CHAPTER III

LITHOSTRATIGRAPHY

3.1 Geology of the Khao Chan area

The study area is almost a square shape covering approximately 24.75 square kilometres. It is mountainous in most part where the main mountain is Khao Chan with the peak of 560 metres (msl.) and oriented in the northwest-southeast direction (Figure 3.1). In the northeastern and northern part, the area is hilly to strong undulatory of approximately 40 metres in relief. The overall relief of the study area is approximately 400 metres.

The area is almost entirely covered with thin mixed deciduous forest. The drainage system of the area is divided into two parts following the drainage divide approximately oriented along the northwest-southeast diagonal of the study area. The drainage pattern in the southwestern part of the drainage divide is classified as structural controlled parallel pattern mainly flowing southwestwardly. The area in the northeastern part of the drainage divide also has a similar drainage pattern flowing northeastwardly.

3.1.1 Stratigraphy

The sedimentary rocks in the vicinity of Khao Chan area are generally classified into three main stratigraphic units, namely, the uppermost part of the Pang Asok Formation, the Khao Khad Formation, and the lowermost part of the Sab Bon Formation (Figure 3.2).

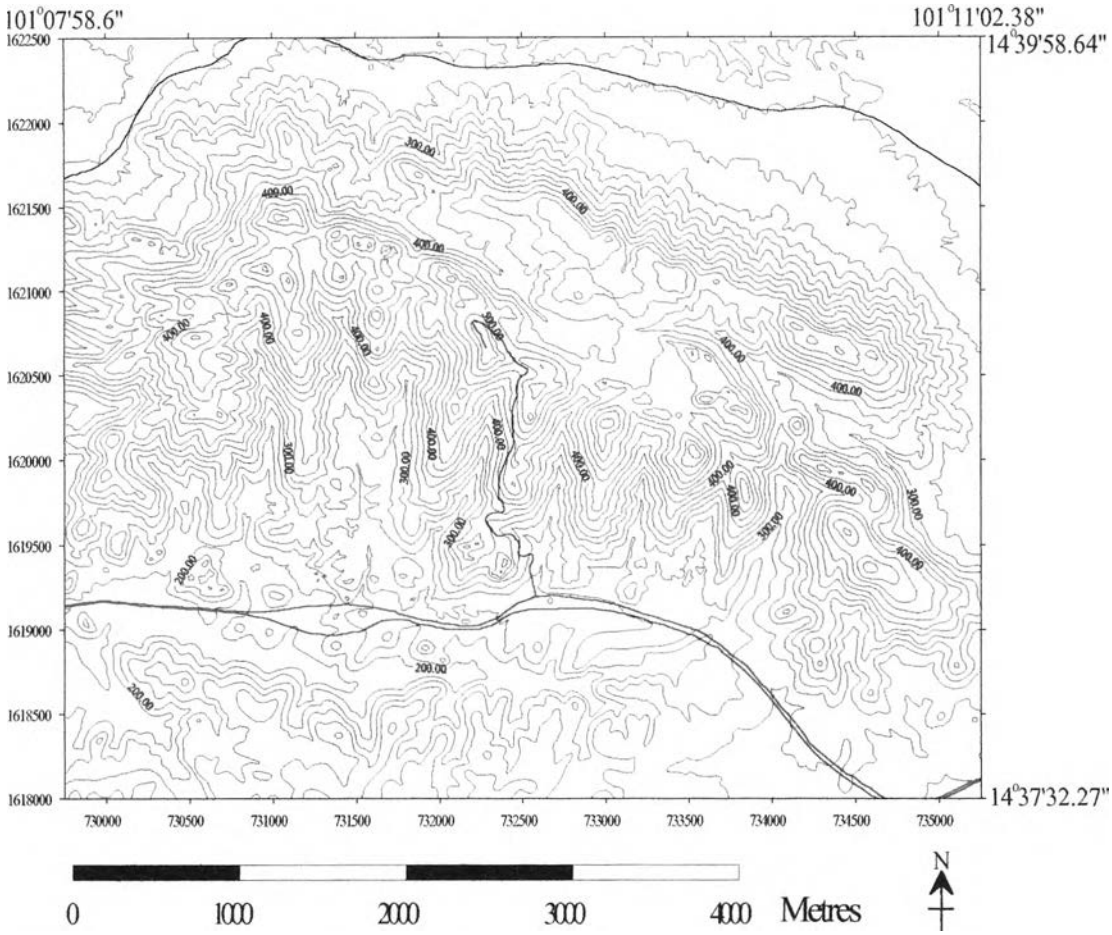

Figure 3.1 Topographic map of Khao Chan area

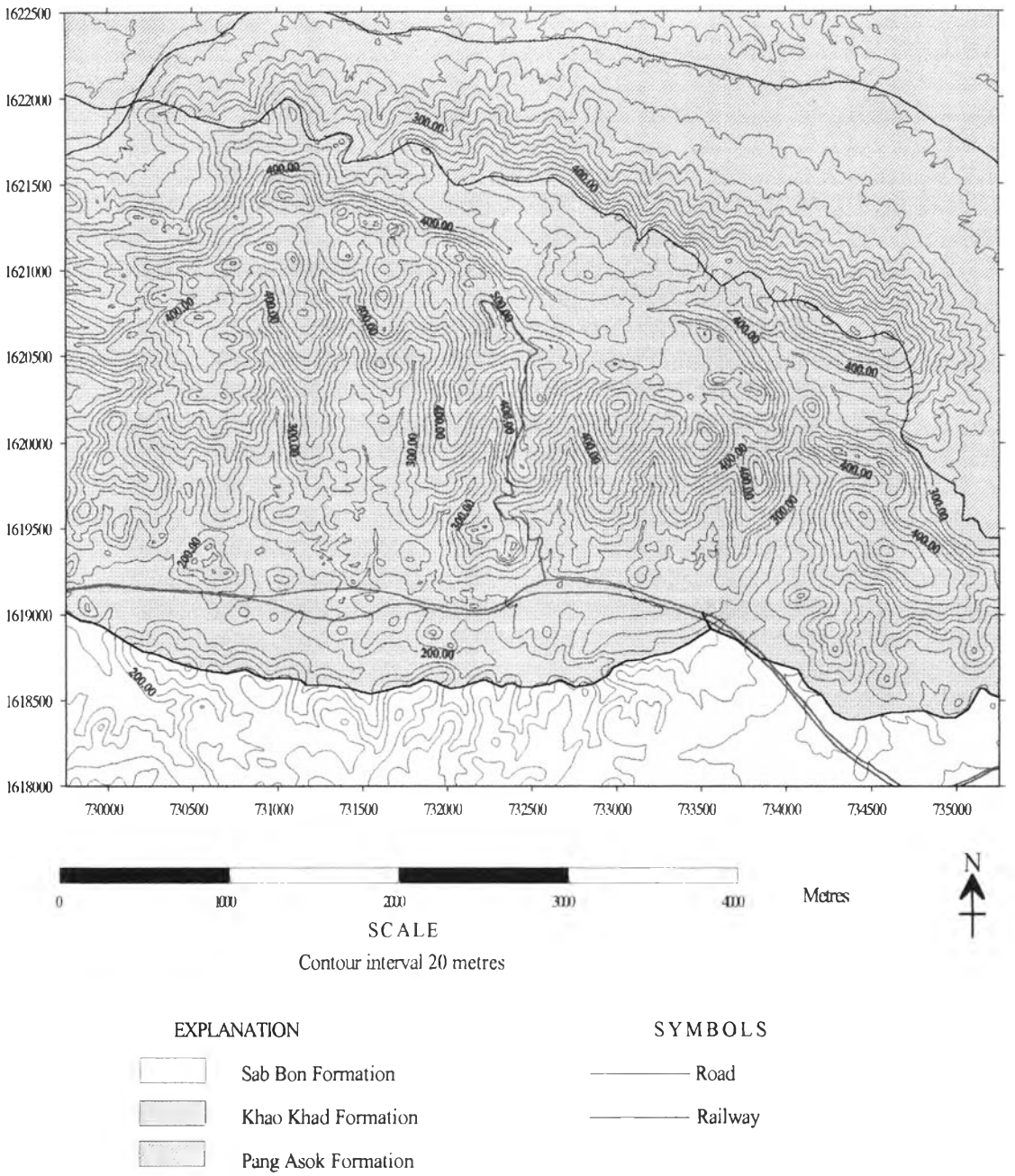

Figure 3.2 Geologic map of Khao Chan area.

The uppermost part of the Pang Asok Formation is the lowest stratigraphic unit in the study area occupying the northern and northwestern parts of the area. This rock unit is characterised by brown, pale brown, pale reddish-brown grading to dark greenish grey shale, and slaty shale intercalated with light greenish grey, somewhat micaceous of lenticular sandstone beds, and grey, argillaceous, fragmental of lenticular limestone beds. The attitude of rocks are approximately oriented in the northwest-southeast direction dipping approximately 25 to 48 degree southwestwardly.

The second stratigraphic unit, the Khao Khad Formation, mainly exposes in the area of Khao Chan. This rock unit is characterised by the interbedding of grey to dark grey carbonate sediments ranging from limestone, dolomitic limestone, dolomite to argillaceous limestone intercalated with grey to dark grey, nodular and banded cherts. It is noted that, this carbonate unit is also interbedded with some thin layers of reddish brown shale, silt shale, and porcelanite. The lithostratigraphy of this formation will be described in detail later on.

The uppermost stratigraphic unit, the lowermost part of the Sab Bon Formation, exposes in the southern part of the area. This unit is characterised by grey, greenish grey, pale brown, greenish brown, yellowish brown to buff, silt shale interbedded with siltstone, and thick bedded, grey to dark grey limestone with nodular chert.

3.1.2 Geological structures

The geological structures of Khao Chan area is considered under three main headings, namely, folds, faults, and fractures (Figure 3.3). With respect to the folds, this area is the normal limb of a major overturn syncline with the fold axis oriented in the east-west direction, plunging towards the east/west (Figure 3.4). Besides, the associated minor folds are generally characterised by a series of horizontal to gently plunging with the minor fold axes parallel to the regional fold axis, close to open, upright to inclined,

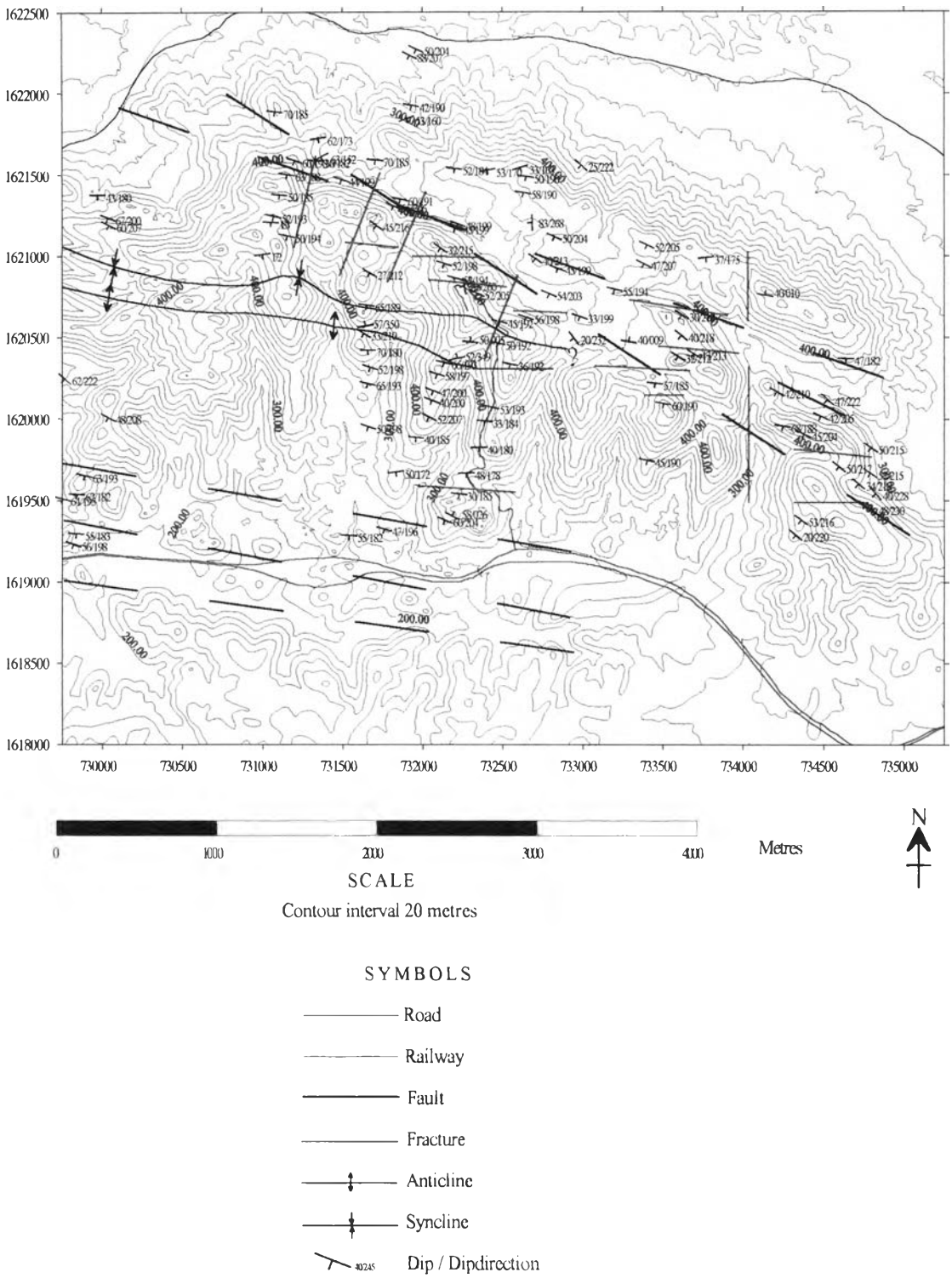

Figure 3.3 Geological structure map of Khao Chan area

asymmetric and symmetric folds with subrounded to subangular hinge area (Phothong, 1985), Figures 3.5, 3.6,and 3.7. The contour diagram of attitudes of bedding in carbonate-clastic sequences of the Khao Chan area is present in Figure 3.8.

The Khao Chan area has been offset by at least one set of reverse fault with gentle-dipping fault-plains and small displacement (Figure 3.9). The trend of fault set is parallel, and oriented in the northwest-southeast direction. The reverse fault set is located in the middle part of the area.

In addition to the folds and faults, all of rock sequences in the area show well-developed, steeply or vertically dipping fractures. There are at least two main alignment of fractures, namely, northeast-southwest trend, and northwest-southeast trend approximately perpendicular to the fault sets.

3.1.3 Igneous rocks

Igneous rocks are locally exposed in Khao Chan area. They are characterised by andesitic or dioritic composition forming as small dikes and sills passing through the carbonate-clastic sequences.

3.2 Lithofacies of Khao Chan area

Prior to the present study, there were detailed stratigraphic investigations conducted on the Khao Khad Formation, namely, Borax and Steward (1966), and Hinthong (1985). Borax and Steward (1966) conducted the geological reconnaissance of the Paleozoic stratigraphy in the area along the western margin of the Khorat plateau including the area under the present study. Most of the mappings were conducted along traverse extending normal to the regional strike of the rock formations.

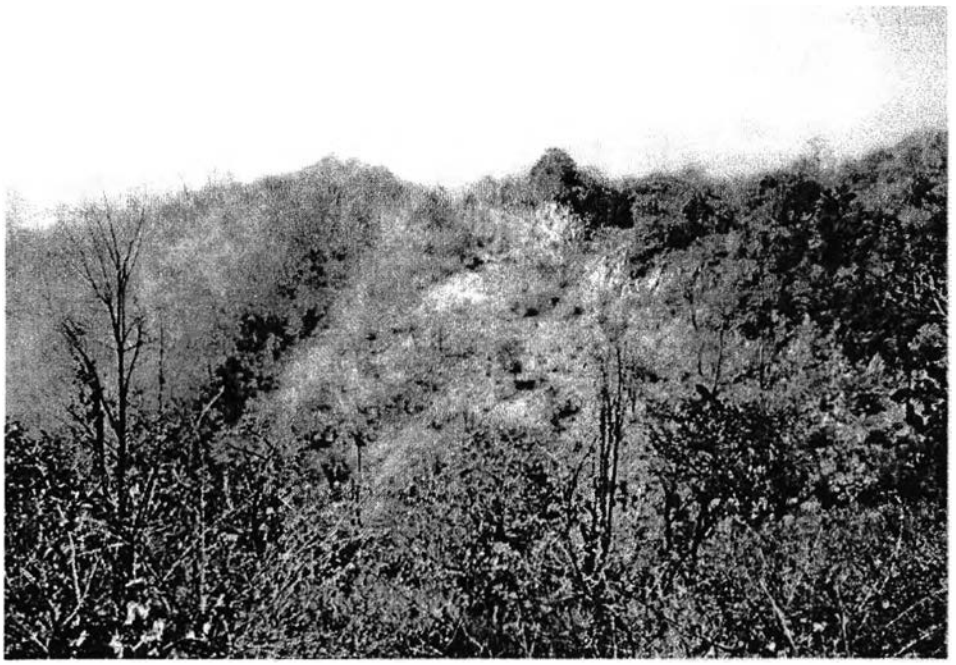

Figure 3.4 Major broad anticline in the central part of the study area, looking westwardly.

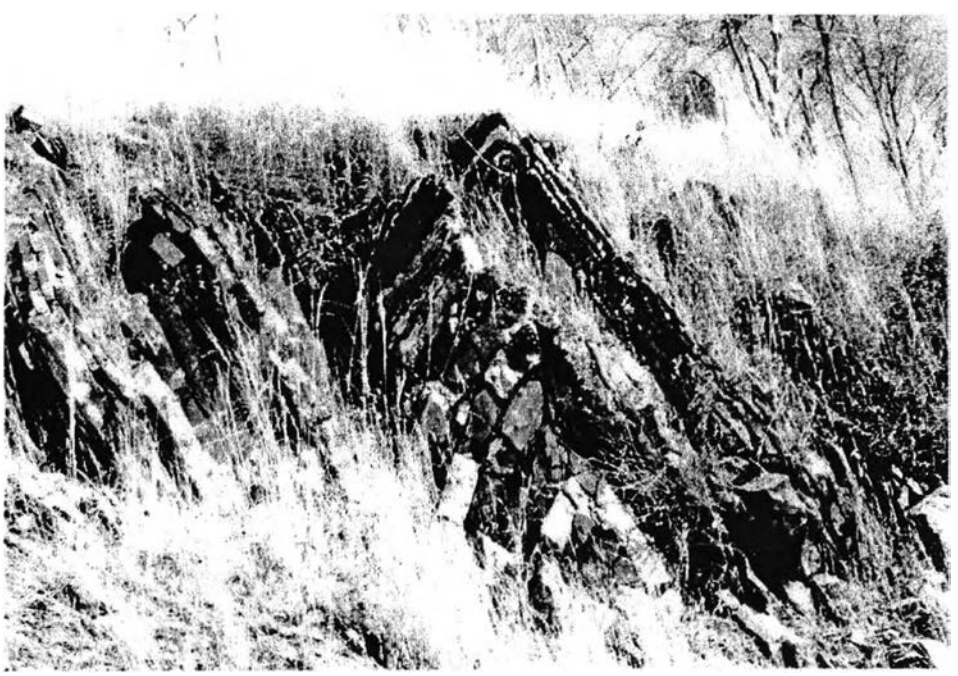

Figure 3.5 The parasitic fold, chevron shape, associates with the major broad anticline.

Figure 3.6 The parasitic closed fold, plunging hinge line with incline axial plane, associates with major broad anticline.

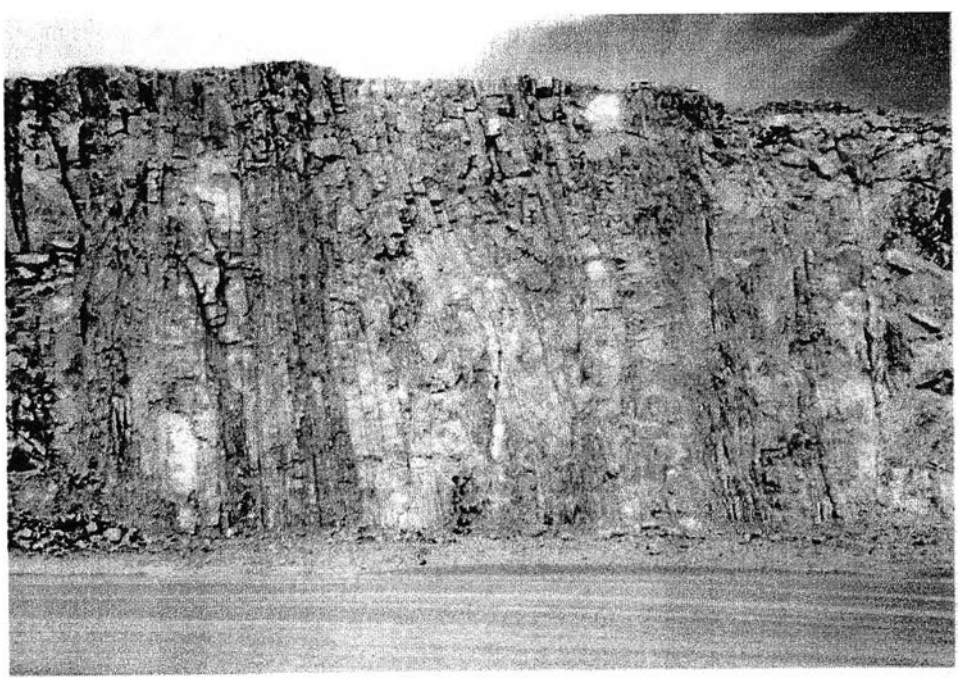

Figure 3.7 The limestone quarry illustrating the strongly disturbed parasitic fold and fault.

