

CHAPTER VIII

CONCLUSIONS

It is apparent from this study that the sedimentary sequences of the Khao Khad Formation in Changwat Saraburi are different in their lithological characteristics in the Khao Khad, Khao Chan and Pak Chong to Khao Yai areas. Within those sequences nodular cherts are commonly associated with limestone beds. Silty shales are frequently interbedded between limestone beds and more abundant toward the upper part of the sequences. In the middle part, however, the limestone was slightly thermally metamorphosed and volcanic rocks are also present as small dikes and sills. The age of the Khao Khad Formation can be marked at the lower part of the succession by the abundant presence of *Robustoschwagerina* sp. indicating the Asselian age of Lower Permian (Borax and Stewart, 1966; Thambunya, 1999; Tittirananda, 1976), and at the upper boundary it is marked by the presence of *Yabeina* sp. in limestone associate with silty shale in the upper part indicating the Capitanian age of Middle Permian (Borax and Stewart, 1966; Tittirananda, 1976). Therefore the age of the Khao Khad Formation lies between Lower and Middle Permian.

8.1 Lithostratigraphy of the Khao Khad Formation

Stratigraphically, the Khao Khad Formation in the study area overlies the Pang Asok Formation and is conformably underlain by the Sab Bon Formation with the total thickness of about 2,476 metres. Based on the lithostratigraphic correlation of the three measured sections, there are fifteen lithofacies which can briefly summarized in ascending order as follows:

1) Calcilutite with nodular chert lithofacies are medium light grey to dark grey, thin-to-medium-bedded calcilutite to fine calcirudite, interbedded with dark grey banded chert, partly nodular chert and siliceous limestone. Petrographically the rocks are classified as finely laminated fossiliferous micrite, algal biomicrite, packed biomicrite, packed biomicrudite, and poorly washed biosparite, biopelsparite, biosparudite and biopelsparudite with some microcrystalline chert bands and nodules. Grains are fusulinid tests, pellets, brachiopods and gastropods shells, algal fragments.

2) Algal biolithite lithofacies are light to medium grey, medium-bedded calcarenite, calcirudite and biolithite. Petrographically the rocks are classified as pelsparite, biopelsparite, biosparudite and algal biolithite. Grains are pellets, small micritized bioclasts, crinoid fragments, algal fragments, foraminiferal tests, and shells of brachiopods, gastropods and cephalopods.

3) Crinoidal calcirudite lithofacies are light grey to medium grey, medium-to-thick-bedded, crinoidal calcarenite to fine calcirudite. Petrographically the rocks are defined as unsorted crinoidal biosparudite and crinoidal biosparite. Grains are mainly crinoidal fragments and common bryozoan fragments.

4) Crinoidal calcirudite with nodular chert lithofacies are grey to dark grey, medium- to thick-bedded, coarse calcarenite and fine calcirudite with scattered dark grey chert nodules. Petrographically the rocks are sorted biosparite and biosparudite with some microcrystalline chert. Grains are broken fragments of crinoids, intraclasts, foraminiferal tests bryozoans and unidentified calcareous skeletons.

5) Crinoidal calcirudite with banded dolomite lithofacies are light grey, medium-to thick-bedded, coarse calcarenite to fine calcirudite with dolomitic limestone alternating with thin bedded dolomite. Petrographically the rocks are

classified as sorted biosparite, biosparudite, poorly-washed biosparite with fine to coarse crystalline dolomite. Grains are essentially crinoidal fragments, foraminiferal tests and intraclasts.

6) Grade-bedded calcarenite with banded chert lithofacies are grey to dark grey, thin- to medium-bedded, graded calcarenite to calcilutite with dark grey chert bands and thinly-laminated to thinly-bedded, reddish brown, fissile silty shale between limestone beds. Petrographically the rocks are classified as poorly-washed intrasparudite and a series of thinly-laminated and graded-bedding sequences of poorly-washed intrasparite, packed biomicrite and fossiliferous micrite, with microcrystalline banded cherts and microcrystalline dolomite. Grains consists of angular boulders, cobbles, pebbles and sands of intraclasts with subordinate calcareous skeletons, crinoids and foraminiferal tests.

7) Fusulinid bearing fine calcirudite lithofacies are medium grey to dark grey, medium- to very thick-bedded calcarenite to fine calcirudite with black nodular cherts and dolomite patches. Petrographically the rocks are defined as packed biopelmicrite, poorly washed biosparite, unsorted biopelsparite, biosparite and biosparudite which were silicified and dolomitized in certain areas. Grains are mainly large fusulinid tests, pellets and small shell fragments.

8) Coral biolithite lithofacies are medium grey to dark grey, thin- to very thick-bedded calcilutite to calcirudite and biolithite with common chert nodules. Petrographically the rocks are classified as packed biomicrite, packed biomicrudite, packed intramicrite, biopelsparite and intraclasts-bearing biosparudite. Grains are large shell fragments of brachiopods and gastropods, large fusulinid tests, fecal pellets, abundant small intraclasts of micrite and coral fragments packed with small unidentified fragments.

9) Laminated dolomitic calcarenite lithofacies are medium grey to dark grey, thin- to medium-bedded, coarse calcilutite interbedded with thin-bedded dolomitic limestone and thinly-laminated dolomite. Petrographically the rocks are classified as packed biomicrite, disturbed micrite with microcrystalline dolomite and macrocrystalline dolomite. Grain is rare.

