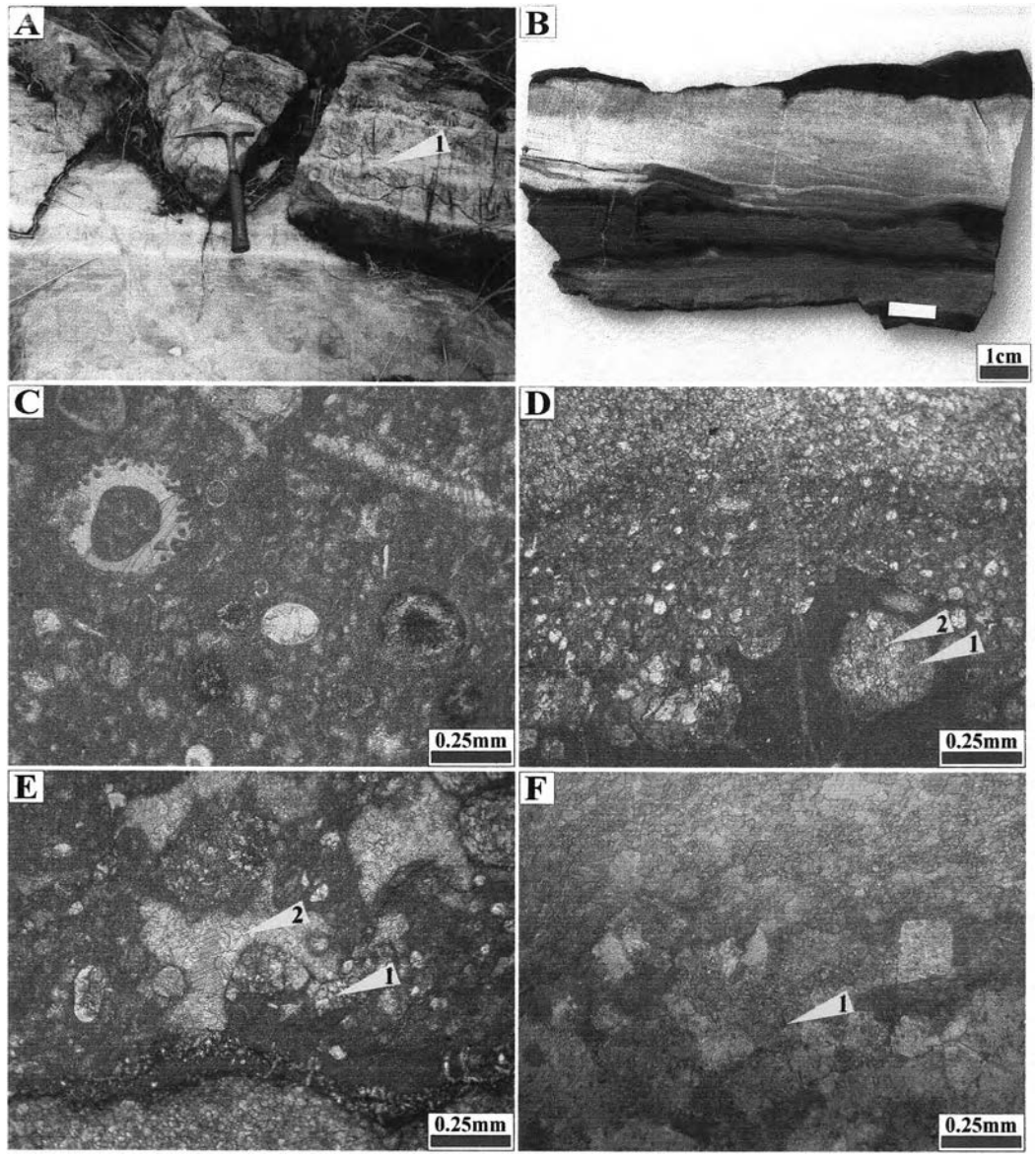


Figure 5.36 **A**: An outcrop of thin- to medium-bedded, medium grey to dark grey calcilutite interbedded with thin-bedded, dolomitic limestone (1) of the unit PK2.; **B**: A dark grey calcilutite slab of the unit PK2 with thinly-laminated dolomite (white).; **C**: Photomicrograph of packed biomicrite of the unit PK2 showing diverse small shell fragments embedded in micrite matrix. (PPL); **D**: Photomicrograph of disturbed micrite of the unit PK2 showing pores filled with sparry calcite (1) and microcrystalline dolomite (2). The top of picture is a microdolomite layer. (Stained, PPL); **E**: Photomicrograph of disturbed micrite of the unit PK2 showing pores filled by microcrystalline dolomite (1) and sparry calcite cement (2). (Stained, PPL); **F**: Photomicrograph of neomorphic dolomitic sparite of formerly dolomitic packed biomicrite of the unit PK2. Minor ferroan calcite is also present as inclusion in dolomite rhombs (1). (Stained, PPL)

### 5.3.3 Unit PK3

The unit PK3 is the top unit of the Khao Khad formation at Pak Chong to Khao Yai area. Bedding lies in east-west trend (81 to 93°) and dips toward south direction with the attitude of 60 to 65°. The unit is exposed as a thick sequence in the measured section nos. 10 and 13 (Figure 5.32) with the total thickness of 322 and 217 meters, respectively.