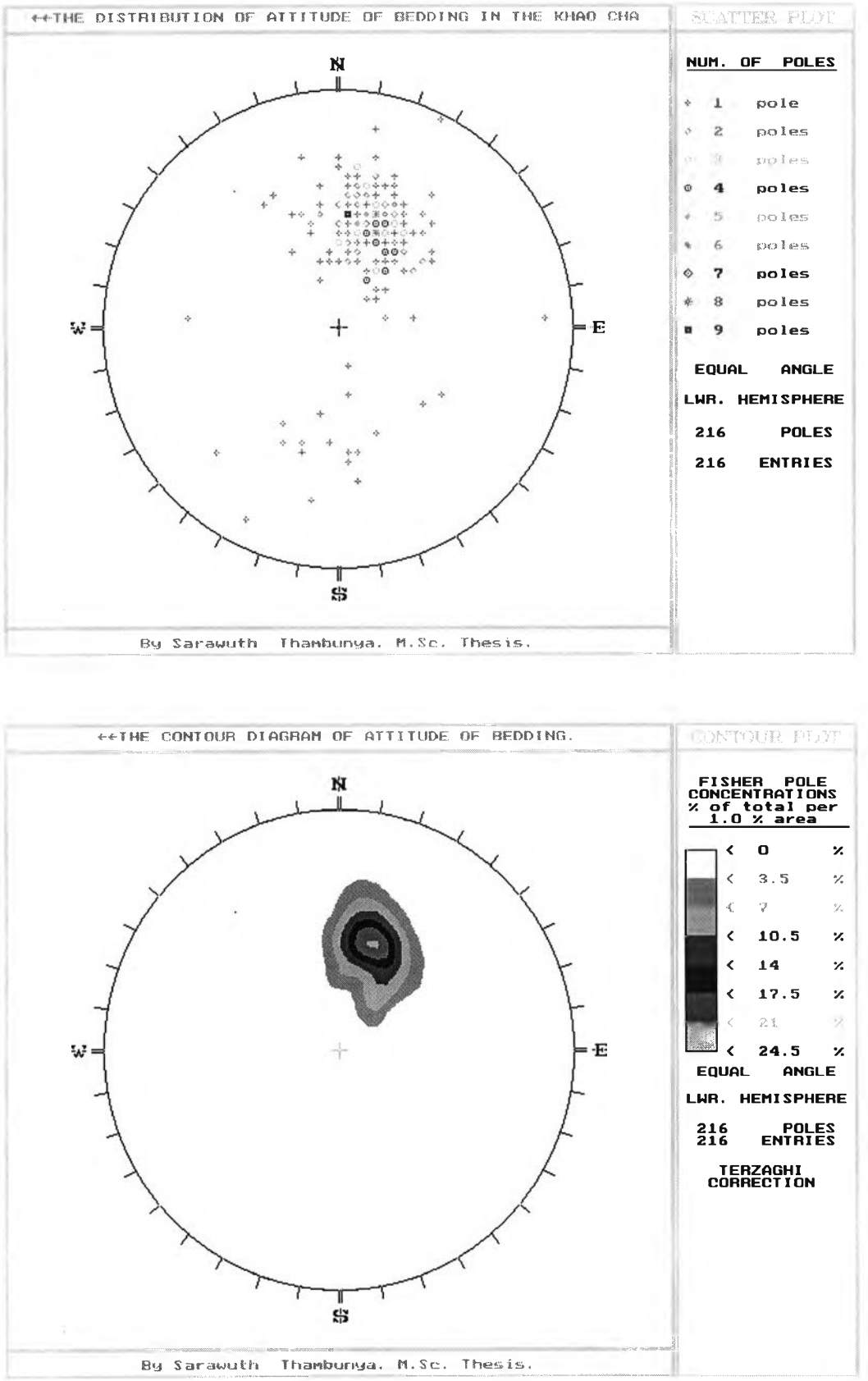

Figure 3.8 The distribution pattern and contour diagram of attitude of bedding.

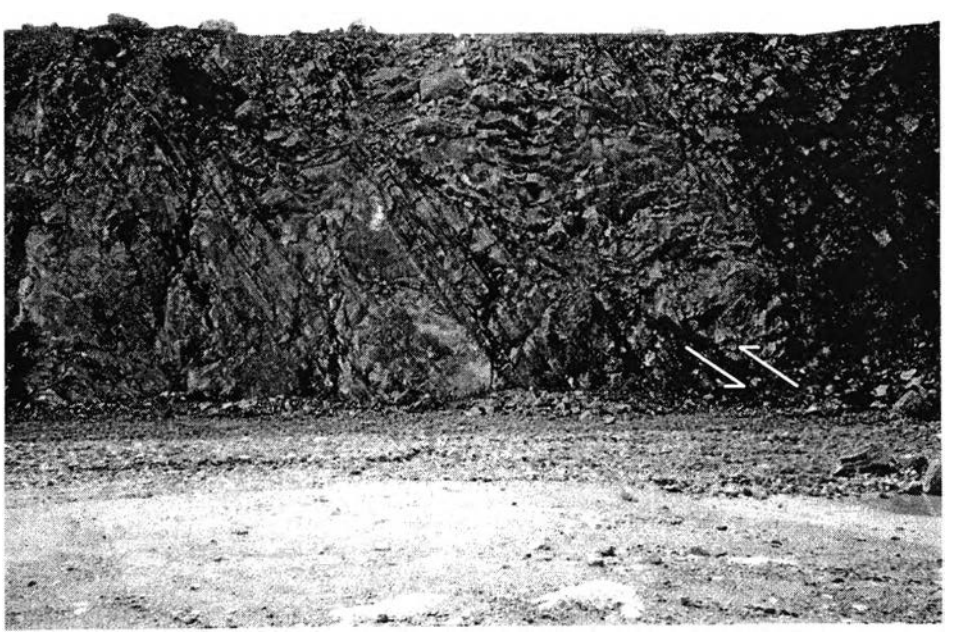

Figure 3.9 The limestone quarry illustrating the minor reverse fault with small displacement of approximately 20 metres.

The sedimentary sequence within the area of Muak Lek / Tab Kwang (formerly known as Thavi Ranch area) can be categorized into two major parts, one predominantly carbonates and the other predominantly clastics. It is noted that the area under the present study is mainly located in the predominantly carbonates.

The carbonate stratigraphic section, particularly within the area under the present study, is shown in Figure 3.10 with the total thickness of 2,568 metres. The carbonate portion of the section consists of limestone, in part limestone-pebble conglomerate, interbedded with subordinate amounts of argillaceous limestone, siltstone, claystone, and chert. Most of the limestone in the lower part of the section is dark grey and very fine-grained, whereas most of the limestone in the upperpart of the section is light grey to tan, fragmental, and contain layers of limestone pebbles. A distinctive pebble-bed, one to two meters in thickness, is located near the top of the section. It is a black, calcareous siltstone with scattered limestone pebbles, unsorted and often with matrix-supported texture, as though the rocks were a turbidite. Possibly many of the pebbly layers were deposited in a near-reef environment.

Hinthong (1985) conducted a detailed measured section in order to establish the lithostratigraphy of the Khao Khad Formation at Khao Khad, Changwat Saraburi, along Saraburi - Lomsak highway with the total thickness of 1,812 metres (Figure 3.11). The sedimentary sequence consists of limestone interbedded with chert, siliceous shale, and sandstone. In the lower part of the sequence, limestones are grey to dark grey, well bedded, mostly thick-bedded, with thin bedded and nodular chert, whereas in the upper part, limestones are characterised as light grey to dark grey, interbedded with siliceous shale, chert and sandstone.

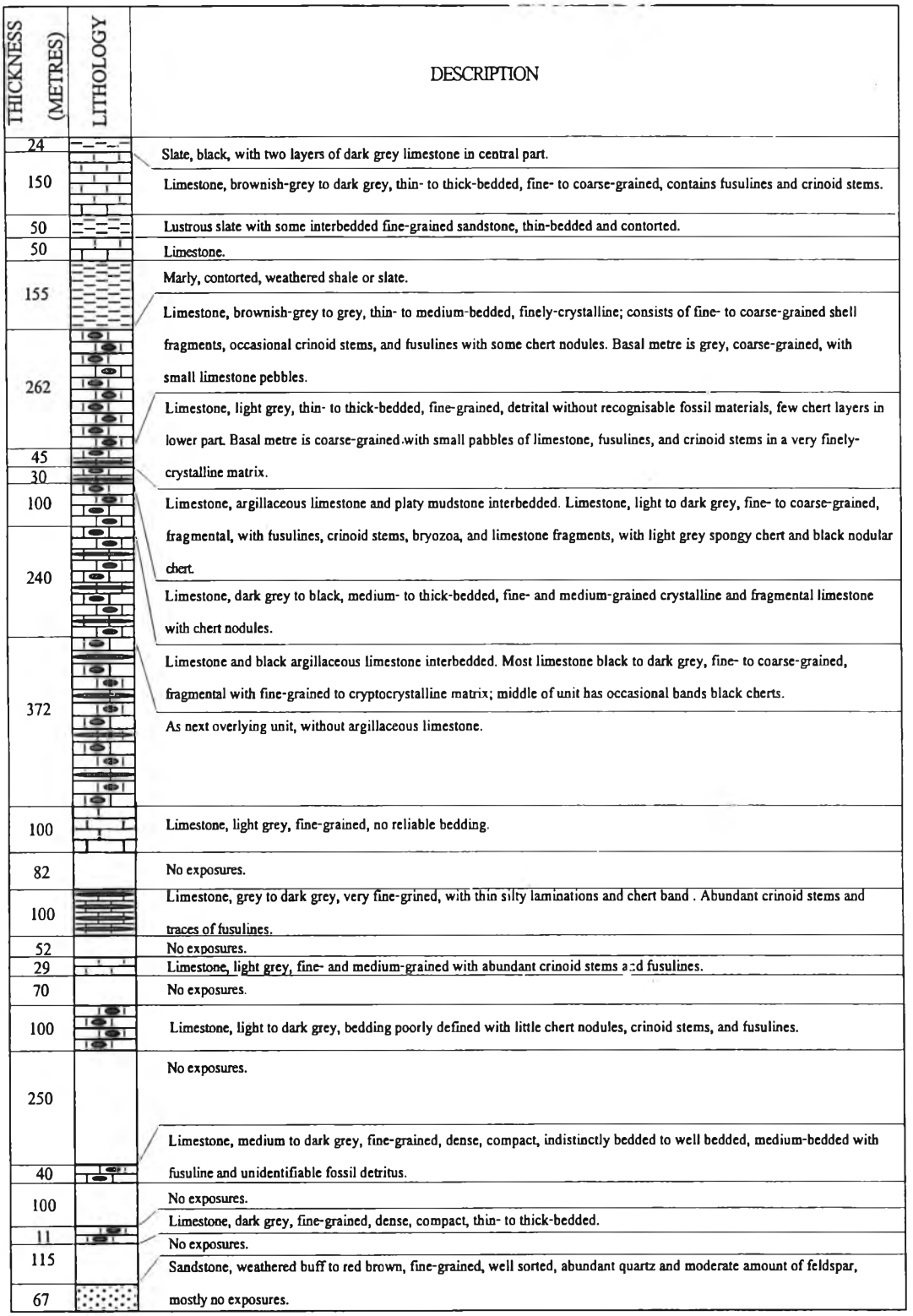

Figure 3.10 Stratigraphic column of sedimentary sequence of Muak Lek /Tab Kwang area, conducted by Borax and Steward (1966). (modified after Borax and Steward, 1966)

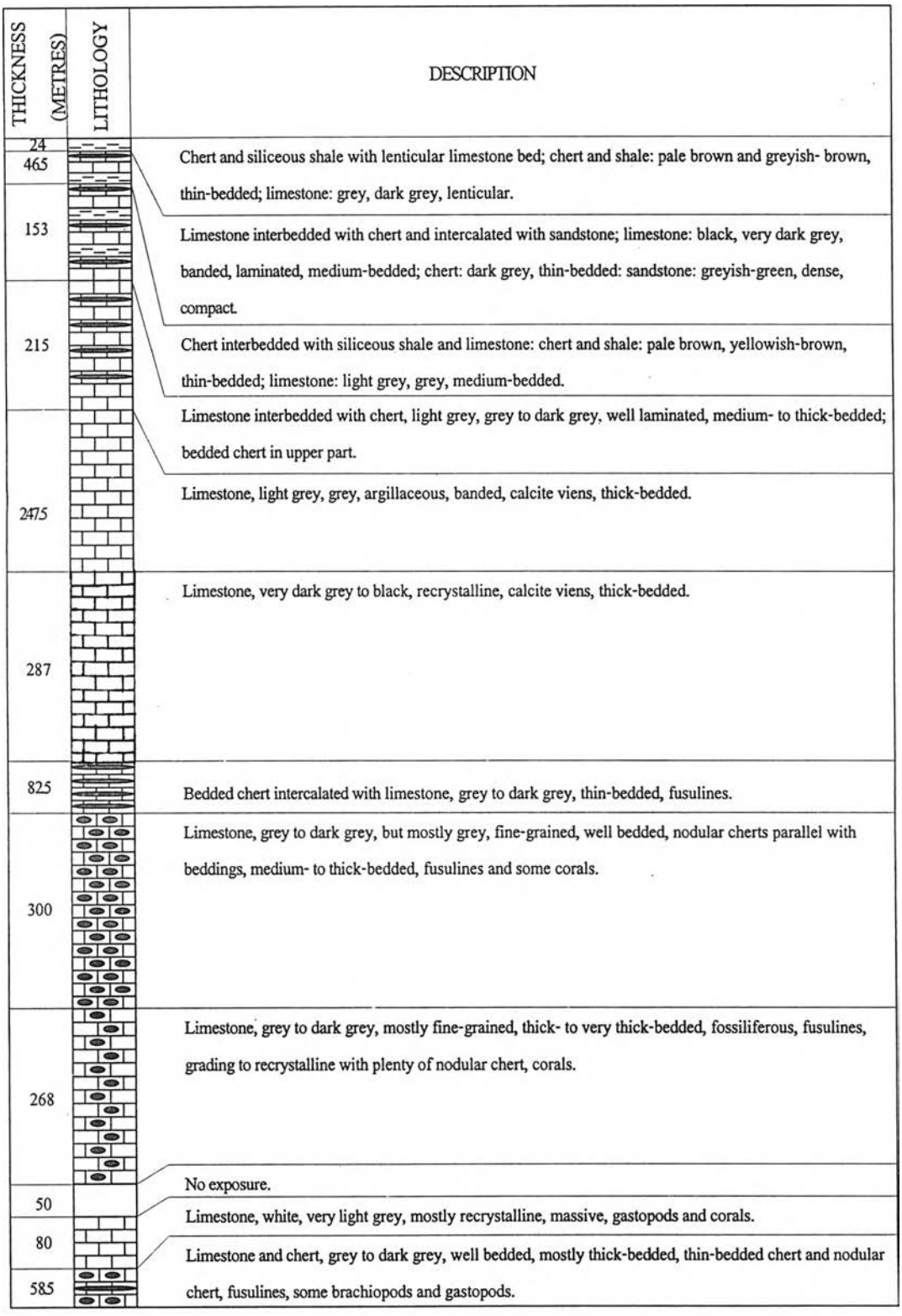

Figure 3.11 Stratigraphic column of the type section of Khao Khad Formation, proposed by Hinthong (1985). (modified after Hinthong, 1985)

Under the present study, totally eleven measured sections are conducted in order to define the characteristics of sedimentary sequence of Khao Chan area. The location of these measured sections are shown in Figure 3.12. All of the sections are oriented in the north-south direction approximately perpendicular to the regional strike, and they are totally 8,603 metres long. Altogether 269 rock samples are obtained from all measured sections. The sampling methods employ is the stratified sampling type, and the samples are undertaken where there is a change in lithological characteristics. The petrographic examination of standard thin-sections of totally 107 samples are carried out to supplement the rock identification. The sedimentary sequence of each measured section are shown in Figure 3.13, using the uppermost boundary of the Pang Asok Formation as the reference datum.

The representative sedimentary sequence of composite section of the Khao Khad Formation at Khao Chan area is shown in Figure 3.14. From the results of direct field observation and the graphic representation of all measured rock sections, it is recognised that there are altogether nine lithofacies. The lithofacies analysis of the sedimentary sequence of the Khao Khad Formation at Khao Chan area is undertaken on the basis of lithological characteristics and sedimentary structures. The description of each lithofacies are presented in ascending order as follows:

Lithofacies I : Dark grey calcilutite with chert nodules

The lithofacies I is characterised by thin- to medium-bedded of wavy- and nonparallel-bed type but in some places wavy and parallel beds occur, dark grey calcilutite with dark grey chert nodules (Figure 3.15). The lower part of the unit is dominantly represented by thinly- to thickly-laminated calcilutite, grey to dark grey, with abundant algal mats, shell fragments or fusulines, Robustoschwagerina *sp.* (Figure 3.16). In contrast, the middle and upper parts are represented by medium-bedded with relatively rare shell fragments and sparse fusulines.

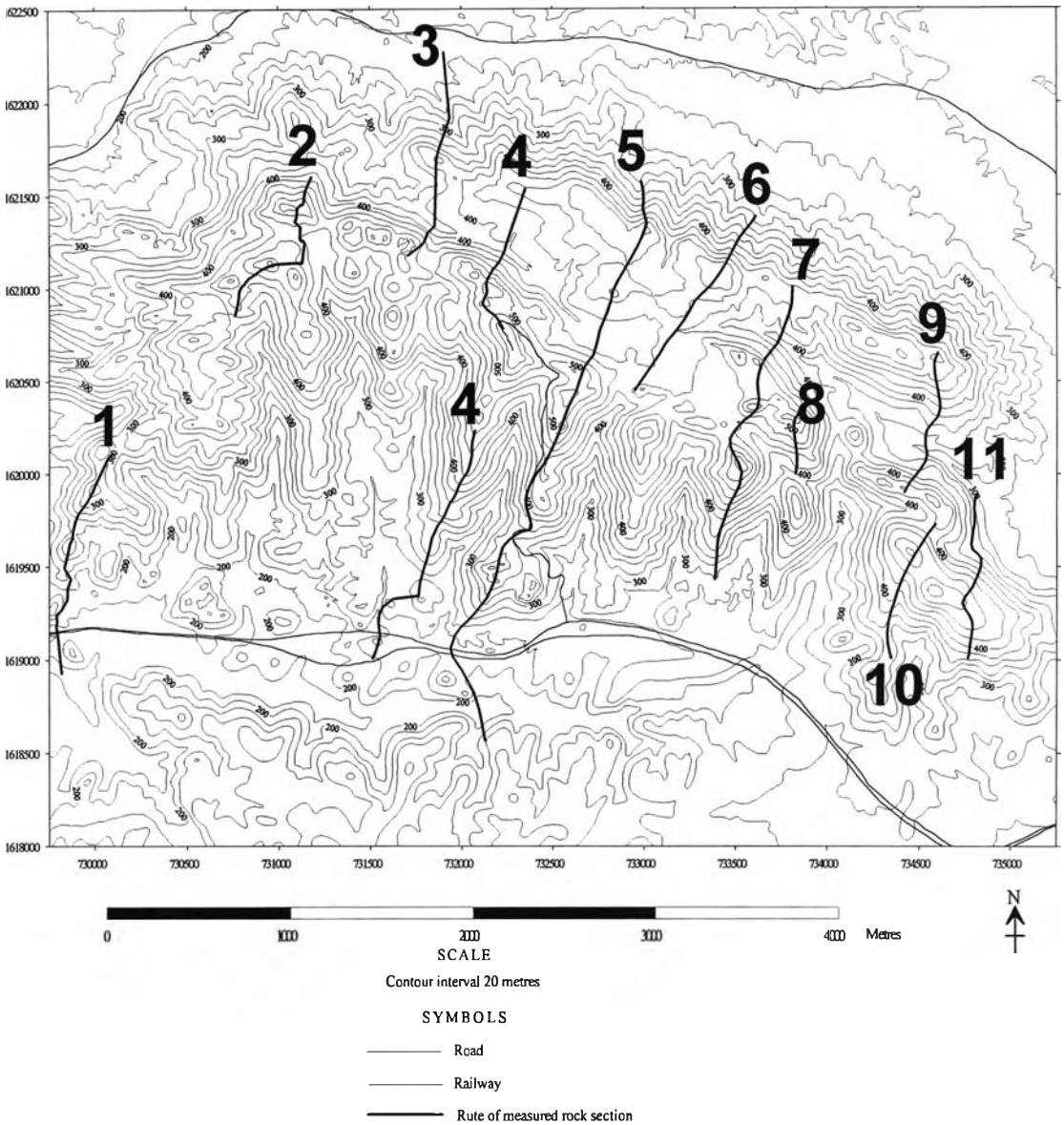

Figure 3.12 The location of eleven measured sections in the Khao Chan area.