10) Fusulinid and intraclasts bearing calcirudite lithofacies are light grey to pinkish grey and medium to dark grey, medium- to thick-bedded of parallel-bedded type, moderately sorted calcarenite to fine calcirudite. Petrographically the rocks are classified as fusulinid bearing biosparite, intraclasts biosparite, intrasparite, biopelsparite and packed biomicrite and intrasparudite with some quartz chert and medium crystalline dolomite. Grains are mainly fusulinid tests, diverse micritized grains and some fecal pellets, unidentified shells, coral fragments and algal coated grains.

11) Fenestral and disturbed dolomitic micrite lithofacies are medium to dark grey, thin- to thick-bedded calcilutite to calcarenite with coquinite bed, algal coated coquinite and dolomitic limestone bed. Petrographically the rocks are classified as packed biomicrite and dismicrite with abundant burrow, fenestral features filled microcrystalline dolomite. Grains are shell fragments.

12) Fusulinid bearing calcarenite lithofacies are medium grey to brownish grey, thin-bedded calcarenite. Petrographically the rocks are classified as packed biomicrite with grains of fusulinid tests, brachiopod fragments and some spicules. The silicified argillaceous limestone contains abundant chalcedonic spherulite.

13) Intraclasts bearing calcarenite lithofacies are alternating sequences of dark grey, thin- to thick-bedded calcarenite, partly calcilutite with dark grey chert nodules

and silty shale thinly-laminated between limestone beds. Petrographically the rocks are classified as packed intramicrite and biomicrite. The grains are fine-grained carbonate intraclasts and minor skeletal fragments of broken crinoid ossicles and foraminiferal tests with some detrital quartz.

14) Argillaceous limestone with silty shale lithofacies are a sequence of grey to dark grey, thin-bedded calcilutite, calcarenite in the lower part and gradually passing upward into clastic associations of thin-bedded silty shale, silty sand and porcelanite with very thick-bedded calcirudite in the uppermost part. Petrographically the rocks are classified as poorly-washed biosparite, intramicrudite, intramicrite, packed biomicrite and micrite. Grains are abundant skeletal fragments of crinoids, foraminifera, corals, algae and unidentified fragments with some intraclasts and detrital quartz.

15) Cross-laminated calcarenite lithofacies are medium grey to dark grey, thin- to thick-bedded, cross-lamination calcarenite with rare small chert nodules. Petrographically the rocks are classified as poorly-washed biosparite, packed biomicrite and sparse biomicrite with some microcrystalline quartz chert. Grains are bioclasts of foraminiferal tests, crinoids, unidentified skeletal fragments and bryozoa together with intraclasts and detrital quartz.

8.2 Facies Change

There are some differences in lithological characteristics among those three measured sections. The grade-bedded calcarenite with banded chert lithofacies, intraclast bearing calcarenite lithofacies and cross-laminated calcarenite lithofacies are absent in the Khao Khad area, while the algal biolithite lithofacies, fusulinid bearing fine calcirudite lithofacies, coral biolithite lithofacies, laminated dolomitic calcarenite

lithofacies, fenestral and disturbed dolomitic micrite lithofacies and fusulinid bearing calcarenite lithofacies are absent in the Khao Chan area. It is noted that only three lithofacies (coral biolithite lithofacies, laminated dolomitic calcarenite lithofacies and fusulinid and intraclastic bearing calcirudite lithofacies) were recognized in the Pak Chong to Khao Yai area.

8.3 Depositional Environments

The depositional environment of the Khao Khad Formation is believed to be the shelf marine with sub-environments of intertidal to subtidal zones near shore, subtidal of shallow restricted marine, barrier bar or shoal, foreslope of barrier bar of the open marine and open shelf marine. Because of the exceptional thickness of this sedimentary sequence, it was likely that the areas were gently subsiding during the time of deposition.

Because of the variation of lithofacies between the three measured sections, there should be small scale differences of paleogeographic environment in each area. Generally, the paleogeography was shallow restricted marine with outer barrier bar of shallow platform. However, there was a turbidite sequence in the Khao Chan area indicating the foreslope environment.

8.4 Diagenesis of the Khao Khad Formation

The diagenetic history of the Khao Khad Formation can be subdivided into two phases, early diagenesis and late diagenesis and are summarized as follows:

The early diagenetic processes involve grain abrasion, grain micritization, microcrystalline calcite cement, meniscus cement, acicular fibrous cementation,

burrowing, microcrystalline dolomitization, radial fibrous calcite cement, dog-tooth calcite cement, early compaction, equant calcite cement, blocky calcite cement, syntaxial overgrowths cementation, dissolution, microcrystalline dolomitization, mesocrystalline dolomitization and silicification.

The processes occurred during late diagenesis are macrocrystalline dolomitization, calcitization or dedolomitization, ferroan calcitization, dissolution compaction and neomorphism.

The carbonate rocks in the Khao Khad Formation contain rather low contents of trace elements similar to those found in the Ratburi limestone and Nam Maholan Formation in Loei

Both oxygen and carbon isotopic values of the carbonate rocks in the Khao Khad Formation show slightly lighter than the original isotopic composition of Permian seawater carbonates similar to those found in the Nam Maholan Formation in Loei. It suggests some isotopic modification during diagenetic evolution.