***Description***: The unit PK3 is well sorted coarse calcarenite to poorly sorted coarse calcirudite with some dolomite patches and rarely chert (Figure 5.37A). They are medium- to thick-bedded of parallel bed type. The weathered surface is medium grey and jagged on the top but smooth on the side. The calcarenite is light to medium grey, well sorted and contains small (0.5 to 1 mm) bioclasts. It is the major rock mass of this unit. The calcarenite grades into poorly sorted fine calcirudite to coarse calcirudite as the amount of intraclasts increase. The intraclasts are medium grey calcisiltite of few mms to several cms in size (Figure 5.37B).

Petrographically, the unit PK3 is fusulinid biosparite, intraclast biosparite, intrasparite and intrasparudite. The fusulinid bearing biosparite consists mainly of fusulinid tests, unidentified micritized shell fragments, intraclasts and sparry calcite cement (Figure 5.37C). The intraclast biosparite, intrasparite and intrasparudite are generally similar to fusulinid biosparite. The differences however are from the differing in size and the degree of abundance of the intraclasts in the rocks. The fusulinid tests were completely micritized but the internal shell structure was not obscured completely. The internal pores of the fusulinids were occluded by sparry calcite cement. The biosparite is also disseminated with some very coarse dolomite rhombs (100 to 400 μms in size) (Figure 5.37D).

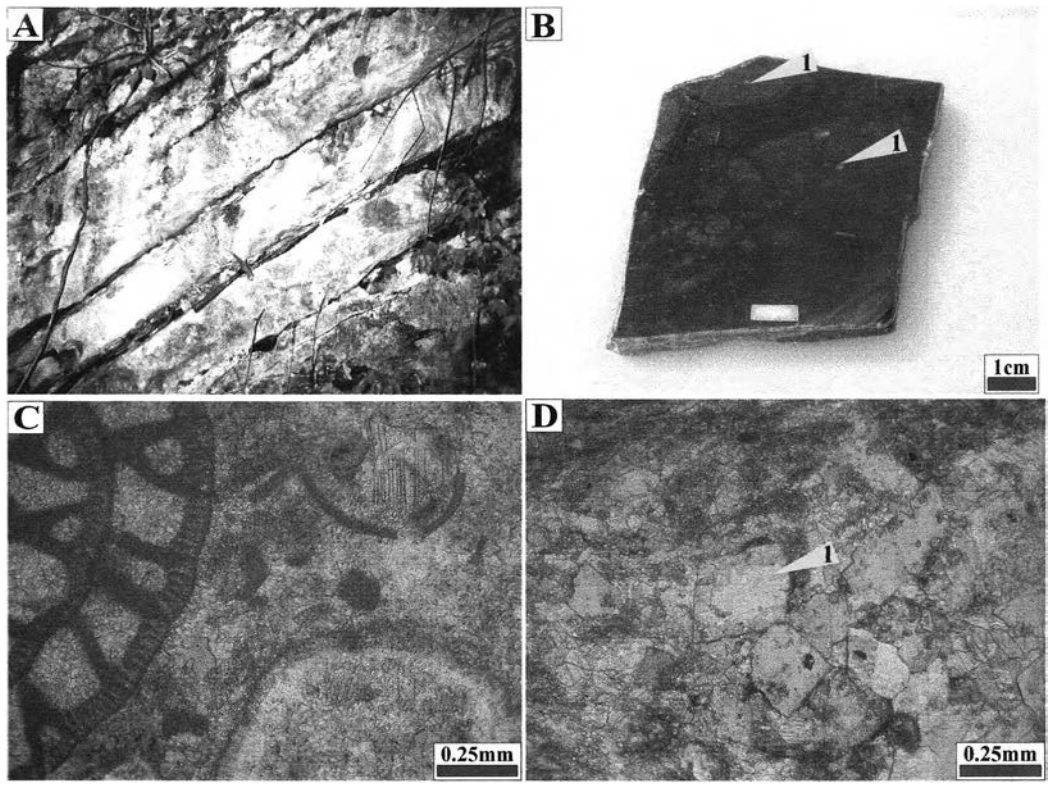


Figure 5.37 **A**: An outcrop of medium- to thick-bedded, light grey to medium grey calcarenite of the unit PK3.; **B**: A rock slab of the medium grey, poorly sorted, coarse calcirudite of the unit PK3 showing some intraclasts (1) deposited together with fine calcirudite.; **C**: Photomicrograph of fusulinid biosparite of the unit PK3 showing fibrous calcite cement occludes the intragranular pore of the fusulinid tests. (PPL); **D**: Photomicrograph of medium crystalline dolomitic biosparite of the unit PK3 showing large dolomite rhombs (1) in sparry calcite groundmass. (Stained, PPL)