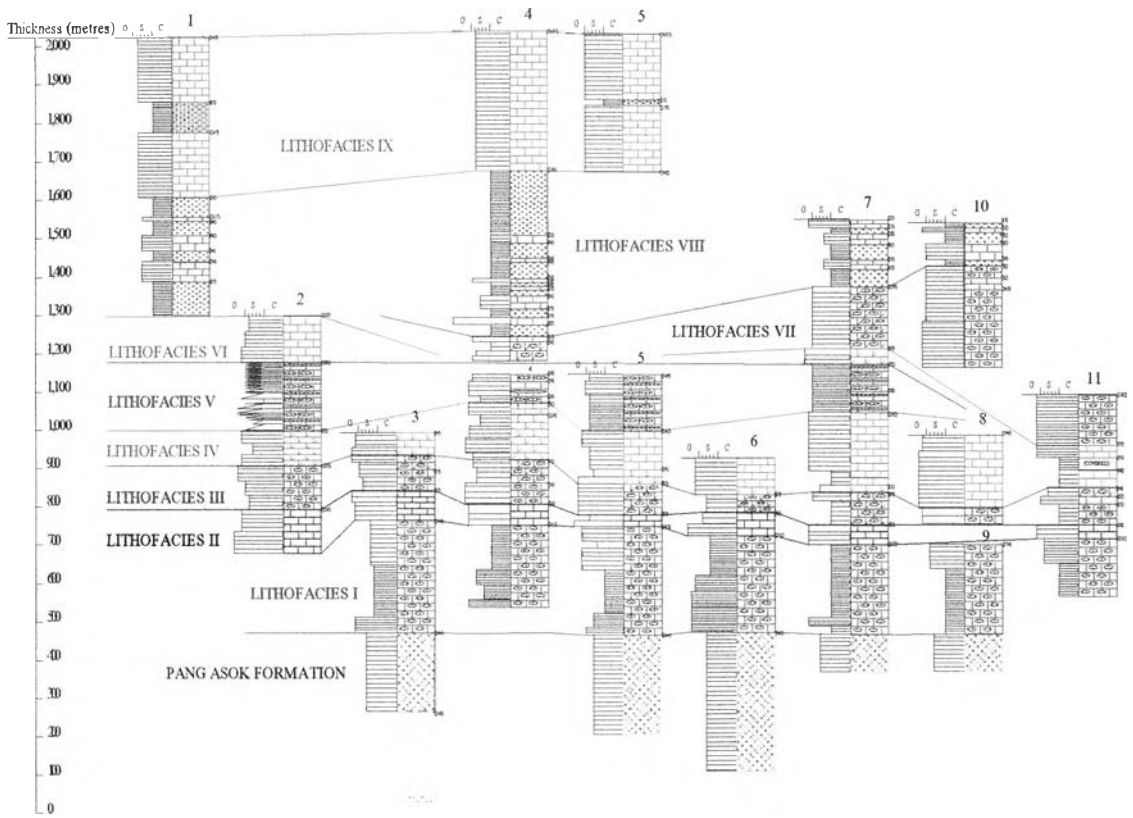

Figure 3.13 Sedimentary sequence of eleven measured sections in the Khao Chan area.

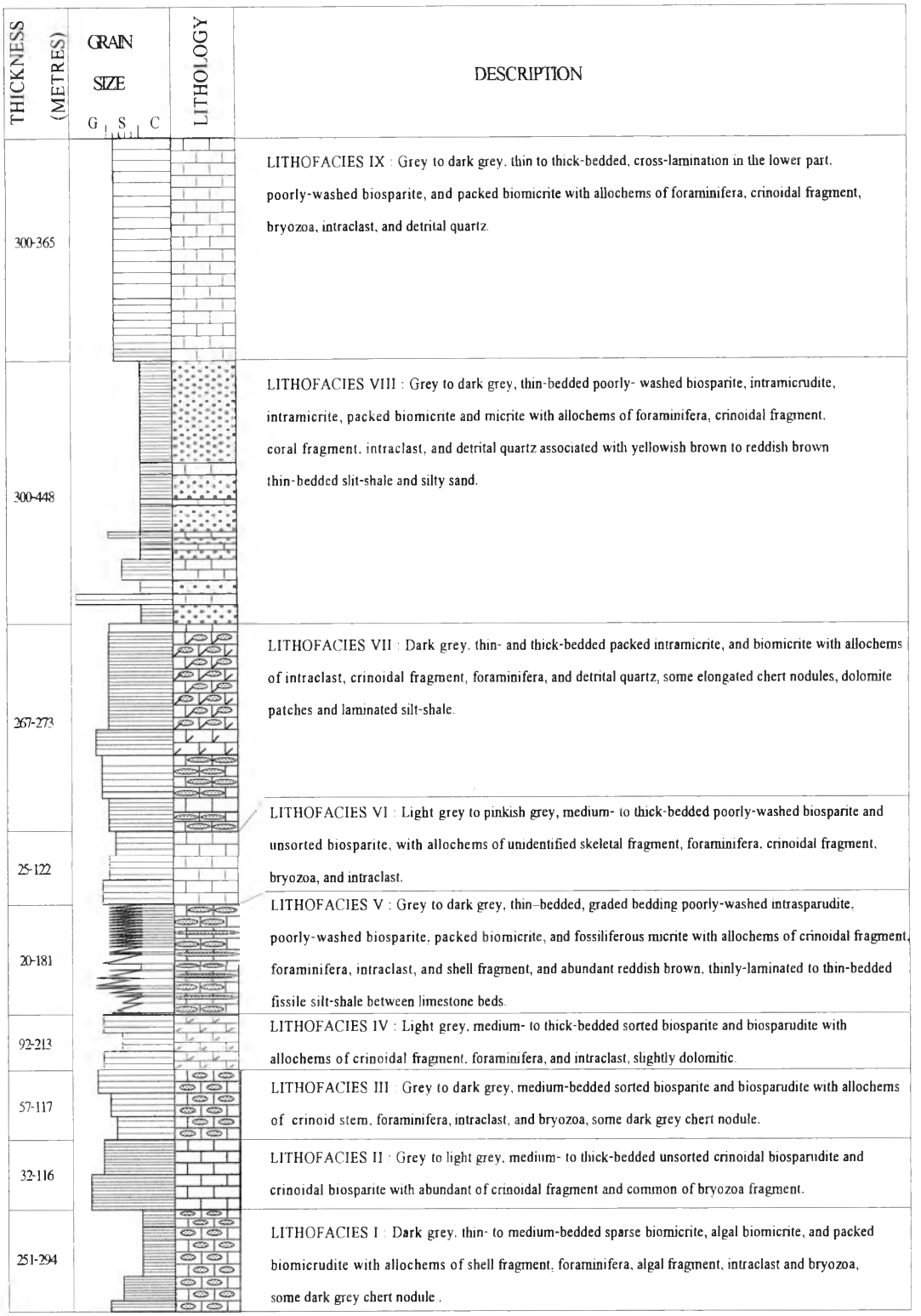

Figure 3.14 The representative sedimentary sequence of composite section of Khao Khad Formation in the Khao Chan area.

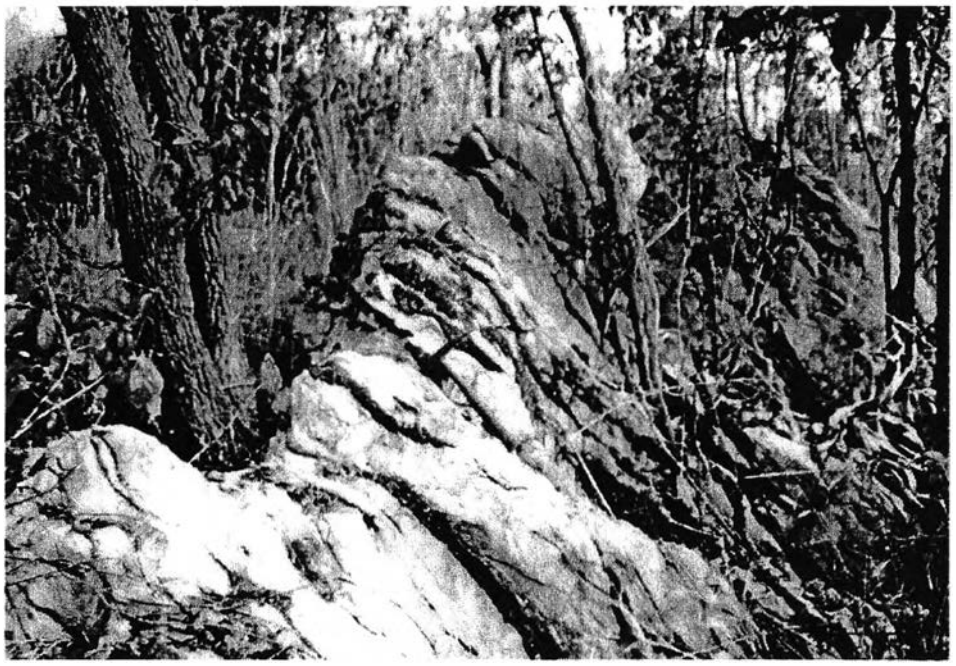

Figure 3.15 The thin- to medium-bedded, dark grey calcilutite with dark grey chert nodules of the lower part of lithofacies I.

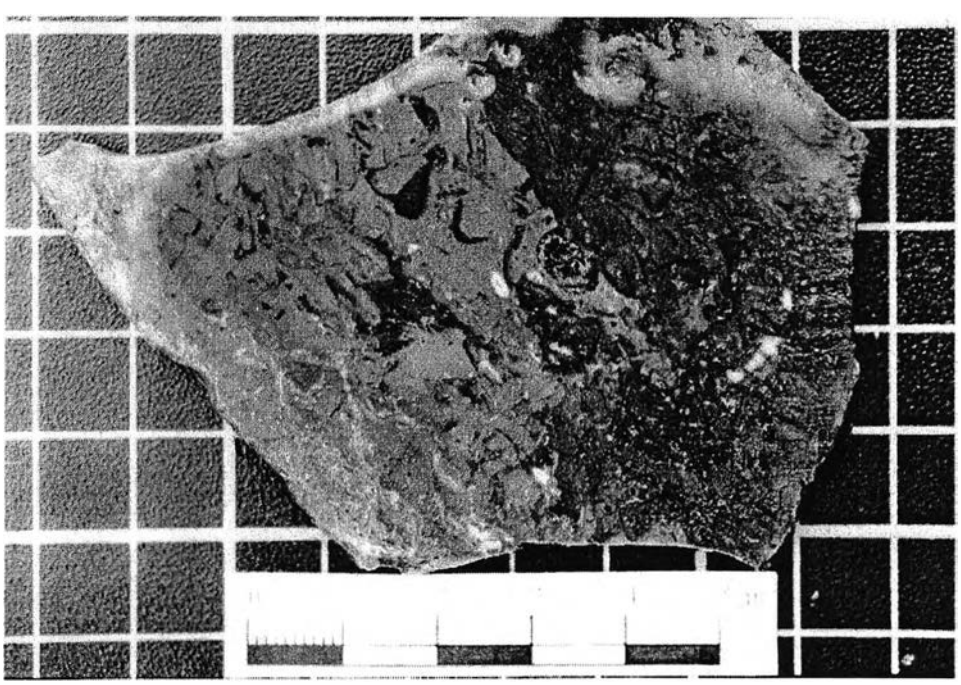

Figure 3.16 The rock slab of greenish grey to dark grey calcilutite of lithofacies I showing the shell fragments with sparse foraminiferal tests.

The lithofacies I is representing the lower part of the lithostratigraphic sequence of the Khao Khad Formation at Khao Chan area with the thickness ranges from 251 to 294 metres. It is underlain by the uppermost unit of the Pang Asok Formation which characterised by yellowish brown, silt-shale intercalated with thin- to medium-bedded, grey to dark grey, fine calcarenite to fine calcirudite, whereas the upper part of the unit is dominantly the thin- to medium-bedded, greenish grey to yellowish brown, medium to fine sand, moderately sorted, subrounded, sandstone.

The lithofacies I is exposed in measured rock-section nos. 3, 4, 5, 6, 7, 9, and 11 with thicknesses of 294, 215, 283, 251, 233, 256, and 151 metres, respectively.

Petrographic studies show that the lithofacies I is sparse biomicrite, algal biomicrite, and paked biomicrudite with some microcrystalline chert. The sparse biomicrite (Figure 3.17) is most abundant in the lithofacies consisting of 10 to 50 per cent of complete or broken organic skeletons of relatively large fragments embedded in a fine-grained matrix. The organic skeletons, such as shell and foraminiferal tests are sharply marked off by a coarsely crystalline calcite which fills the part of shell. In some cases, the internal spaces, or chambers, of shells are partially or wholly filled with coarse sparry calcite. The algal biomicrite (Figure 3.17) is exclusively recognised in the lower part of the lithofacies consisting of unidentified types of algal fragment closely packed with calcareous grains of intraclastic and/or skeletal origins the size ranging from a few microns to a hundred microns. The packed biomicrudite is also exclusively abundant in the lower part of the lithofacies consisting of complete foraminiferal tets, Robustoschwagerina *sp.*, with the size ranging from 2 to 7 millimetres closely packed in micrite matrix. It is noted that the microcrystalline cherts which replaced the carbonate matrix are formed as chert nodules sparsely embedded in the biomicrite (Figure 3.18). Besides, there are some tiny calcareous patches in the chert nodules.

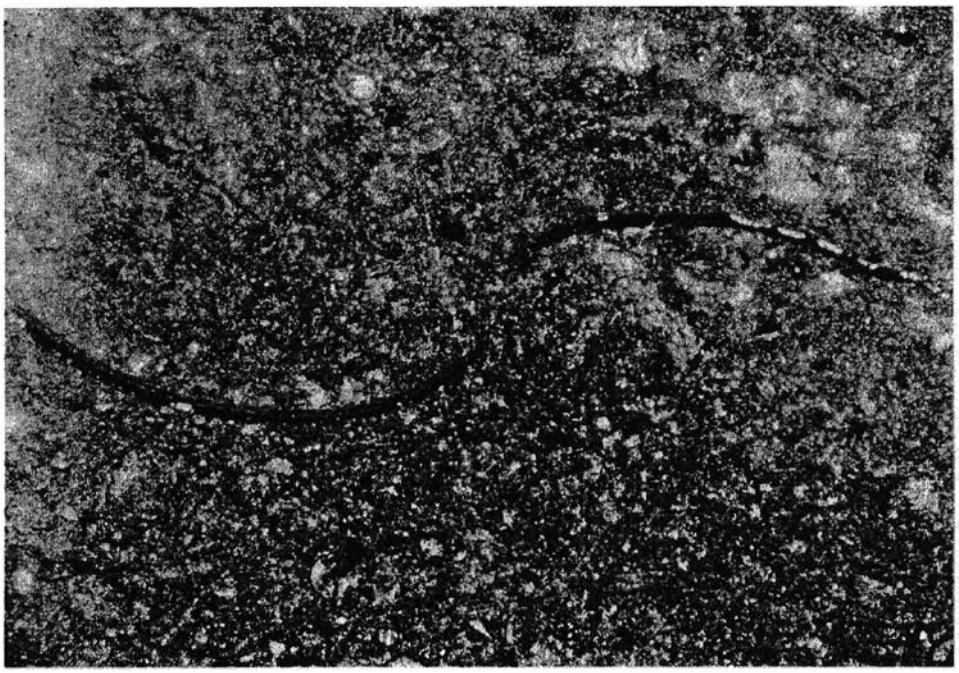

Figure 3.17 The photomicrograph of sparse biomicrite of the lithofacies I showing sparse organic skeletons embedded in micrite. (Crossed nicols, x44)

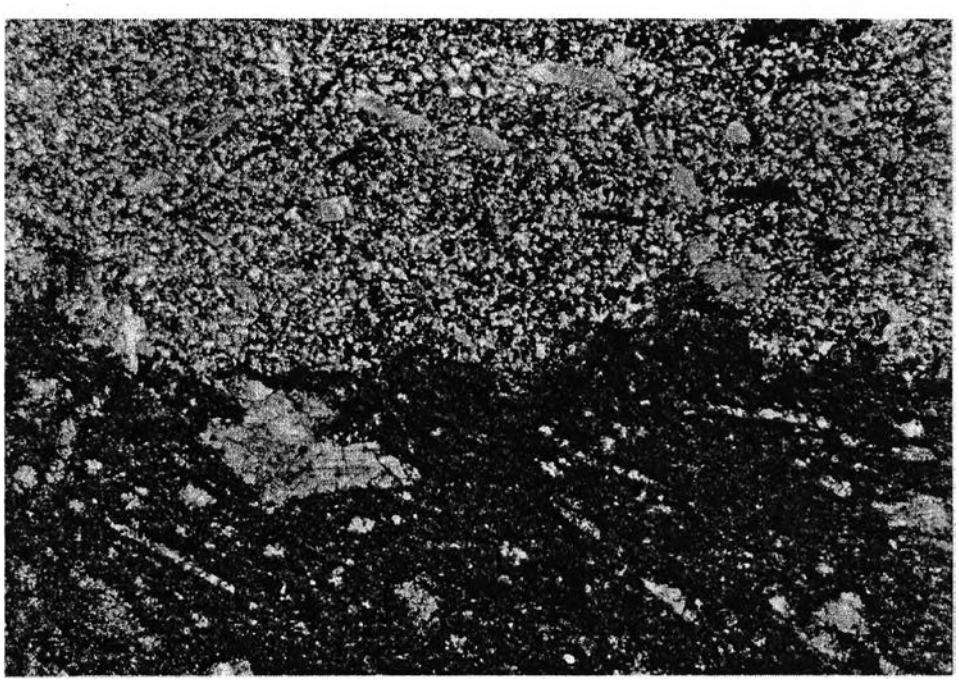

Figure 3.18 The photomicrograph of the biomicrite of the lower part of the lithofacies I (lower haft part of picture) with sharp boundary of fine-grained quartz chert (upper haft part of picture). (Crossed nicols, x44)

Lithofacies II : Encrinites

This lithofacies overlies the dark grey calcilutite with chert nodules, or lithofacies I, with sharp contact. It is represented by grey to light grey, medium- to thick-bedded of parallel-bed type (Figure 3.19), fine calcirudite with grain component of large crinoid stems (with diameter between 0.5 and 2 centimetres) of more than 50 per-cent (Figures 3.20). It is noted that very thin bands of greyish black to reddish silt-shale are always present between every encrinite beds. The total thickness of this lithofacies varies from 32 to 116 metres. It is exposed in measured rock section nos. 2, 3, 4, 5, 6, and 7 with the thickness of 116, 77, 56, 32, 62, and 52 metres respectively.

Petrographic studies show that this lithofacies is unsorted crinoidal biosparite and crinoidal biosparite or encrinite which contains crinoidal fragments more than 50 per cent. They are characterised by the conspicuous ingredients of ossicles of crinoid stems with the size ranging from few millimetres to two centimetres. Each ossicle contains of calcite which behaves as single calcite crystal with the crystallographic C-axis parallel to the central canal (Figure 3.21). The bryozoa fragments are commonly associated with crinoid ossicles (Figure 3.22) and they are cemented together by comparatively clear as well as coarse crystalline calcite or spairy calcite cement. However, the fine-grained matrix is commonly recognised as micrite and pseudosparite with sparse dolomite rhombs in some parts.

Lithofacies III : Calcarenite with chert nodules

Overlying the encrinite lithofacies with gradational contact is the calcaranite with chert nodules, or lithofacies III. It is characterised by medium-bedded; grey to dark grey, coarse calcarenite and fine calcirudite with dark grey chert nodules (Figures 3.23).

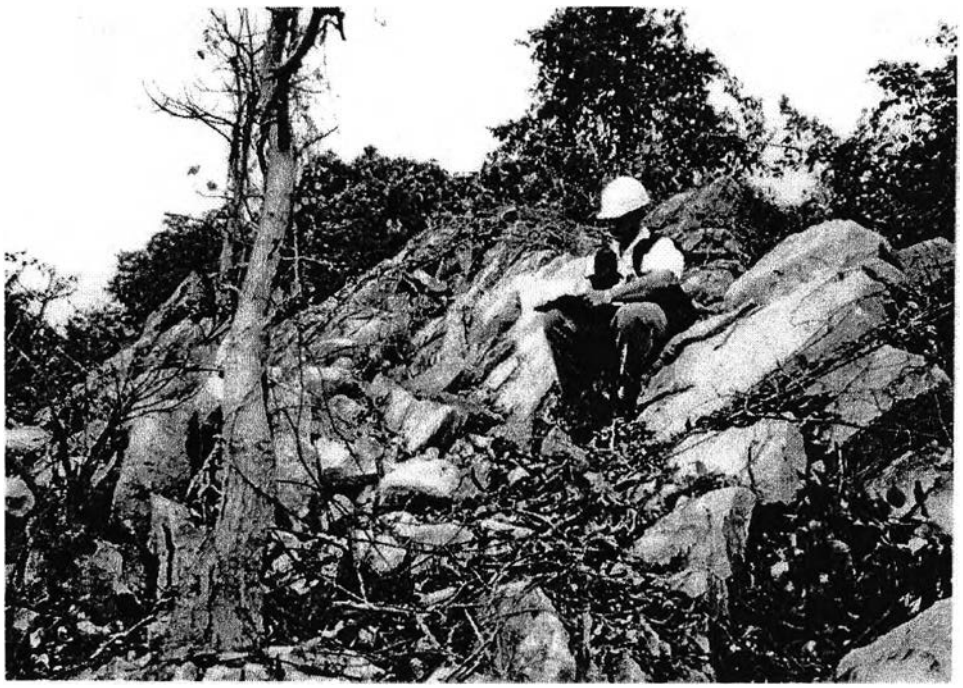

Figure 3.19 The exposure of the encrinite, lithofacies II, showing medium- to thick-bedded.

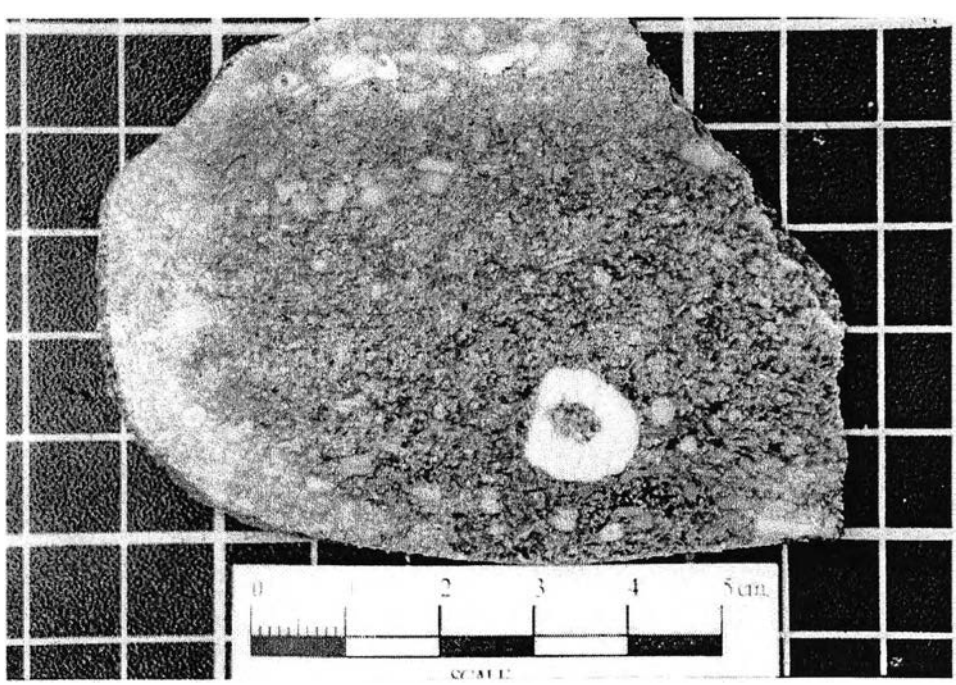

Figure 3.20 The rock slab of the encrinite, lithofacies II, showing poorly sorted crinoidal fragments.

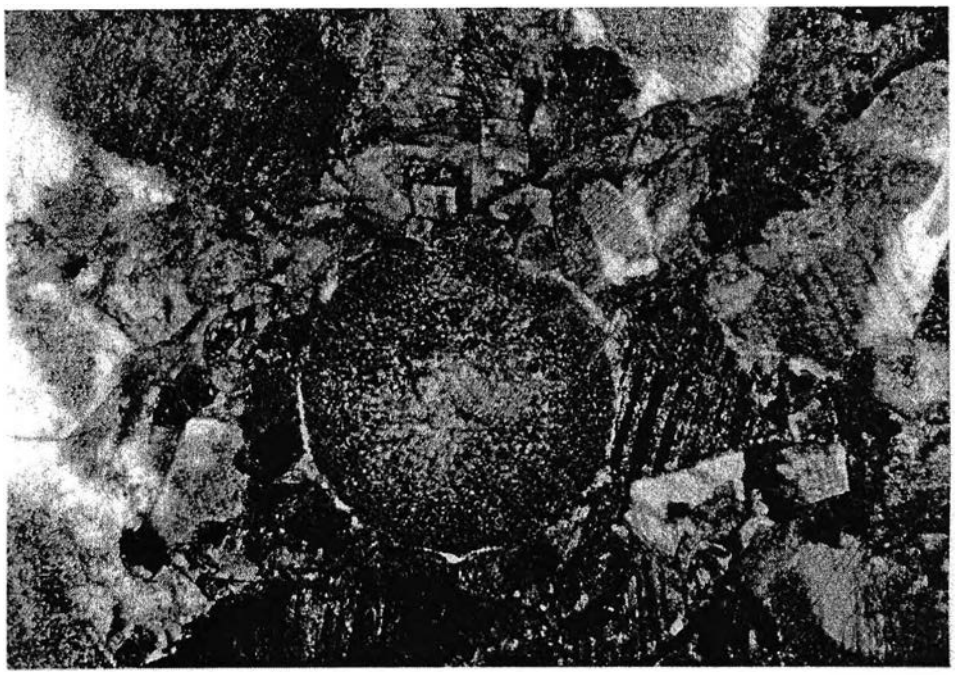

Figure 3.21 The photomicrograph of crinoidal biosparite of the lithofacies II showing sparry calcite cement of the crinoid ossicles, fragments of bryozoa and other skeletal remains with sparse dolomite rhombs. (Crossed nicols, x44)

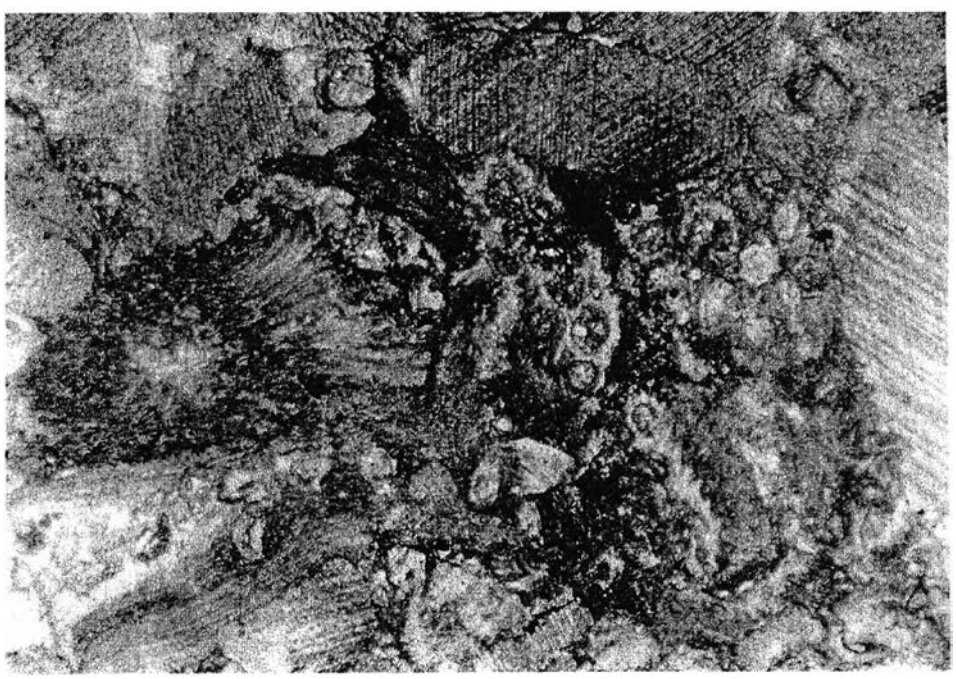

Figure 3.22 The photomicrograph of crinoidal biosparite of the lithofacies II showing fragments of bryozoa and other skeletal remains cemented by sparry calcite. (Crossed nicols, x44)

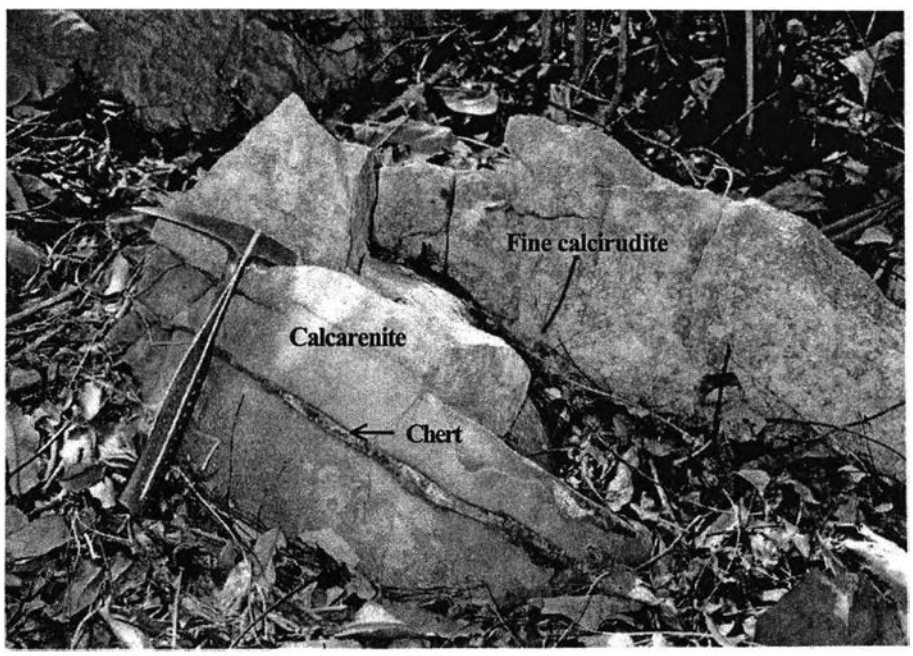

Figure 3.23 The exposure of fine calcirudite with chert nodules of lithofacies III showing the elongated shape of nodular chert.

The major grain components are crinoid stems, foraminefera, and intraclasts, respectively in decreasing order of abundance. It is noted that the skeletal remains of crinoid and foraminifera are present as clasts as well as in chert nodules. The chert nodules vary in size from a few centimetres to a few decimetres scattered in the limestones. Some of limestones, mostly in upper part of the unit, are dolomitic. The entire thickness of this lithofacies varies from 57 to 117 metres. This lithofacies is present in measured section nos. 2, 3, 4, 5, 6, 7, 8, and 11.

Petrographically, the lithofacies III is sorted biospartie and biosparudite with some microcrystalline chert. The sorted biosparite and biosparudite (Figures 3.24) are consisting of broken or disintegrated fragments of calcareous skeletons, crinoids, bryozoa, and unidentified fragments, mixed in various proportions with intraclasts and complete shells of foraminifera. The calcareous allochems, frequently well sorted, are cemented together by comparatively clear crystalline calcite. However, the dark brown, dull colour of microcrystalline matrix can be recognised in some parts between the boundary of carbonate grains. In addition, the dark grey colour of mostly microcrystalline cherts are embedded as lenses and elongated nodular shape in sorted biosparite and biosparudite. The silicification has been more intense in the matrix of the carbonate rocks than the stout clcareous allochems, and can be recognised the microcrystalline chert throughout the matrix of nodular cherts partially silified of pre-existing calcareous skeletons.

Lithofacies IV : Fine calcirudite

The light grey, fine calcirudite, or lithofacies IV overlies the calcarenite with chert nodules. It is represented by medium-to thick-bedded, light grey, coarse calcarenite to fine calcirudite with some dolomitic limestones alternating with thin bedded dolomite (Figures 3.25). The skeletal grain components of this lithofacies are similar to those of the underlying lithofacies.

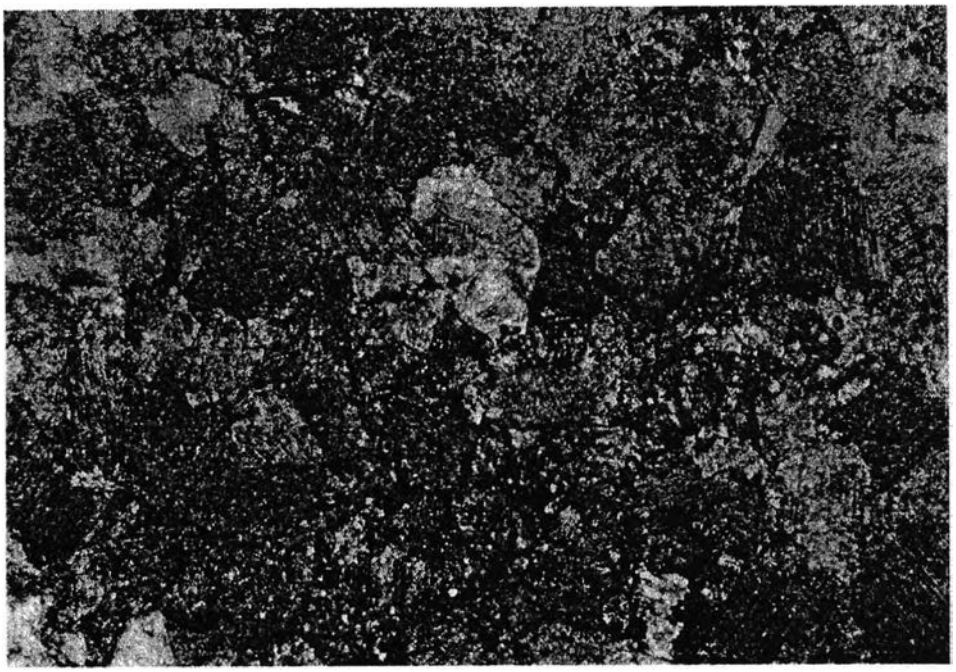

Figure 3.24 The photomicrograph of sorted biosparite of the lithofacies III showing closely packed of carbonate allochems which cemented by sparry calcite with some micrite infilled between carbonate grains. (Crossed nicols, x44)

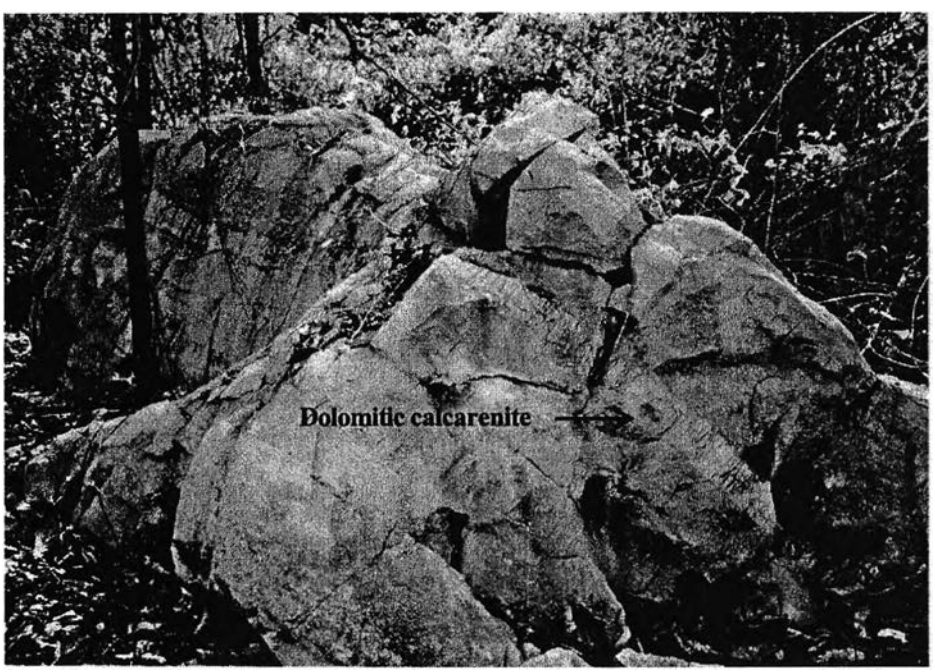

Figure 3.25 The outcrop of medium-bedded calcarenite interbedded with mediun-bedded calcirudite with thin-bedded dolomitic calcarenite of the lithofacies IV.

The total thickness of the light grey, fine calcirudite facies varies in the range of 92 to 213 metres, and it is exposed in measured rock section nos. 2, 3, 4, 5, 6, 7, 8, and 11.

The petrographic studies of the lithofacies IV show that the characteristics of this lithofacies is quite similar to those of the lithofacies III and consisting of sorted biosparite and biosparudite, but it is more intensely dolomitised. The sorted biosparite and biosparudite are consisting essentially of crinoidal fragments, foraminiferal tests, and intraclasts, which closely packed together and cemented by sparry calcite with sparse micrite, some parts may be called poorly-washed biosparite (Figure 3.26). The sparry calcite of ten to hundred microns in size are usually recognised in the chamber of foraminiferal tests. The selective dolomitisation can be recognised as laminated to thin-bedded dolomitic biosparite containing over 10 per cent dolomite of uncertain origin and extending with approximately uniform character over a wide area conformable to the bedding of carbonate rocks (Figure 3.27). Dolomite has a very strong tendency to form idiomorphic crystals so that they formed rhombohedral shape cut across the primary structures or pre-existing carbonate allochems (Figure 3.28)

Lithofacies V : Graded bedding calcarenite with chert bands

Upward from the light grey, fine calcirudite, or lithofacies IV is the graded-bedding calcarenite with chert bands, or lithofacies V. It is represented by thin-bedded of grey to dark grey with normal graded bedding of calcarenite to calcilutite and dark grey chert bands. There are abundant thinly-laminated to thin-bedded, reddish brown, fissile silt-shale between limestone beds (Figure 3.29). It is noted that four calcirudite beds of 9-13 metres thick are present in the middle part of this unit (Figures 3.30). These four calcirudite beds are exceptionally characterised by the remarkable large grain components or intraclasts.

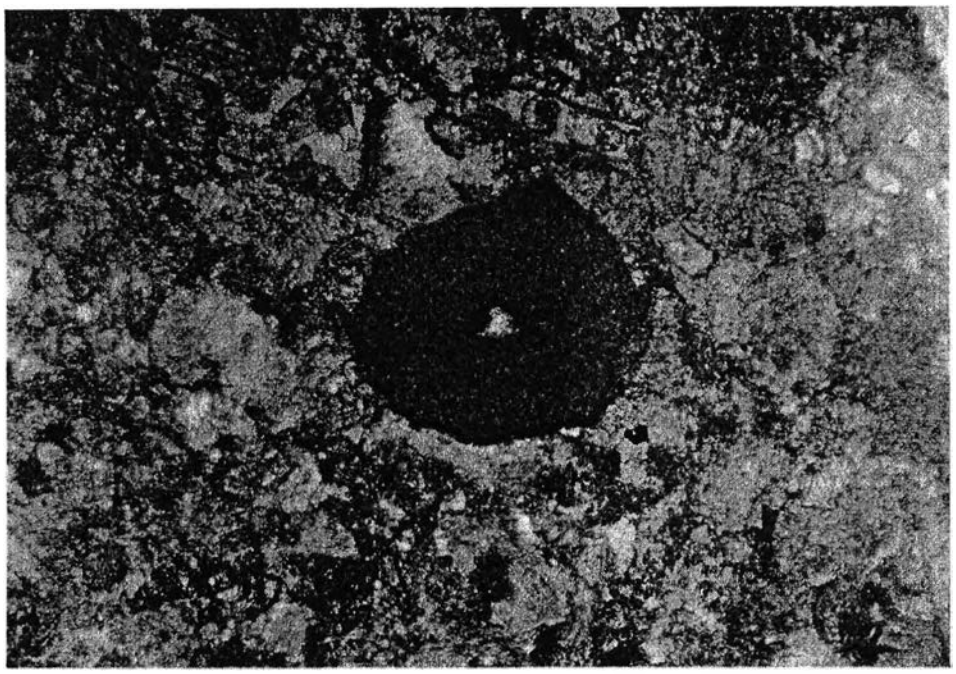

Figure 3.26 The photomicrograph of poorly-washed biosparite of the lithofacies IV. (Crossed nicols, x44)

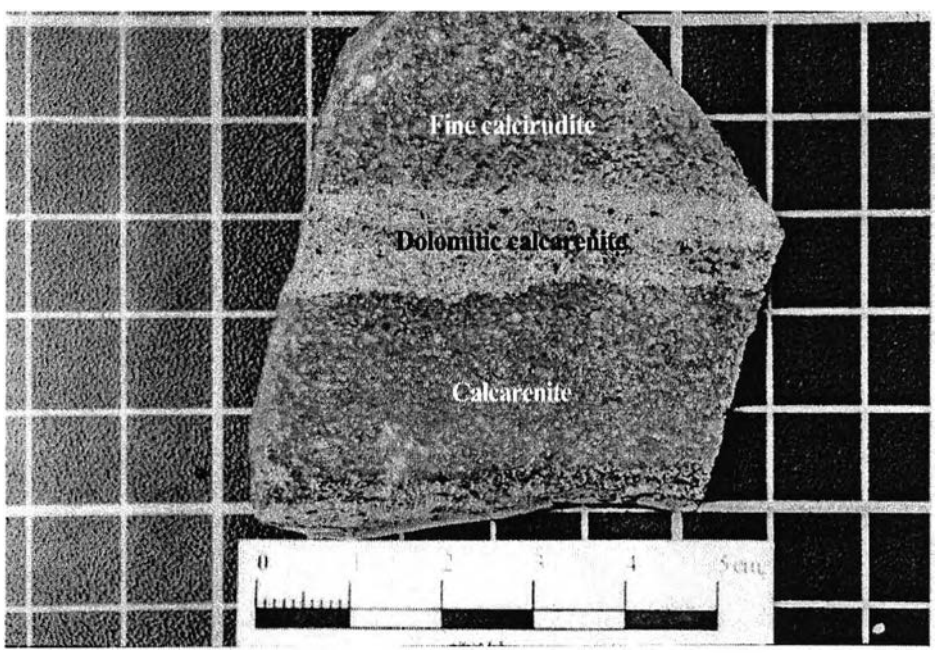

Figure 3.27 The rock slab of calcarenite of the lithofacies IV showing the light grey, thin-bedded dolomitic calcarenite, in the middle, between fine calcirudite and calcarenite

Figure 3.28 The photomicrograph of dolomitic calcarenite of the lithofacies IV showing the dolomite rhombs cut across the foraminiferal test.
(Crossed nicols, x44)

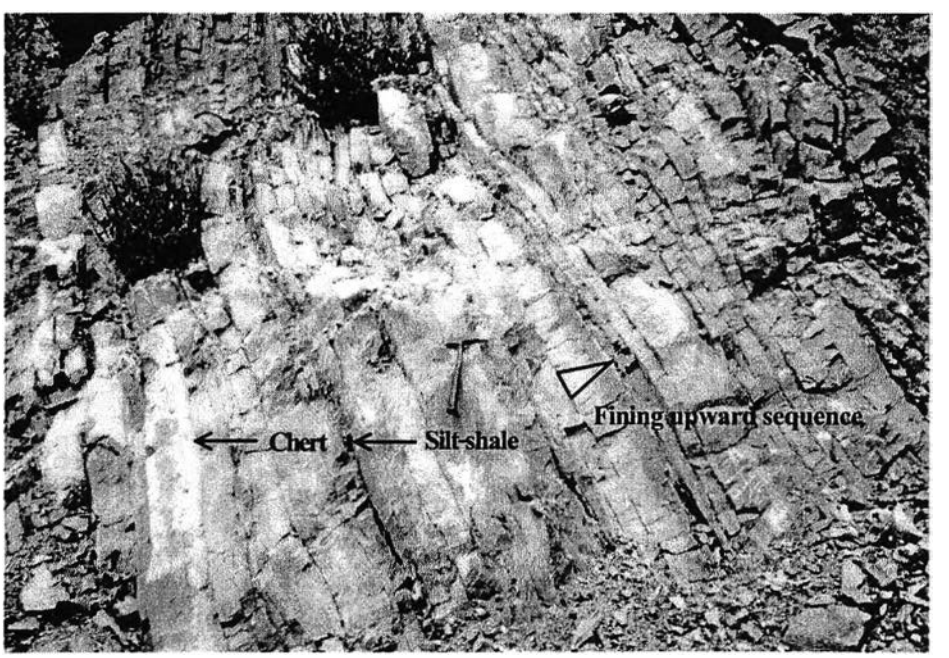

Figure 3.29 The exposure of thin-bedded, grey to dark grey of a series of graded bedding calcarenite to calcilutite with banded chert and thinly-laminated to thin-bedded, reddish brown, fissile silt-shale between limestone beds of the lithofacies V.

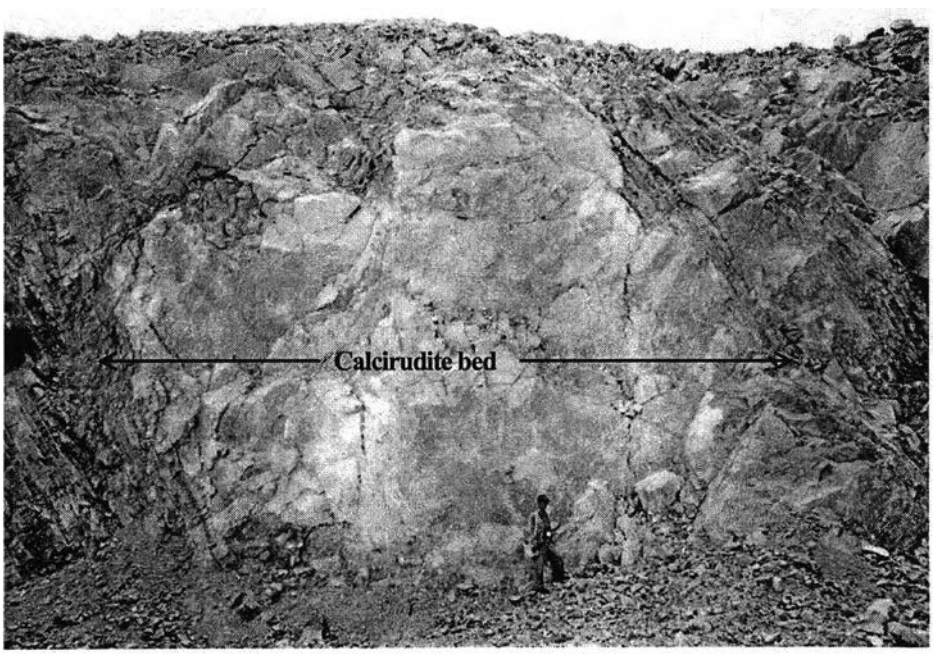

Figure 3.30 The exposure of very thick-bedded calcirudite, 13 metres thick, between a series of graded bedding of thin-bedded calcarenite to calcilutite, in the middle part of the lithofacies V.

The grain components of this lithofacies are fusuline, crinoidal fragments, intraclasts, and shell fragments, respectively in decreasing order of abundance. The thickness of this unit varies in the range of 20 to 181 metres thickening westwardly. It is exposed as a thick sequence in measured rock section no.2, and also recognised in measured rock section nos. 4, 5, and 7.

Petrographic studies of the lithofacies V show that the graded-bedding calcarenite is consisting of poorly-washed intrasparudite, poorly-washed biosparite, packed biomicrite and fossiliferous micrite with microcrystalline banded cherts. The poorly-washed intrasparudite is exclusively recognised in the calcirudite beds consisting 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 3.31). The rest of allochems are subordinate calcareous skeletons, mostly, crinoid ossicles, foraminiferal tests, and other skeletons fragments, with micrite cemented by sparry calcite.

Apart from four beds of poorly-washed intrasparudite earlier described, the lithological characteristics of this lithofacies is mainly a series of graded-bedding sequences of poorly-washed biosparite, packed biomicrite, and fossiliferous micrite, respectively in ascending order.

The poorly-washed biosparite is consisting of finer grained carbonate sediments inwhich the particles are smaller than 1 millimetre of skeletal fragments and intraclasts with some micrite and cemented by sparry calcite (Figure 3.32). The clear crystalline calcite of decimicrons size usually infilled the chamber of fossils. The packed biomicrite and fossiliferous micrite are associated in the upper part of graded-bedding calcarenite (Figure 3.33). The lithological boundary between the packed biomicrite and fossiliferous micrite is apparently transitional with progressively decrease in the degree of abundance of calcareous allochems where the calcareous matrix is

Figure 3.31 The exposure of calcirudite in the middle part of the lithofacies V showing the abundance of intraclasts with the size varies from millimetres to decimetres.

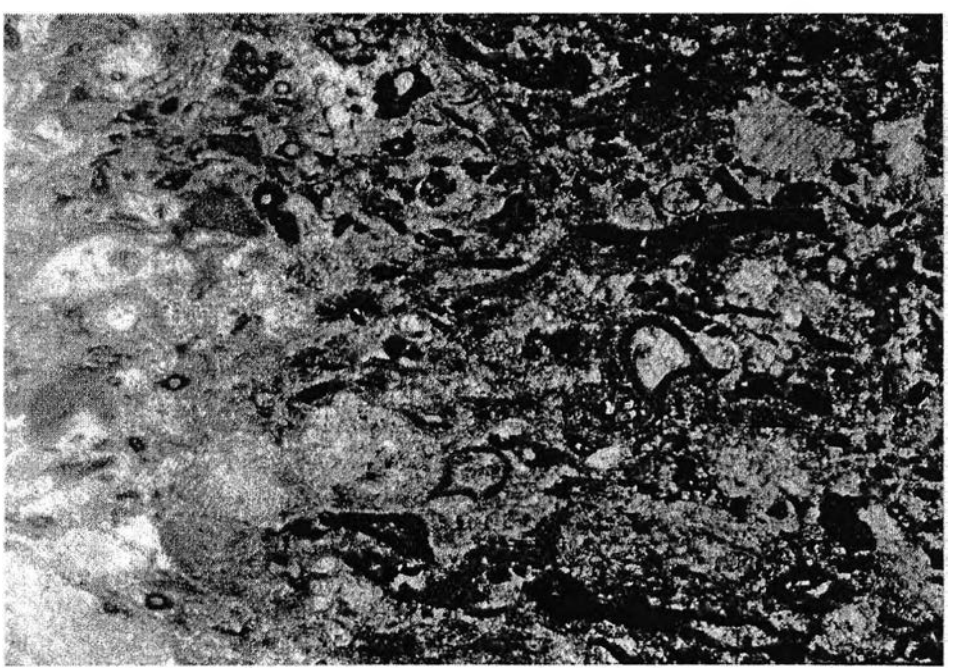

Figure 3.32 The photomicrograph of poorly-washed biosparite of the lithofacies V showing moderately sorted of calcareous skeletons. (Crossed nicols, x44)

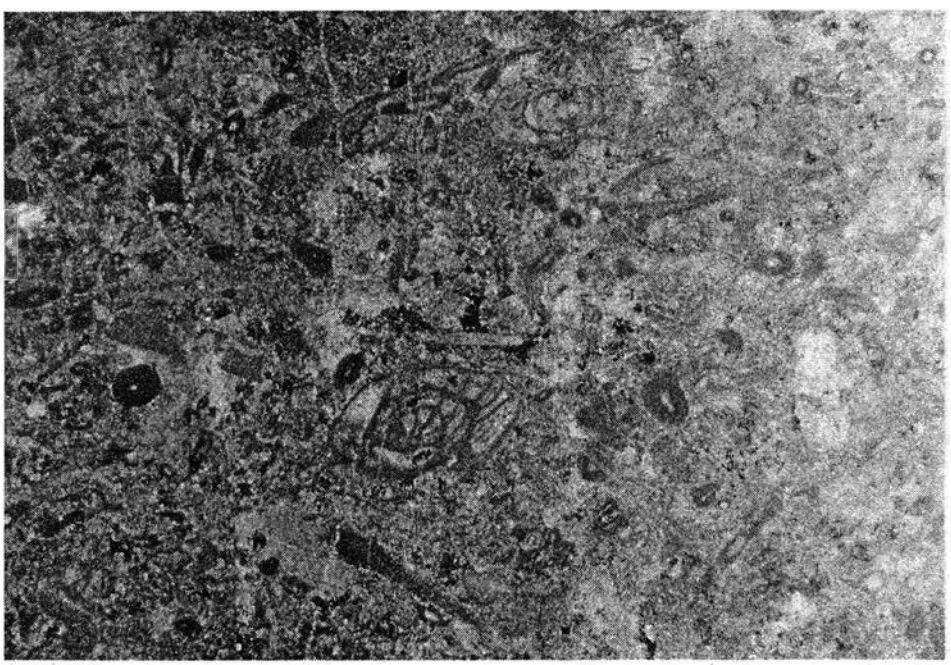

Figure 3.33 The photomicrograph of packed biomicrite of the lithofacies V.

(Crossed nicols, x44)

proportionately increasing. The microcrystalline banded cherts are occasionally associated with packed biomicrite and fossiliferous micrite consisting of fine-grained cherts or microcrystalline cherts replacing throughout the carbonate matrix with sparse carbonate remnants distributed in cherts (Figure 3.34).

Lithofacies VI : Pinkish grey calcarenite

Overlying the graded bedding calcarenite with chert band, or lithofacies V, is the light grey to pinkish grey calcarenite, or lithofacies VI. It is characterised by medium- to thick-bedded of light grey to pinkish grey, moderately sorted, calcarenite to fine calcirudite (Figures 3.35, and 3.36). The skeletal grain components are unidentified skeletal fragments fusuline, crinoidal stems, bryozoa and intraclasts. It is noted that there are thinly-laminated, reddish brown, silt-shale between limestone beds, especially, in the upper part of the unit. The banded argillaceous calcilutite with silt-shale laminated can be distinguished with varying thickness from a few centimetres to a few decimetres. The thickness of this lithofacies varies in the range of 25 to 122 metres. It is well exposed in the measured rock section no.2, and also recognised in measured rock section nos. 4, and 7.

Petrographic studies show that the lithofacies VI is consisting of poorly-washed biosparite and unsorted biosparite. The poorly-washed biosparite is represented by abundant allochems of unidentified skeletal fragments and fragments of fusuline, crinoid, bryozoa, and intraclasts with micrite and cemented by sparry calcite. The unsorted biosparite is consisting of allochems of fusuline, intraclasts, crinoidal fragments, and unidentified skeletal fragments of various size ranging from several microns to few centimetres cemented with ten to hundred microns-size of sparry calcite (Figure 3.37).

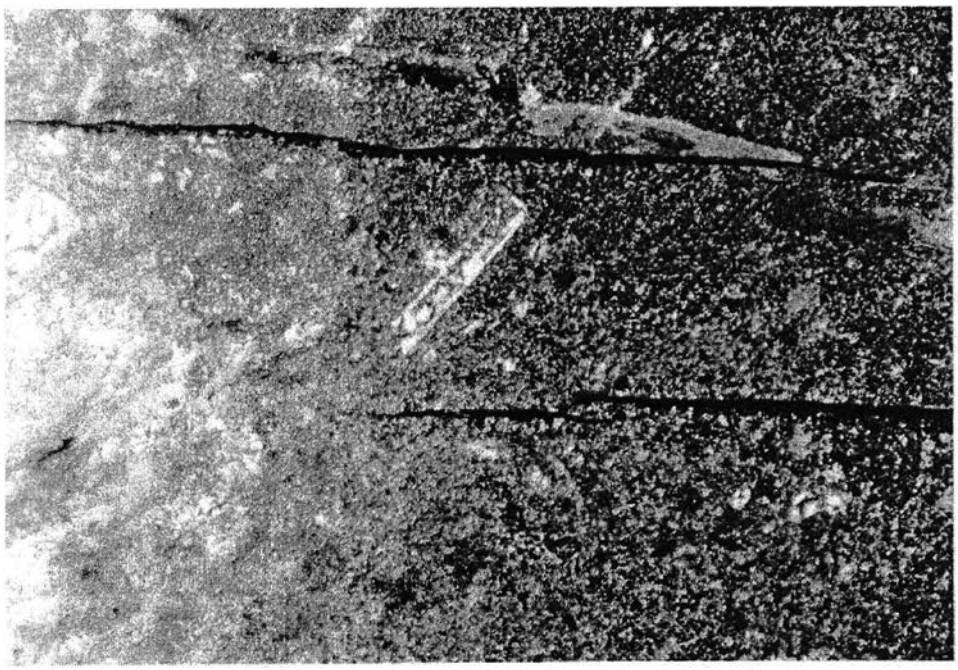

Figure 3.34 The photomicrograph of fossiliferous micrite in the lower part of picture, and microcrystalline chert in the middle and upper parts of picture, of the lithofacies V. (Crossed nicols, x44)

Figure 3.35 The exposure of mediun- to thick-bedded, pinkish grey calcarenite of the lithofacies VI contact with thin-bedded, graded-bedding calcarenite of the lithofacies V.

Figure 3.36 The rock slab of light grey, moderately sorted, slightly metamorphosed calcarenite of the lithofacies VI.

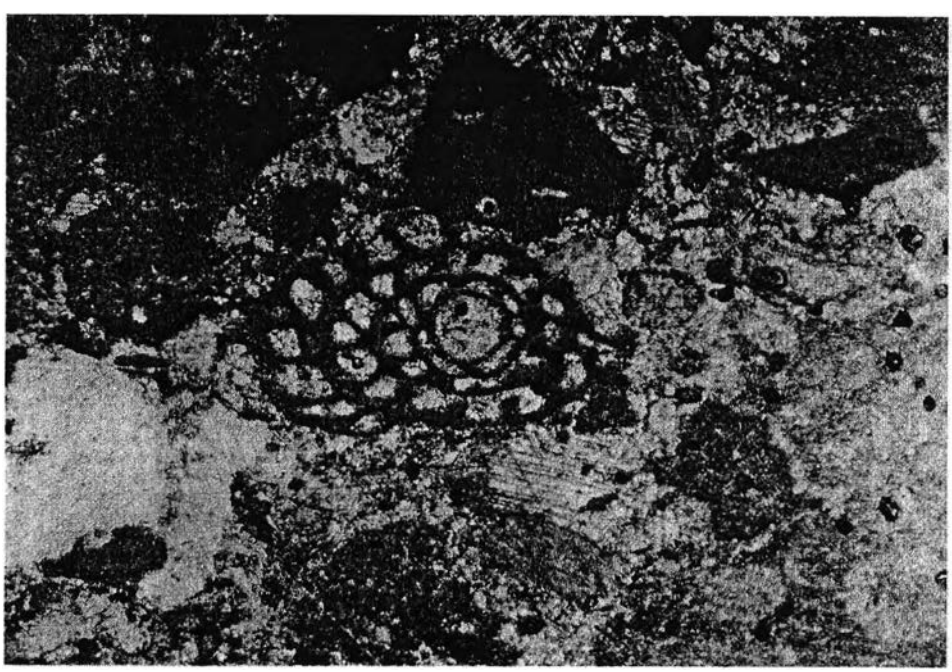

Figure 3.37 The photomicrograph of unsorted biosparite of the lithofacies VI showing the skeletal fragments cemented by sparry calcite. (Crossed nicols, x44)

Lithofacies VII : Calcarenite with chert nodules

The dark grey calcarenite with chert nodules lithofacies overlies the ligh grey to pinkish grey calcarenite of the lithofacies VI. It is characterised by thin- to thick-bedded, dark grey, calcarenite to fine calcirudite, partly calcilutite, with dark grey chert nodules.

They are alternating sequences of thin-bedded and thick-bedded with thinly-laminated of silt-shale between limestone beds. The succession of this lithofacies have been intensively folded so that the various shapes of parasitic folds are usually recognized throughout the sequence (Figure 3.38). Besides, the rock strata are faulted. Therefore, it is difficult to recognise the original stratigraphic seuence of this lithofacies. The nodular cherts are scattered throughout the succession with elongate shape. In addition, the nodular cherts are also associated with some calcitic parts of patchy dolomitic limestone (Figure 3.39). The diameter of chert nodules vary in the range of a few centimetres. Some parts of this lithofacies are patchy dolomitic limestone, mostly, in the middle and upper parts of the lithofacies. The thickness of the lithofacies varies between 267 to 273 metres with the trend to be thickening westwardly.

Petrographic studies of the lithofacies VII show that the lithofacies is consisting of packed intramicrite and biomicrite. The packed intramicrite is composed dominantly of fine-grained carbonate intraclasts more than 50 per cent which derived from adjacent strata and minor skeletal fragments packed with fine grained carbonate matrix (Figure 3.40). The biomicrite is characterised by abundant complete and broken organic skeletons of crinoid ossicles, foraminiferal tests with some intraclasts and detrital quartz (Figure 3.41).

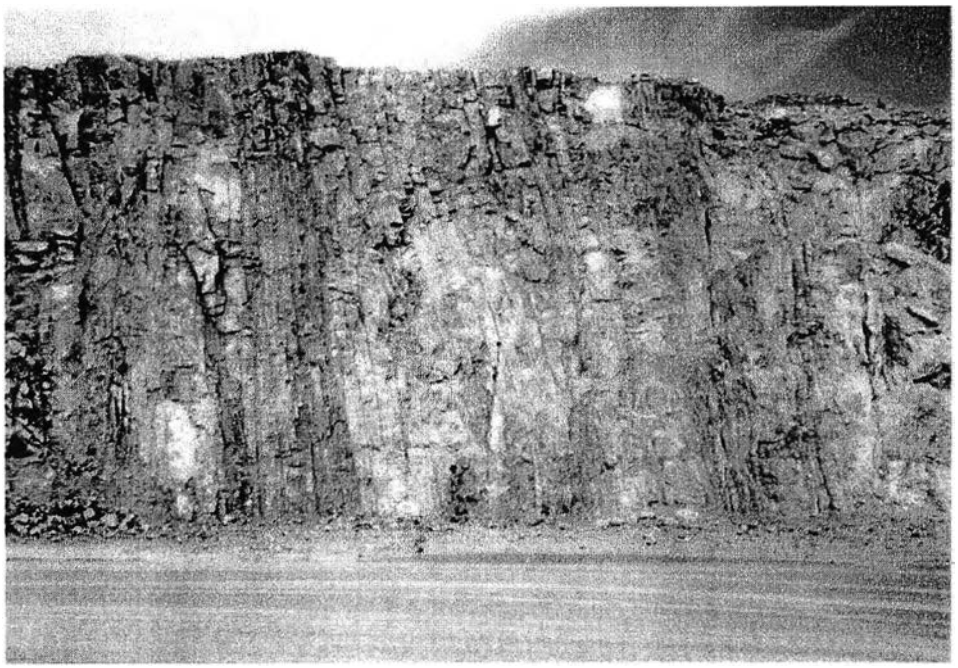

Figure 3.38 The exposure of thin- to medium-bedded, dark grey, calcarenite of the lithofacies VII showing strongly folding.

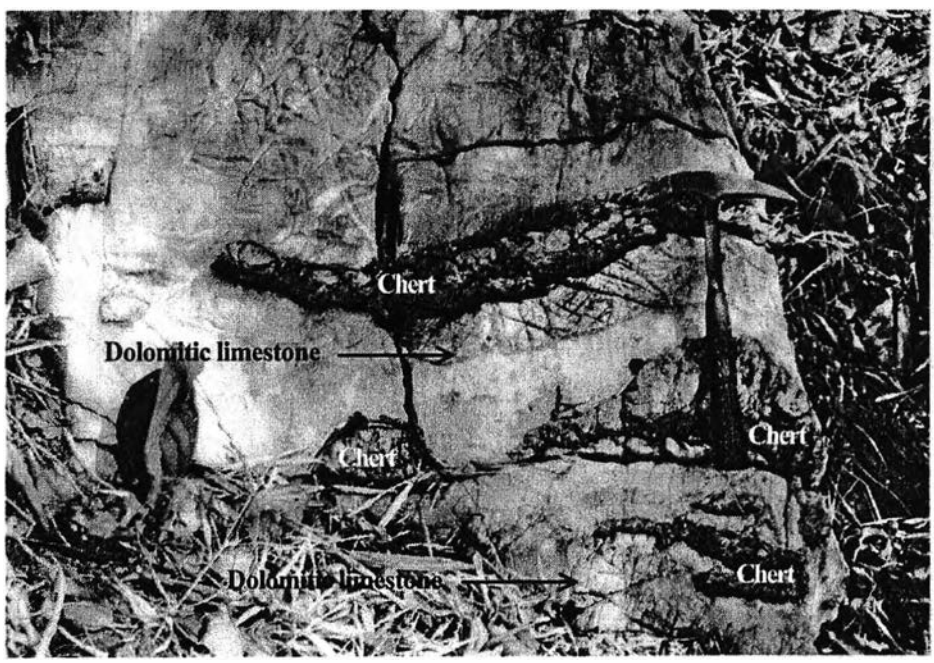

Figure 3.39 The exposure of medium-bedded, dark grey calcarenite of the lithofacies VII showing elongate chert nodules and dolomitic limestone patches embedded in limestone beds.

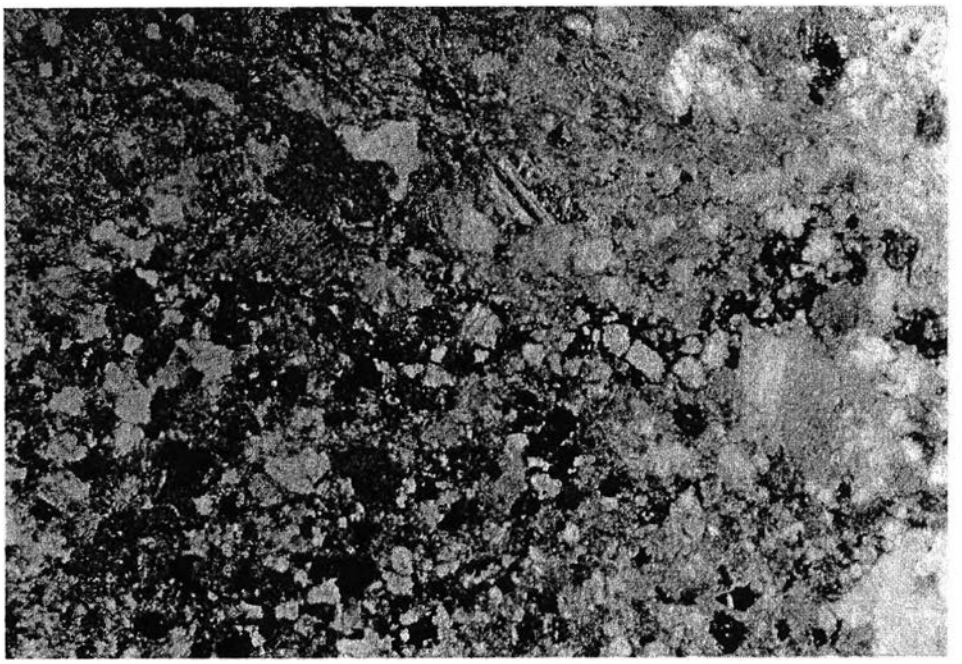

Figure 3.40 The photomicrograph of packed intramicarenite of the lithofacies VII showing more than 50 per cent of sand size intraclasts with fine-grained carbonate matrix. (Crossed nicols, x44)

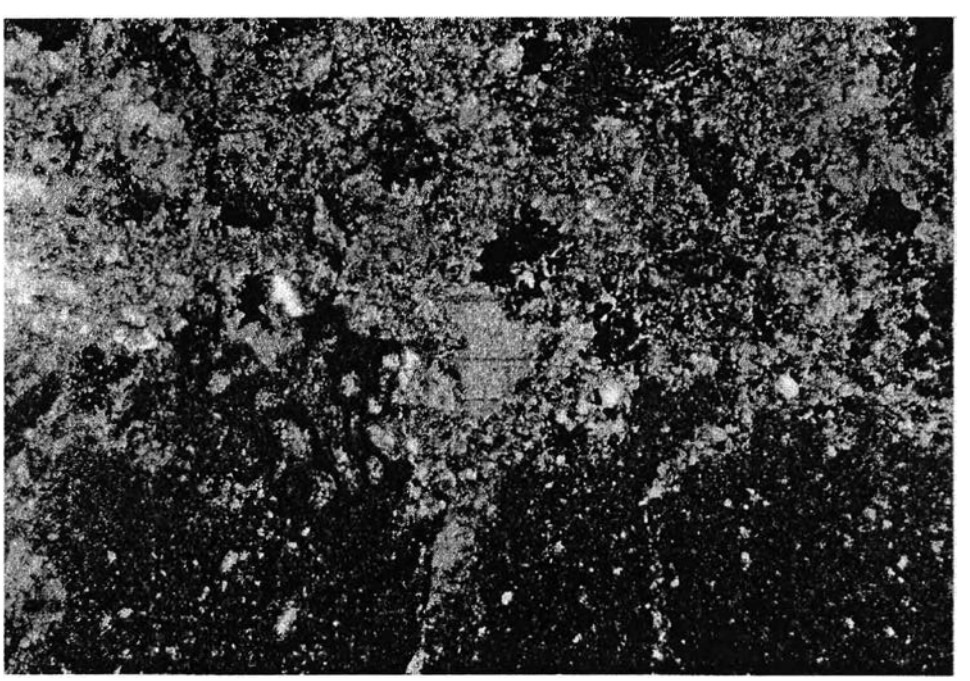

Figure 3.41 The photomicrograph of biomicrite and microcrystalline chert of the lithofacies VII showing some detrital quartz scatter between contact zone. (Crossed nicols, x44)

Lithofacies VIII : Mixed calcarenite and clastic sediments

Conformably overlying the dark grey calcarenite with chert nodules is the grey to dark grey thin-bedded calcarenite in the lower part gradually passing upward into clastic associations of thin-bedded silt-shale, silty sand and porcelanite with very thick-bedded calcirudite in the uppermost part of the unit, or lithofacies VIII (Figures 3.42). The cumulative thickness ratio of carbonates/clastics of this lithofacies is approximately 4:1. It is noted that the uppermost calcirudite of 1 to 2 metres thick is essentially compacted intraclast with size range between 1 to 10 centimetres (Figure 3.43). The overall thickness of this lithofacies varies within the range of 300 to 448 metres.

Petrographic studies of the lithofacies VIII show that the lithofacies is consisting of poorly-washed biosparite, intramicrudite, intramicrite, packed biomicrite, and micrite. The poorly-washed biosparite is characterised by abundant skeletal fragments of foraminifera, crinoid, coral, and unidentified fragments with some intraclasts, detrital quartz, and fine-grained matrix cemented by sparry calcite. The intramirudite is consisting of abundant intraclasts with size varies from few millimetre to few centimetres, mostly, elongate shape, angular to subrounded (Figure 3.44). The foraminiferal tests and crinoidal fragments are also present, embedded in fine-grained matrix. The elongate allochems are oriented subparallel to the bedding plane of calcirudite bed. Intramicrite and packed biomicrite are composed of skeletal fragments, as earlier described in the poorly washed biosparite, embedded in fine grained matrix; wherever the intraclasts are relatively abundant more than 25 per cent, it is called intramicrite (Figure 3.45). Micrite is composed wholly of microcrystalline calcite with size less than four microns and lack of allochems (Figure 3.46). The poorly-washed biosparite, intramicrite, packed biomicrite, and micrite are distributed throughout the lithofacies whereas the intramicrudite is present only in the upper part of the lithofacies. The porcelanite contains abundant sponge spicules of ten to a hundred microns size mixed with fine-grained unidentified impurities (Figure 3.47).

Figure 3.42 The outcrop of thin-bedded, dark grey mixed calcarenite and sandy calcarenite of the lithofacies VIII.

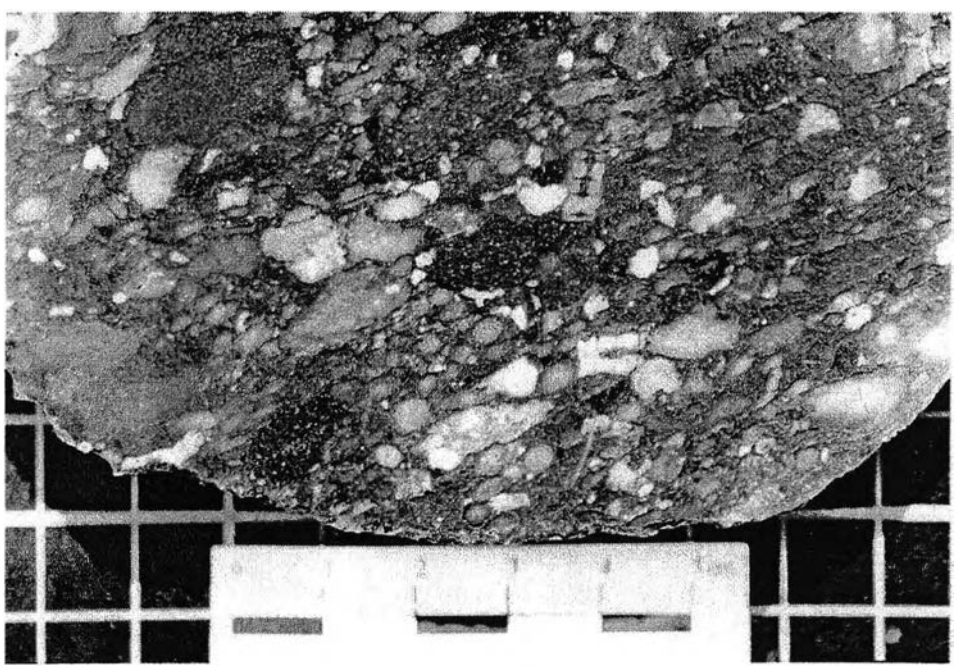

Figure 3.43 The rock slab of calcirudite of the uppermost part of the lithofacies VIII showing abundant intraclasts packed with foraminiferal tests and crinoidal fragments.

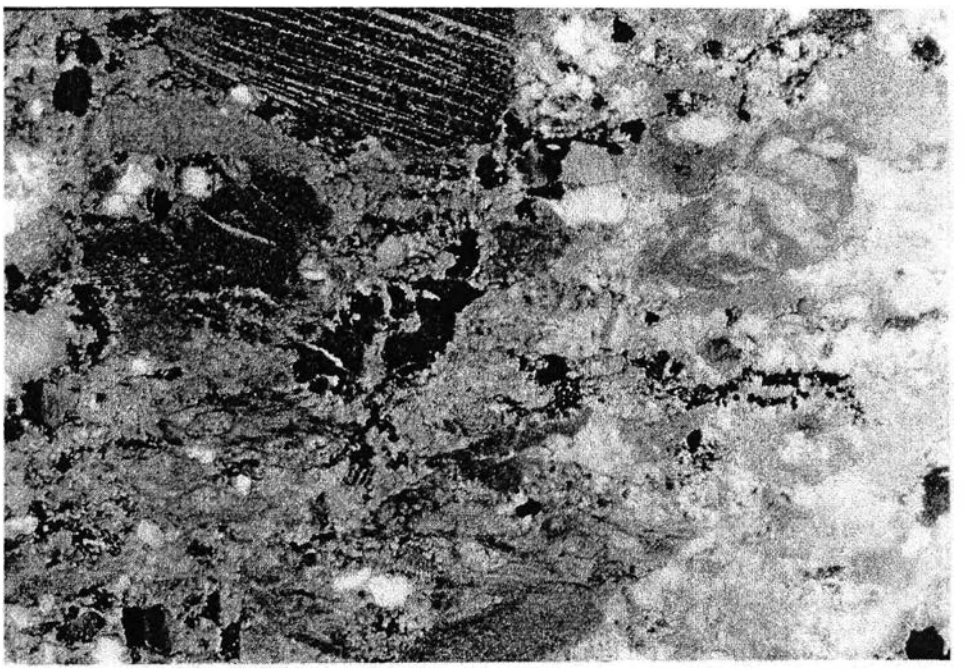

Figure 3.44 The photomicrograph of intramicrite of the lithofacies VIII showing abundant detrital quartzs and intraclasts. (Crossed nicols, x44)

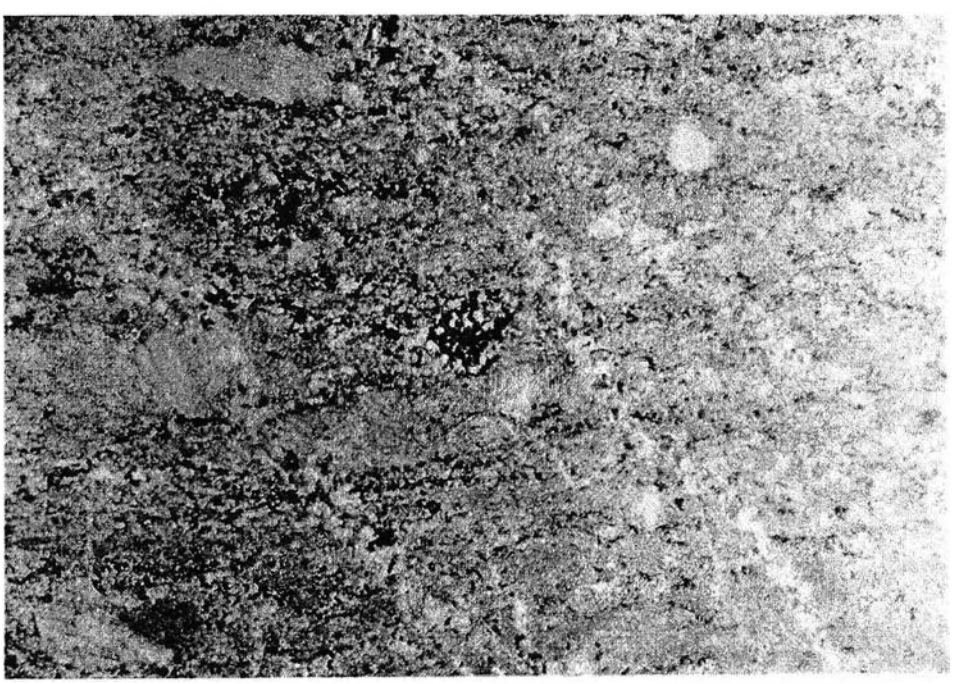

Figure 3.45 The photomicrograph of intramicrite of the lithofacies VIII showing abundant intraclasts with some spot of microcrystalline chert embedded in fine-grained matrix. (Crossed nicols, x44)

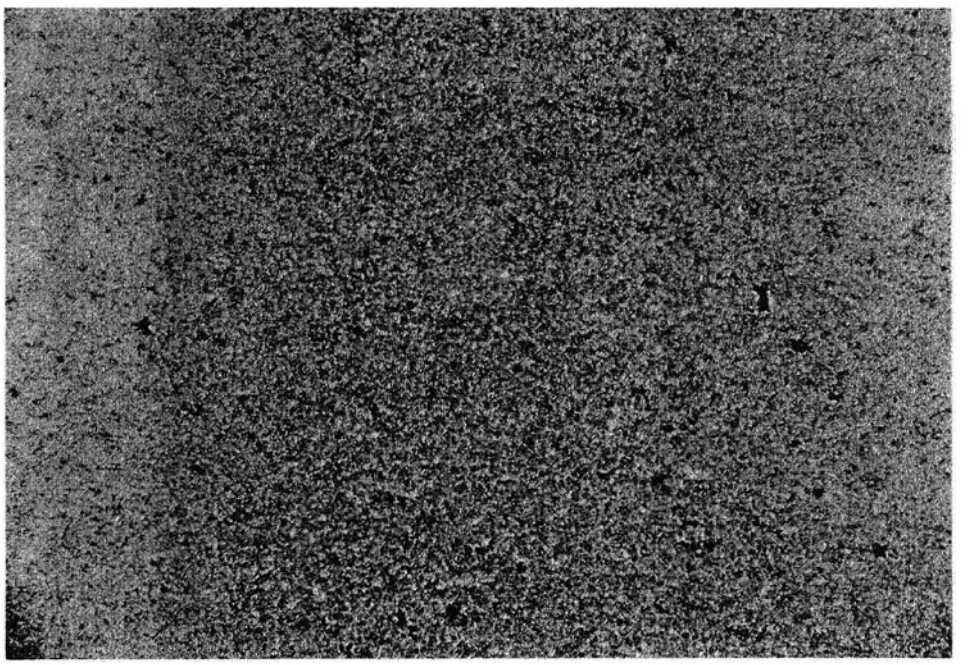

Figure 3.46 The photomicrograph of micrite of the lithofacies VIII showing the lack of allochems. (Crossed nicols, x44)

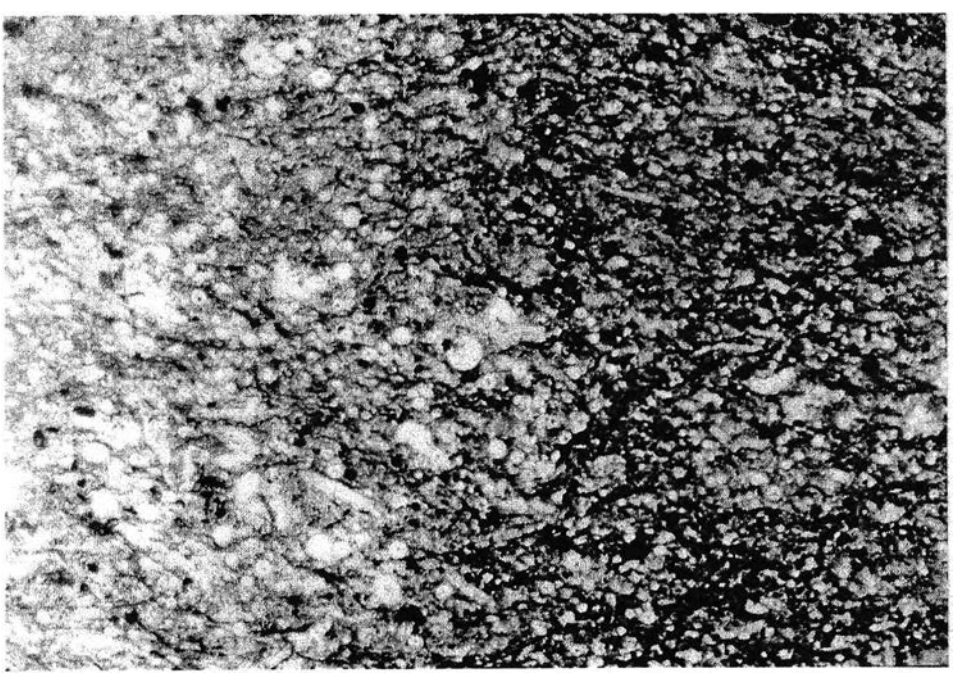

Figure 3.47 The photomicrograph of porcelanite of the lithofacies VIII showing abundant sponge spicules with impurity of fine-grained brownish colour. (Plane polarise light, x44)

Lithofacies IX : Dark grey calcarenite

The uppermost unit of the sedimentary sequence at Khao Chan area is grey to dark grey, thin- to thick-bedded calcarenite, or lithofacies IX (Figure 3.48). This lithofacies exhibits the thinning out toward the east direction. with thickness ranging from 300 to 365 metres. The lithofacies IX marks the termination of Khao Khad Formation in the Khao Chan area with abrupt lithological change upwardly into the fine grains clastic sequence of the Sab Bon Formation. It is represented in the measured rock section nos 1, 4, and 5. The overall lithofacies of the Khao Khad Formation in the Khao Chan area can be best represented in the western part of the area. It can be summarised and graphically presented in Figure 3.15.

Petrographically, the lithofacies is consisting of poorly-washed biosparite, and packed biomicrite. The poorly washed biosparite is characterised by fragments of organic skeletons, such as foraminiferal tests, crinoidal fragments, unidentified skeletal fragments, and bryozoa fragments, with intraclasts, detrital quartz, and micrite remain cemented by sparry calcite of ten to twenty microns sizes. The packed biomicrite is characterised by complete and broken organic skeletons of comparatively large fragments, and inorganic grains of intraclasts embedded in the micrite matrix (Figure 3.49). The organic skeletons of packed biomicrite are, mostly, unidentified skeletal fragments, foraminiferal tests, crinoidal fragments, and bryozoa fragments.

3.3 Facies analysis

In general, numerous parameters characterise depositional environments. These parameters can be recognised through their effect on depositing sediments. The environmental reconstruction is based on a knowledge of environmental processes and their products or facies, which build up the sedimentary sequence. Analogous facies models are used as a basis for understanding of depositional environment.

Figure 3.48 The exposure of grey calcarenite of the lithofacies IX showing inclusion of dark grey calcilutite indicating reverse movement of microfault.

Figure 3.49 The photomicrograph of packed biomicrite of the lithofacies IX showing unidentified skeletal fragments packed with fine-grained matrix.
(Crossed nicols, x44)

The facies models are constructed from real and theoretical studies of both modern environments and the rock records. Therefore, a study of sedimentary facies or facies analysis in the rock records allows some interpretation of the conditions present in ancient depositional settings.

In the present study, an attempt has been made to conduct the facies analysis in order to reconstruct the depositional environment. The factual information of each lithofacies earlier described is served as the background for the interpretation, using depositional model of Reeckman and Friedman (1982), and Wilson (1975).

Lithofacies I : Calcilutite with chert modules

This lithofacies is generally characterised by 251 to 294 metres thick of calcilutite with chert nodules. The facies has a tendency to be thickening westwardly. The lithological characteristics of this lithofacies can be microscopically designated as sparse biomicrite with unbroken shell fragments, algal biomicrite, and packed biomicrudite. The chert nodules are represented by compacted body of chert of varying size and shape regularly disseminated throughout to sequence.

The sedimentary structure of this lithofacies is characterised by wavy laminated and thin-bedded in the lower part gradually passing upward into medium-bedded in the upper part of the sequence.

Interpretation: The presence of abundant micrite with domination and embedded unbroken shell fragments indicate the low energy index of depositional environment under the subtidal or subwavebase zone of restricted marine condition. The presence of chert also indicates the restricted marine environment (Reeckman and Friedman, 1982). It is further suggested that the depositional environment might be the subtidal zone of restricted marine of the inner shelf behind the barrier bar or shoal. The

rather thick sequence of this lithofacies obviously indicates the gentle subsiding depositional environment with the rate of carbonate deposition almost equal to the rate of subsidence.

Lithofacies II : Encrinite

The encrinite lithofacies is generally characterised by 32 to 116 metres thick with a tendency to be thickened westwardly of coarse calcarenite and fine calcirudite. The carbonate grain components are almost entirely fragments of crinoid, particularly crinoid stems and bryozoa. Microscopically, the rock can be designated as unsorted crinoidal biosparudite and crinoidal biosparite. It is noted that very thin bands of greyish black to reddish silt-shale are always present between every encrinite beds.

Interpretation : The bedded clean washed, unsorted biosparudite and biosparite of almost entirely crinoid stem indicate the depositional environment of the slightly subsiding barrier bar or shoal. The rather thick encrinite lithofacies certainly requires carbonate deposition under subsiding condition. The presence of thin bands of silt-shale between encrinite beds indicate the small brake of carbonate deposition with the influx of terrestrial fine-grained clastic sediments.

Lithofacecs III : Calcarenite with chert nodules

The lithofacies is characterised by medium- to thick-bedded calcarenite to fine calcirudite of 57 to 117 metres thick, with the tendency to be thickening westwardly. The sequence is slightly dolomitic in the upperpart, whereas the chert nodules are distributed throughout the sequence. Microscopically, the rock is designated as sorted biosparite and biosparudite with carbonate grain components of crinoid, foraminifera, intraclasts, and bryozoa, respectively in decreasing order of abundance.

Interpretation : There seems to be a certain degree of similarity in lithology between lithofacies II and III with only the differences in the presence of chert nodules and some carbonate grain components, namely, foraminifera and intraclasts. Therefore, it is concluded that the depositional environment of the lithofacies III is the slightly subsiding barrier bar or shoal of the open marine.

Lithofacies IV : Fine calcirudite

The overall lithological characteristics of the lithofacies IV is rather similar to that of lithofacies III with total thickness of 92 to 213 metres. There is also a tendency of this lithofacies to be thickening westwardly. The nature of carbonate rock is classified as both poorly-washed and sorted biosparite/biosparudite with carbonate grain components similar to those of the lithofacies III. It is noted that the whole sequence have been dolomitised in various degrees as revealed from the vertical profile of calcite/dolomite ratio depending upon the grain size characteristics. The bed with relatively finer grain size usually exhibits the higher degree of dolomitsation.

Interpretation : The presence of calcarenite to fine calcirudit indicates the moderately high energy index of depositional environment, and the dolomitisation is most favourable in the intertidal zone and barrier bar or shoal due to the seepage of Mg-rich brine in the lagoonal area towards the barrier bar (Reeckman and Friedman, 1982). Therefore, it is concluded that the fine calcirudite lithofacies were deposited in the barrier bar or shoal of slightly subsiding coastal zone.

Lithofacies V: Graded bedding calearenite with chert banded

The lithofacies is characterised by a sequence of totally 20 to 181 metres thick of cyclic thin-bedded calcarenite/calcilutite interbedding. The bedding characteristics shows the gradual change upwardly from medium-bedded of the underlying lithofacies IV to

thin-bedded of the lithofacies V. The carbonate grain components are mainly fusulines, crinoids, intraclasts and shell fragments, respectively, in decreasing order of abundance. Microscopically the rock is designated as intrasparudite, poorly-washed biosparite, packed biomicrite and fossiliferous micrite with locally dolomitised. It is noted that banded cherts are usually present in limestone beds. In addition, four calcirudite beds with thicknesses vary from 9 to 13 metres have been recognised in the middle part of the sequence, particularly in the western part of the study area. The sedimentary structure of this lithofacies is characterised by normal graded bedding.

Interpretation: The presence of cyclic sequence of calcarenite grading to calcilutite with poorly-washed intrasparudite, poorly-washed biosparite, packed biomicrite and fossiliferous micrite indicates the deposition under the foreslope of barrier bar of the open marine. The four calcirudite beds of thickness between 9 to 13 metres in the sequence suggest the deposition under exceptionally strong energy index of presumably storm conditions in the fore slope of the barrier bar. However, the absence of hummocky cross-bedding structure which is the typical storm deposits in the upper part of each bed might be due to erosional after storm condition or completely destroyed by the carbonate diagenesis.

Lithofacies VI : Pinkish grey calcarenite

The lithofacies VI is characterised by 25 to 122 metres thick of calcarenite to calcirudite with tendency to be thickening westwardly. The lithological characteristics of this lithofacies can be microscopically designated as poorly-washed biosparite and unsorted biosparite with the grain components of foraminifera, crinoidal fragments, bryozoa, unidentified skeletal fragments, and intraclasts, respectively, in decreasing order of abundance.

Interpretation: The presence of calcarenite to calcirudite with poorly-washed biosparite, and unsorted biosparite show the slight fluctuation of the energy index of the depositional environment. Crinoidal fragments are abundant in the barrier and intertidal zone, and the intraclasts are also abundant in subtidal and intertidal zone. Therefore, it is concluded that the lithofacies were deposited under the intertidal zone of the inner shelf behind the barrier bar or shoal.

Lithofacie VII : Calcarenite with chert nodules

Lithofacies VII is characterised by thin- to thick-bedded calcarenite to fine calcirudite of 267 to 273 metres thick. The sequence is alternating of thin-bedded and thick-bedded limestone with thinly lamination of silt-shale in between. The chert nodules are scattered throughout the sequence. Microscopically, they are designated as packed intramicrite, and biomicrite with allochems of intraclasts, crinoidal fragments, foraminifera and detrital quartz, respectively, in decreasing order of abundance.

Interpretation: The distribution of detrital quartz and intraclasts are preferably restricted to the inner shelf especially in the intertidal and subtidal zones near the shoreline. Similarly, the presence of calcarenite and fine calcirudite are also recognised in the intertidal zone of slightly high energy index of depositional environment. On the contrary, the presence of micrite and thinly-lamination of silt-shale indicate slightly low energy index of depositional environment. Thus, it is concluded that the calcarenite with chert nodules lithofacies were deposited in subtidal and intertidal zones of the inner shelf.

Lithofacies VIII : Limestone interbedded with silt-shale

Lithofacies VIII is characterised by 300 to 448 metres thick of a sequence of thin-bedded calcarenite gradually passing upwards into clastic associations of thin-bedded silt-shale and silty sand. It is noted that a very thick-bedded calcirudite has been

recognised in the uppermost part of the sequence. Microscopically, they are designated as poorly-washed biosparite, micrite, intramicrite, packed biomicrite, and intramicrudite with allochems of foraminifers, intraclasts, crinoidal fragments, detrital quartz and coral fragments respectively in decreasing order of abundance.

Interpretation : There seems to be a certain degree of gradually passing upward sequence from lithofacies VII to lithofacies VIII because of the increasing of the proportion of clastic rocks in the sequence. Therefore, the depositional environment of this lithofacies should be intertidal and subtidal zones of the inner shelf. Because of the gradually increasing of clastic sediments, detrital quartz, intraclasts and micrite in the upper part of the sequence; it is therefore concluded that the depth of the depositional basin was decreasing. This might be due to either the marine regression or the rate of depositional was greater than the rate of subsidence.

Lithofacies IX : Dark gray calcarenite

Lithofacies IX is characterised by thin-to thick-bedded of calcarenite with the total thicken of 300 to 365 metres. It is consisting of poorly-washed biosparite and packed biomicrite with allochems of foraminifera, crinoidal fragments, bryozoas, intraclasts, and detrital quartz, respectively in decreasing order of abundance. It is noted that the cross-lamination has been recognised in the lower part of the sequence, and the uppermost part of the sequence is gradually change from calcarenite to clastic sequence of silt-shale.

Interpretation : The presence of calcarenite indicates slightly high energy index of depositional environment. But the presence of micrite in poorly-washed biosparite and packed biomicrite indicate that the energy index is relatively not high enough to remove all of the carbonate mud matrix. In addition, the cross-lamination is most favourable formed in the intertidal zone of restricted inner shelf. Therefore, it is

concluded that the dark grey calcarenite lithofaces were deposited in the intertidal and subtidal zone of restricted inner shelf.

3.4 Reconstruction of depositional environment

From the analysis of altogether nine lithofacies of eleven measured rock sections earlier described, it can be generally concluded that the carbonate/clastic sedimentary sequences of the Khao Khad Formation at Khao Chan area of totally 1,285 to 1,857 metres were deposited under the restricted marine or inner shelf, barrier bar and foreslope environment. The information regarding various aspects of all lithofacies as well as the depositional facies interpretation are summarised and present in Table 3.1.

Under the present study, the recognition of various depositional environments is based upon six criteria, namely, texture, mineral composition, grain component, sedimentary structure, fossil content, and geometry. Upon the characterisation of these criteria of each lithofacies, the comparison is being made with the mixed corbonate/clastic deposetional model of Reeckmann and Friedman (1982). The characteristics of depositional environment including the facies analysis of the present study are summarised in Figure 3.50.

It is noted that almost all of the lithofacies have the tendency to be thinning eastwardly. Beside, the sedimentary succession in the western part of the study area is generally characterised by relatively thick carbonate sediments of carbonate shelf facies. The presence of relatively abundant of terrigeneous clastic sediments are apparent eastwardly. Therefore, it is believed that the continental land-mass during the time of deposition was presumably located in the east direction of the depositional basin. Furthermore, the relatively thick sedimentary sequences of the Khao Khad Formation at Khao Chan area of approximately 1,285 to 1,857 metres must be deposited under the

Table 3.1 The lithofacies characteristics and depositional environment.

Lithofacies	Thickness (metres)	Lithological characteristics	Depositional environment
Lithofacies IX Dark grey calcarenite	300 - 365 (thinning eastwardly)	Grey to dark grey, thin to thick-bedded, cross-lamination in the lower part, poorly-washed biosparite, and packed biomicrite with allochems of foraminifera, crinoidal fragment, bryozoa, intraclast, and detrital quartz.	Intertidal and subtidal zone of restricted inner shelf.
Lithofacies VIII Limestone interbedded with silt-shale	300 - 448	Grey to dark grey, thin-bedded poorly- washed biosparite, intramicrudite, intramicrite, packed biomicrite and micrite with allochems of foraminifera, crinoidal fragment, coral fragment, intraclast, and detrital quartz associated with yellowish brown to reddish brown, thin-bedded silt-shale and silty sand.	Intertidal and sudtidal zone of inner shelf.
Lithofacies VII Calcarenite with chert nodules	267 – 273	Dark grey, thin- and thick-bedded packed intramicrite, and biomicrite with allochems of intraclast, crinoidal fragment, foraminifera, and detrital quartz, some elongated chert nodules, dolomite patches, and laminated silt-shale.	Subtidal and intertidal zone of inner shelf.
Lithofacies VI Pinkish grey calcarenite	25 – 122 (thinning eastwardly)	Light grey to pinkish grey, medium- to thick-bedded poorly-washed biosparite and unsorted biosparite, with allochems of unidentified skeletal fragment, foraminifera, crinoidal fragment, bryozoa, and intraclast.	Intertidal zone of barrier or shoal.
Lithofacies V Graded bedding calcarenite with chert banded	20 – 181 (thinning eastwardly)	Grey to dark grey, thin–bedded, graded bedding poorly-washed intrasparudite, poorly-washed biosparite, packed biomicrite, and fossiliferous micrite with allochems of crinoidal fragment, foraminifera, intraclast, and shell fragment, and abundant reddish brown, thinly-laminated to thin-bedded fissile silt-shale between limestone beds.	Subtidal zone of outer barrier or foreslope.
Lithofacies IV Fine calcirudite	92 - 213 (thinning eastwardly)	Light grey, medium- to thick-bedded sorted biosparite and biosparudite with allochems of crinoidal fragment, foraminifera, and intraclast, slightly dolomitic.	Barrier or shoal.
Lithofacies III Calcarenite with chert nodules	57 – 117 (thinning eastwardly)	Grey to dark grey, medium-bedded sorted biosparite and biosparudite with allochems of crinoid stem, foraminifera, intraclast, and bryozoa, some dark grey chert nodule.	Barrier bar or shoal.
Lithofacies II Encrinite	32 – 116 (thinning eastwardly)	Grey to light grey, medium- to thick-bedded unsorted crinoidal biosparudite and crinoidal biosparite with abundant of crinoidal fragment and common of bryozoa fragment.	Barrier bar or shoal.
Lithofacies I Calcilutite with chert nodules	251 - 294 (thinning eastwardly)	Dark grey, thin- to medium-bedded sparse biomicrite, algal biomicrite, and packed biomicrudite with allochems of shell fragment, foraminifera, algal fragment, intraclast and bryozoa, some dark grey chert nodule.	Subtidal zone of restricted marine of inner shelf.

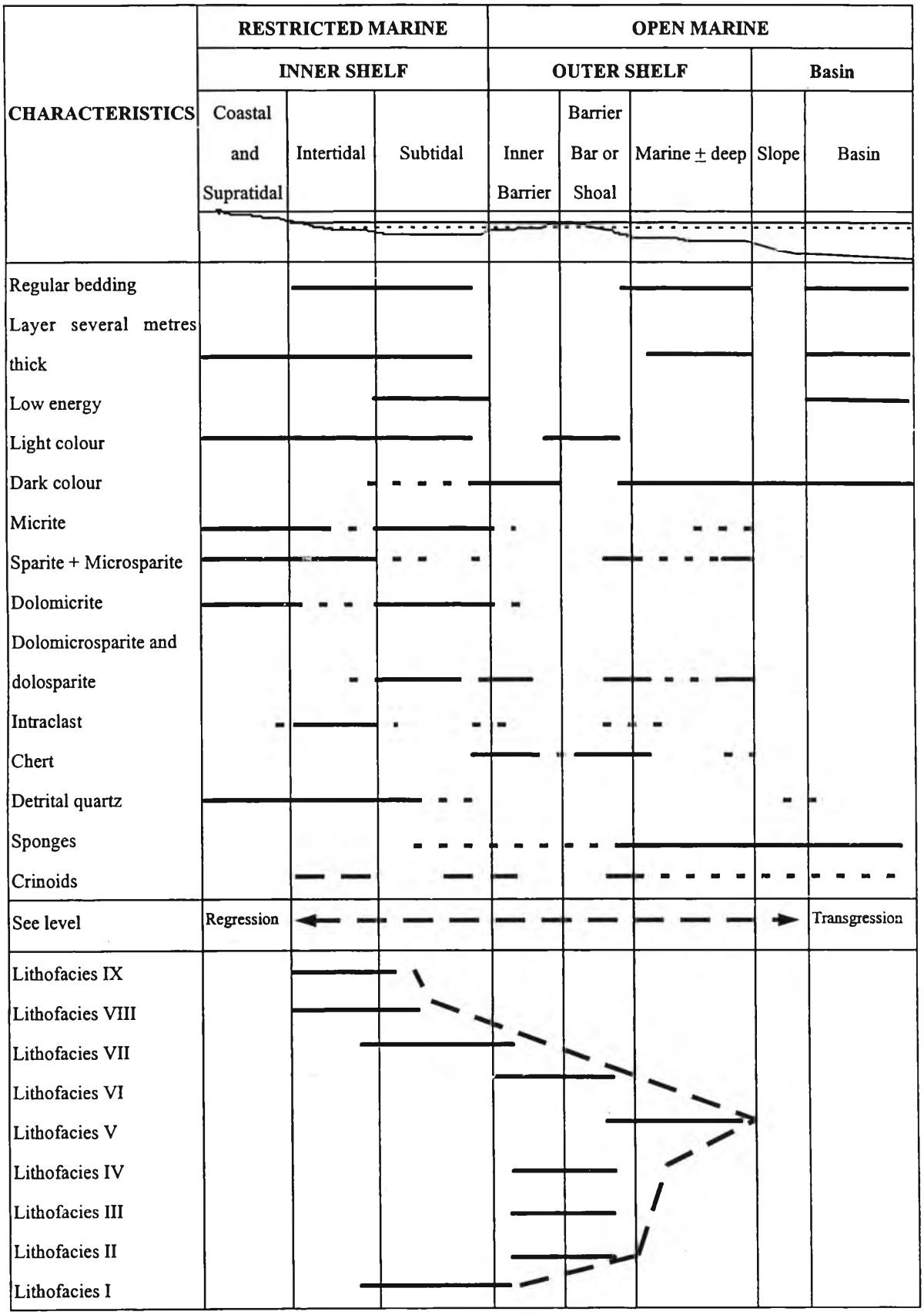

Figure 3.50 The characteristics of depositional environment and the facies analysis of the present study

gentle subsiding restricted marine or inner shelf basin over a relatively long period of time during the Permian age.

The reasoning of epeirogenic subsidence of the Permian nearshore depositional environment of the Khao Khad Formation is that the overall thickness nearshore sedimentary facies is much greater than the depth of depositional basin. Therefore, in order to acquire the approximately 1,285 to 1,857 metres thick of nearshore carbonate/clastic sediments, it is anticipated the depositional basin must be slowly subsiding during the time of sedimentation.

The lower boundary of the Khao Khad Formation in Khao Chan area, lithofacies I, is marked by the presence of abundant index fossil of Robustoschwagerina *sp.* indicating the Asselian age of Lower Permian (Loeblich and Tappan, 1988) as shown in Figure 3.51. Whereas the overlying of the Khao Khad Formation at Khao Chan area, Sab Bon Formation, is marked by the presence of Agatheceras *sp.* indicating the Kungurian-Kazanian age of Middle Permian (Hinthong, 1985).

Therefore, it is estimated that the rate of deposition was approximately 7 centimetres per a thousand years, regardless of the compacting factor, whereas the rate of deposition in bays and lagoons are in range from few millimetres to a hundred centimetres per a thousand years (Kukal, 1971).

The schematic block diagram representing the depositional model of the Khad Formation at Khao Chan Area is constructed as shown in Figure 3.52.

3.5 Proposed lithostratigraphy of Khao Chan area

Under the present study, lithostratigraphic units are bodies of sedimentary rock distinguished on the basis of lithological characteristics and they are generally conform

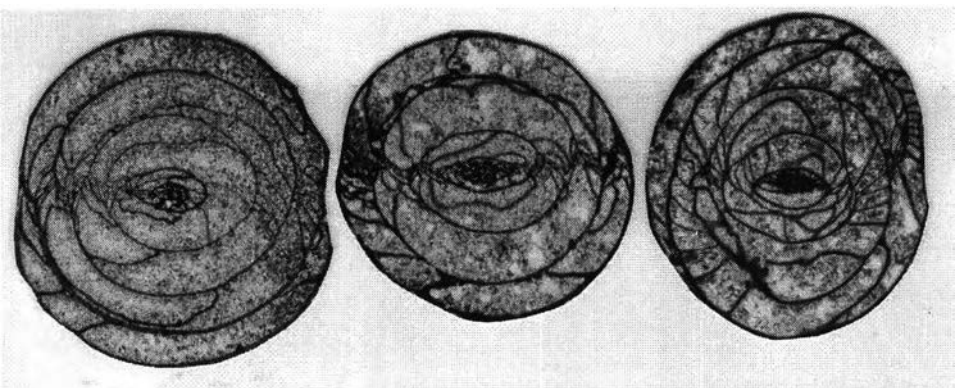

Figure 3.51 The Photomicrograph of index fossil of Robustoschwagerina *sp.*, indicating the Asselian age of Lower Permian (Loeblich and Tappan, 1988). (x7.5)

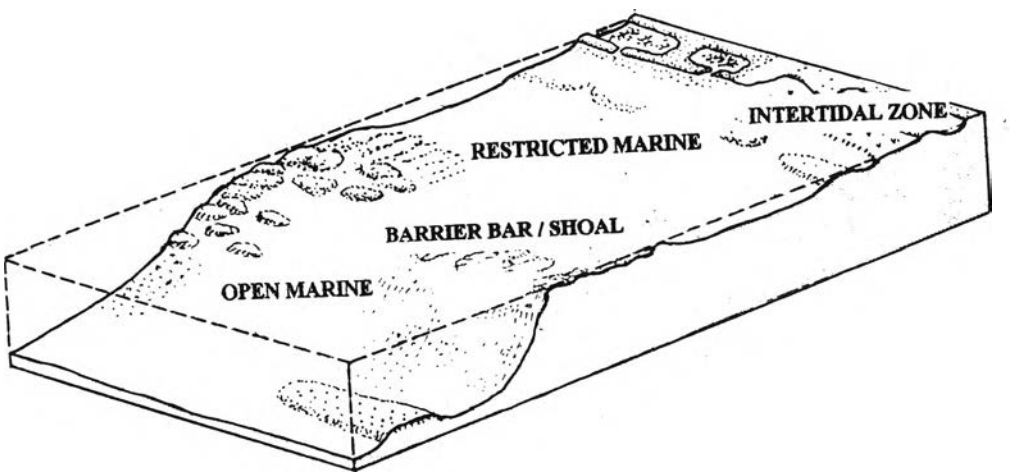

Figure 3.52 The schematic block diagram representing the depositional model of the Khad Formation at Khao Chan Area.

to the law of superposition. The stratigraphic unit of a single lithology rarely exist as isolated bodies but are commonly in contact with other rock bodies of different lithology either vertically and/or laterally. These contacts are formed between rock units that developed difference lithologies owing to difference conditions in the depositional environment (Figure 3.53).

Considering the detailed characteristics of nine lithofacies of the Khao Khad Formation at Khao Chan area, it is earlier concluded that they were deposited under seven depositional environments with distinctive depositional facies. It is against thisbackground of facies analysis, the seven lithostratigraphic units have been accordingly proposed. These seven lithostratigraphic units are informal members of the Khao Khad Formation at Khao Chan area. They are KC1 member, KC2 member, KC3 member, KC4 member, KC5 member, KC6 member, and KC7 member, respectively in ascending order.

KC1 member is designated from the lithofacies I consisting of dark grey, thin- to medium-bedded sparse biomicrite, algal biomicrite, and packed biomicrudite with allochems of shell fragment, foraminifera, algal fragment, intraclast and bryozoa, some dark grey chert nodule. They are deposited in subtidal zone of restricted marine of inner shelf with the thickness varies from 251 to 294 metres, thinning eastwardly.

KC2 member is designated from the lithofacies II, III and IV consisting of light grey to dark grey, medium-bedded sorted biosparite, crinoidal biosparite, and unsorted biosparudite with allochems of crinoid stem, foraminefera, intraclast, and bryozoa, some dark grey chert nodule and slightly dolomitic. They are deposited in zone of barrier bar or shoal with the thickness varies from 181 to 446 metres, thinning eastwardly.

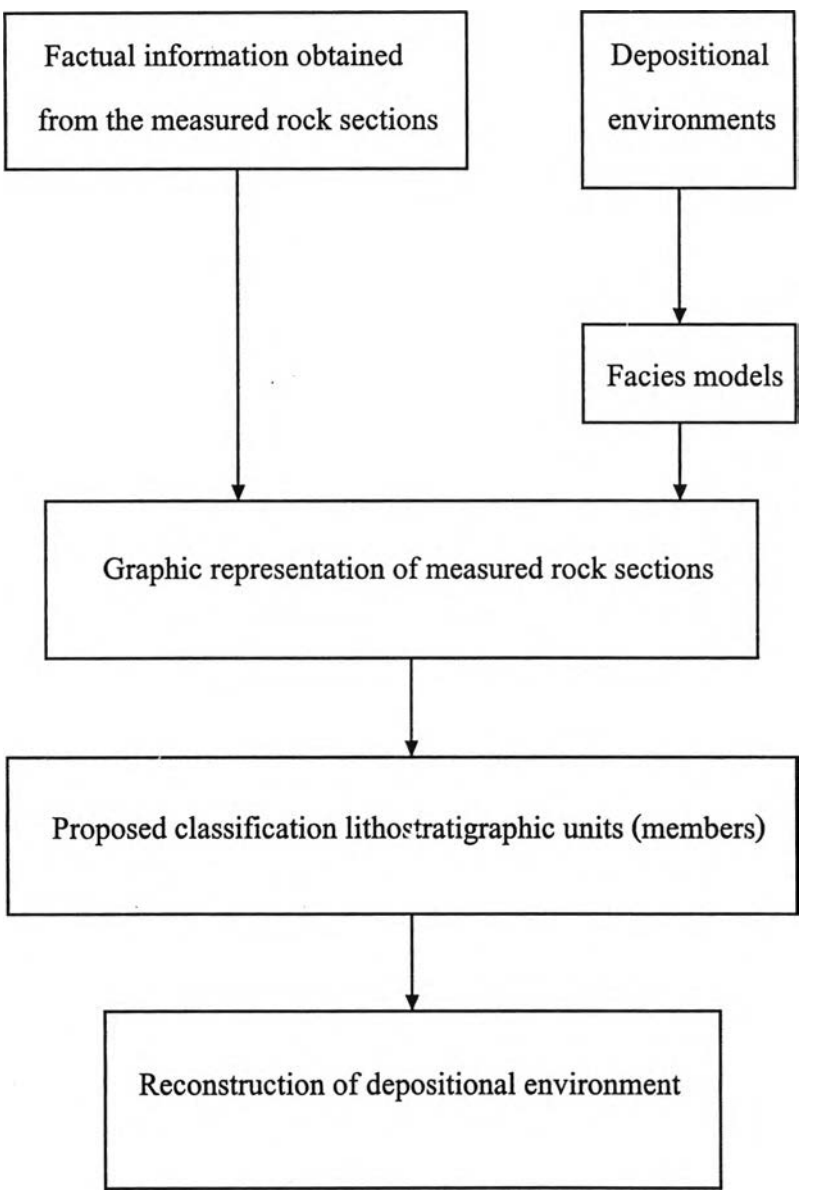

Figure 3.53 The conceptual diagramme illustrating the basis of proposed lithostratigraphy

KC3 member is designated from the lithofacies V consisting of grey to dark grey, thin–bedded, graded bedding poorly-washed intrasparudite, poorly-washed biosparite, packed biomicrite, and fossiliferous micrite with allochems of crinoidal fragment, foraminifera, intraclast, and shell fragment, and abundant reddish brown, thinly-laminated to thin-bedded fissile silt-shale between limestone beds. They are deposited in subtidal zone of outer barrier or foreslope with the thickness varies from 20 to 181 metres, thinning eastwardly.

KC4 member is designated from the lithofacies VI consisting of light grey to pinkish grey, medium- to thick-bedded poorly-washed biosparite and unsorted biosparite, with allochems of unidentified skeletal fragment, foraminifera, crinoidal fragment, bryozoa and intraclast. They are deposited in intertidal zone of barrier or shoal with the thickness varies from 25 to 122 metres, thinning eastwardly.

KC5 member is designated from the lithofacies VII consisting of dark grey, thin- and thick-bedded packed intramicrite, and biomicrite with allochems of intraclast, crinoidal fragment, foraminifera, and detrital quartz, some elongated chert nodules, dolomite patches, and laminated silt-shale. They are deposited in subtidal and intertidal zone of inner shelf with the thickness varies from 267 to 273 metres, thinning eastwardly.

KC6 member is designated from the lithofacies VIII consisting of grey to dark grey, thin-bedded poorly- washed biosparite, intramicrudite, intramicrite, packed biomicrite and micrite with allochems of foraminifera, crinoidal fragment, coral fragment, intraclast, and detrital quartz associated with yellowish brown to reddish brown, thin-bedded silt-shale and silty sand. They are deposited in intertidal and sudtidal zone of inner shelf with the thickness varies from 300 to 448 metres.

KC7 member is designated from the lithofacies IX consisting of grey to dark grey, thin to thick-bedded, cross-lamination in the lower part, poorly-washed biosparite,

and packed biomicrite with allochems of foraminifera, crinoidal fragment, bryozoa, intraclast, and detrital quartz. They are deposited in intertidal and subtidal zone of restricted inner shelf with the thickness varies from 300 to 365 metres, thinning eastwardly.

Detailed of the proposed stratigraphic unit are summarised in Table 3.2. In addition the geological map of the area under the present study illustrating the areal distribution of this stratigraphic units are shown in Figure 3.54.

3.6 Comparison of the Khao Khad Formation at the type locality with that of the Khao Chan area

In order to compare the lithostratigraphy of the Khao Khad Formation at the type locality with that of the Khao Chan area under the present study, several similarities of lithological characteristics of each member with difference in thickness are considered. It is apparent that the sedimentary sequences of both locations are quite similar in the lower and middle parts. However, the KC7 member is absent in the upper part of the type location. The detailed comparison are described in ascending order as follows :

Refer to the Khao Khad Formation earlier proposed by Hinthong (1985) where the type section is located at Khao Khad, Amphoe Phra Phuttabat, Changwat Saraburi with the total thickness of 1,812 metres.

In the lower part, the lithology of the lowest unit, unit 1, is characterised by limestone and chert, grey to dark grey, well bedded, mostly thick-bedded, thin-bedded chert and nodular chert, with allochems of fusuline, brachiopods and gastopods, can be correlated with the KC1 member. However, the thickness of both location are quite difference with the thickness at the type location of 58.5 metres, whereas the thickness at the Khao Chan area varies from 251 to 294 metres.

Table 3.2 The proposed stratigraphy of the Khao Khad Formation at Khao Chan area.

Lithostratigraphic units	Thickness (metres)	Lithological characteristics	Depositional environment
KC7 member	300 - 365 (thinning eastwardly)	Grey to dark grey, thin to thick-bedded, cross-lamination in the lower part, poorly-washed biosparite, and packed biomicrite with allochems of foraminifera, crinoidal fragment, bryozoa, intraclast, and detrital quartz.	Intertidal and subtidal zone of restricted inner shelf.
KC6 member	300 - 448	Grey to dark grey, thin-bedded poorly- washed biosparite, intramicrudite, intramicrite, packed biomicrite and micrite with allochems of foraminifera, crinoidal fragment, coral fragment, intraclast, and detrital quartz associated with yellowish brown to reddish brown, thin-bedded silt-shale and silty sand.	Intertidal and sudtidal zone of inner shelf.
KC5 member	267 - 273 (thinning eastwardly)	Dark grey, thin- and thick-bedded packed intramicrite, and biomicrite with allochems of intraclast, crinoidal fragment, foraminifera, and detrital quartz, some elongated chert nodules, dolomite patches, and laminated silt-shale.	Subtidal and intertidal zone of inner shelf.
KC4 member	25 – 122 (thinning eastwardly)	Light grey to pinkish grey, medium- to thick-bedded poorly-washed biosparite and unsorted biosparite, with allochems of unidentified skeletal fragment, foraminifera, crinoidal fragment, bryozoa, and intraclast.	Intertidal zone of barrier or shoal.
KC3 member	20 – 181 (thinning eastwardly)	Grey to dark grey, thin–bedded, graded bedding poorly-washed intrasparudite, poorly-washed biosparite, packed biomicrite, and fossiliferous micrite with allochems of crinoidal fragment, foraminifera, intraclast, and shell fragment, and abundant reddish brown, thinly-laminated to thin-bedded fissile silt-shale between limestone beds.	Subtidal zone of outer barrier or foreslope.
KC2 member	181 – 446 (thinning eastwardly)	Light grey to dark grey, medium-bedded sorted biosparite, crinoidal biosparite, and unsorted biosparudite with allochems of crinoid stem, foraminefera, intraclast, and bryozoa, some dark grey chert nodule and slightly dolomitic.	Barrier bar or shoal.
KC1 member	251 - 294 (thinning eastwardly)	Dark grey, thin- to medium-bedded sparse biomicrite, algal biomicrite, and packed biomicrudite with allochems of shell fragment, foraminifera, algal fragment, intraclast and bryozoa, some dark grey chert nodule.	Subtidal zone of restricted marine of inner shelf.

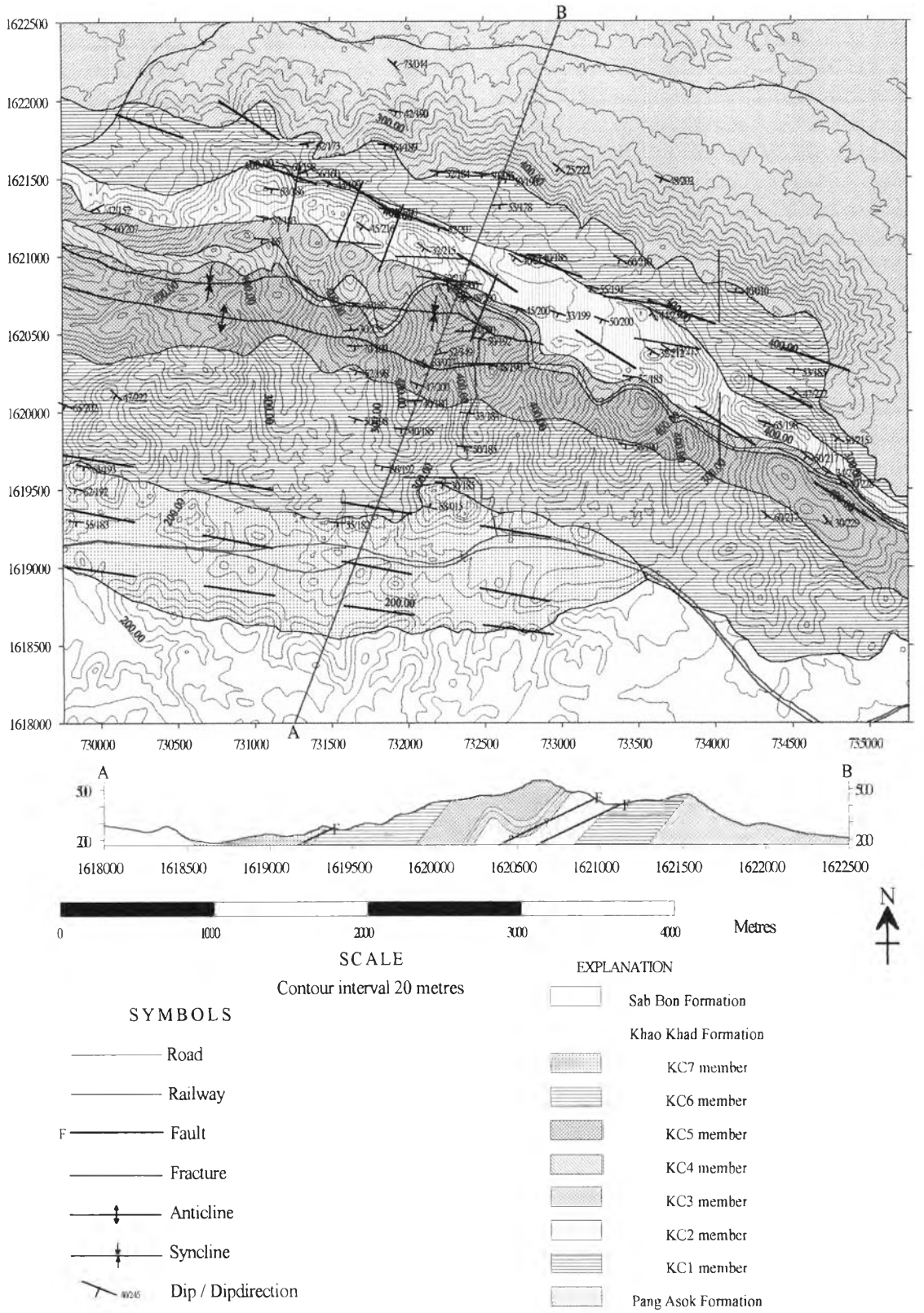

Figure 3.54 The geological map of Khao Chan area illustrating the areal distribution of different lithostratigraphic units.

The sedimentary sequence overlying the lowermost unit is unit 2, limestone, white to very light grey, very thick-bedded, with allochems of gastopods and corals; with no exposure of 50 metres thick. The unit 3 is limestone, grey to dark grey, mostly fine-grained, thick- to very thick-bedded, fossiliferous, fusulines, grading to crystalline with plenty of nodular chert, corals. The unit 4 is limestone, grey to dark grey, mostly grey, fine-grained, well bedded, nodular cherts parallel with bedding plane, medium- to thick-bedded, with allochems of fusulines and some corals. The units 2, 3 and 4 can be correlated with the KC2 member. Besides, the thickness of both location are quite different that the thicknesses of units 2, 3, and 4 at the type location are 80, 268, and 300 metres, respectively, whereas the thicknesses of KC2 member or lithofacies 2, 3, and 4 at the Khao Chan area vary from 32 to 116, 57 to 117 and 92 to 213 metres, respectively.

In the middle part, the unit 5 is bedded chert intercalated with limestone, gray to dark gray, thin-bedded, with fusulines. The overlying unit, unit 6 is limestone, light grey to black, crystalline, calcite veins, thick-bedded. The unit 7 is limestone interbedded with chert, light grey to dark grey, well laminated, medium- to thick-bedded with bedded chert in upper part. The units 5, 6, and 7 can be correlated with the KC3, KC4 and KC5 members, respectively. The thickness of both location are different that the thicknesses of unit 5, 6, and 7 at the type location are 82.5, 534.5, and 215 metres, respectively, whereas the thicknesses at the Khao Chan vary from 20 to 81, 25 to 122 and 267 to 273 metres, respectively.

In the upper part, the unit 8 is limestone interbedded with chert and intercalated with siltstone, shale, and sandstone; limestone, light grey to dark grey, thin- to medium-bedded; chert and shale, pale brown, yellowish-brown, thin-bedded. The unit 8 can be correlated with the KC6 member. The thickness of both location are different that the thickness at the type location is 213.5 metres, whereas the thickness at the Khao Chan area varies from 300 to 448 metres. It is noted that the KC7 member is absent in the upper part of the type location.

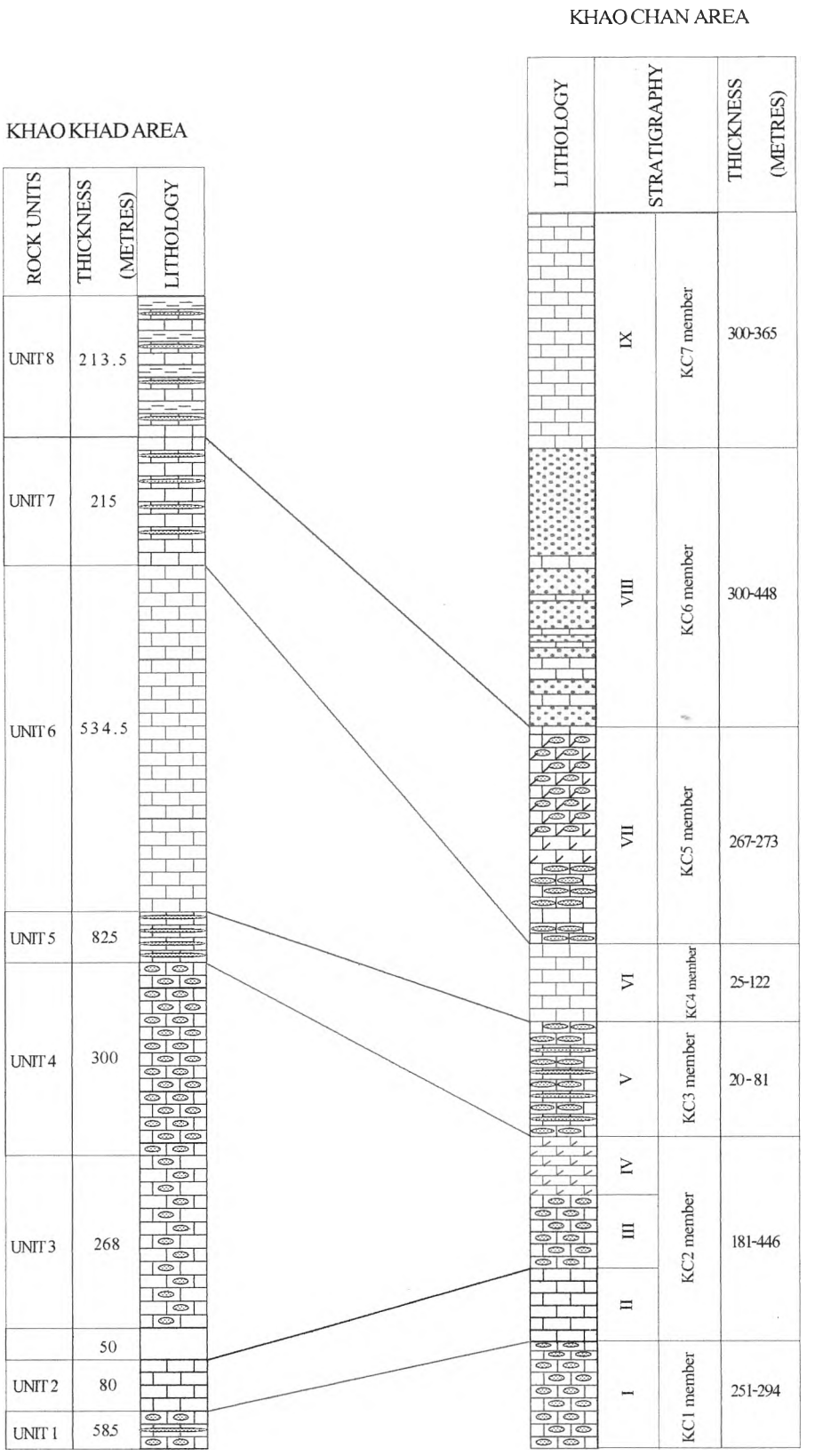

Figure 3.55 The correlation chart of the Khao Khad Formation at the type locality and at the Khao Chan area