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THE TRIASSIC KODIANG LIMESTONE FORMATION IN KEDAH, W. MALAYSIA

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ABSTRACT

The Triassic Kodiang Limestone Formation is formally described as a new lithostratigraphic unit in the Malay Peninsula. The thickness of the stratotype measured is more than 125 m.

The carbonate sediments, consisting of algal stromatolites, intraformational breccias, limestone conglomerates with sedimentary slumps, black mudstones with radiolarian chert, and limestone turbidites, were deposited in a shelf, slope, and basinal environment. The paleoslope was dipping to the east.

INTRODUCTION

In Kedah, one of the states of Malaysia, Paleozoic and Mesozoic rocks are outcropping. The oldest known sequence of sedimentary rocks in this part of the Malay Peninsula ranges from Upper Cambrian to Lower Devonian in age. After some doubtful folding during Devonian times, an Upper Paleozoic sequence of sediments was deposited until the end of the Permian, when it was interrupted by thrusting and granite intrusions, after which Triassic sediments were deposited. At the end of the Triassic a major orogenic phase terminated the previous marine sedimentation. The Paleozoic and Triassic rocks were folded, generally along north-south axes. The orogeny was succeeded by a period of erosion, and deposition of probable Jurassic molasse sediments. Sedimentary rocks of younger ages are nearly absent. In Cenozoic times faulting and epeirogenic movements caused the present shape of this area (Gobbett, 1973).

On the coastal plain of Kedah and Perlis a great number of isolated prominent limestone hills are present. Most of these are of limestones of Paleozoic age, with the exception of the hills in the vicinity of Kodiang village (Kedah), which were demonstrated to be of Middle to Upper Triassic age by Ishii and Nogami (1966), and Koike (1973). Jones et al. (1966) informally used the name "Kodiang limestone" for these rocks. A short description of the "Kodiang limestone" was given by Burton (1973). The present paper formally establishes the Kodiang Limestone as a formational unit.

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There are two reasons for formalizing a new stratigraphic unit in this area. First, the lithology of the Kodiang Limestone is completely different from the other limestones in the area (the Permian Chuping Formation and the Lower Paleozoic Setul Formation). Second, this is the only known limestone of Triassic age in the region. The nearest known Triassic limestone, although of Lower Triassic age, is in Kelantan, about 250 km away to the southeast.

TYPE LOCALITY AND DESCRIPTION OF STRATOTYPE

The type locality of the Kodiang Limestone Formation can be found in the area around Kodiang village, about 30 km north of Alor Star (fig. 1 and 3A). From the seven limestone hills that compose the type locality, a composite stratotype was determined in Bukit Kecil and in Bukit Kalong (stratigraphic terminology used in this report is according to Hedberg, 1972). The lower part of the Formation was measured in the active quarry of Bukit Kecil (fig. 3B), the upper part in the abandoned quarry of Bukit Kalong (fig. 3E). The units in the highest part of the succession exposed in Bukit Kecil could be correlated with their counterparts in Bukit Kalong, about 200 m away. In the latter we distinguish a few more units on top of those exposed in Bukit Kecil. The measurement of the stratigraphic section was carried out with a 20 m tape and Brunton compass. All stratigraphic units were sampled. The limestones were described according to the classification of Dunham (1962), as far as possible. The following observations were made in the quarries of Bukit Kecil and Bukit Kalong (fig. 2).

The lowest four units of the Kodiang Formation, which overlie badly exposed siliciclastic mudstones, are quite similar. Slight variations in colour and bedding enables a distinction into four units at this locality, but it is also justified to consider them as one single unit of about 42 m thickness, predominantly composed of flat to wavy laminated limestones. The depositional texture is unrecognizable due to recrystallization. The lamination seems to be caused by ghost structures, stylolites and slight differences in size of

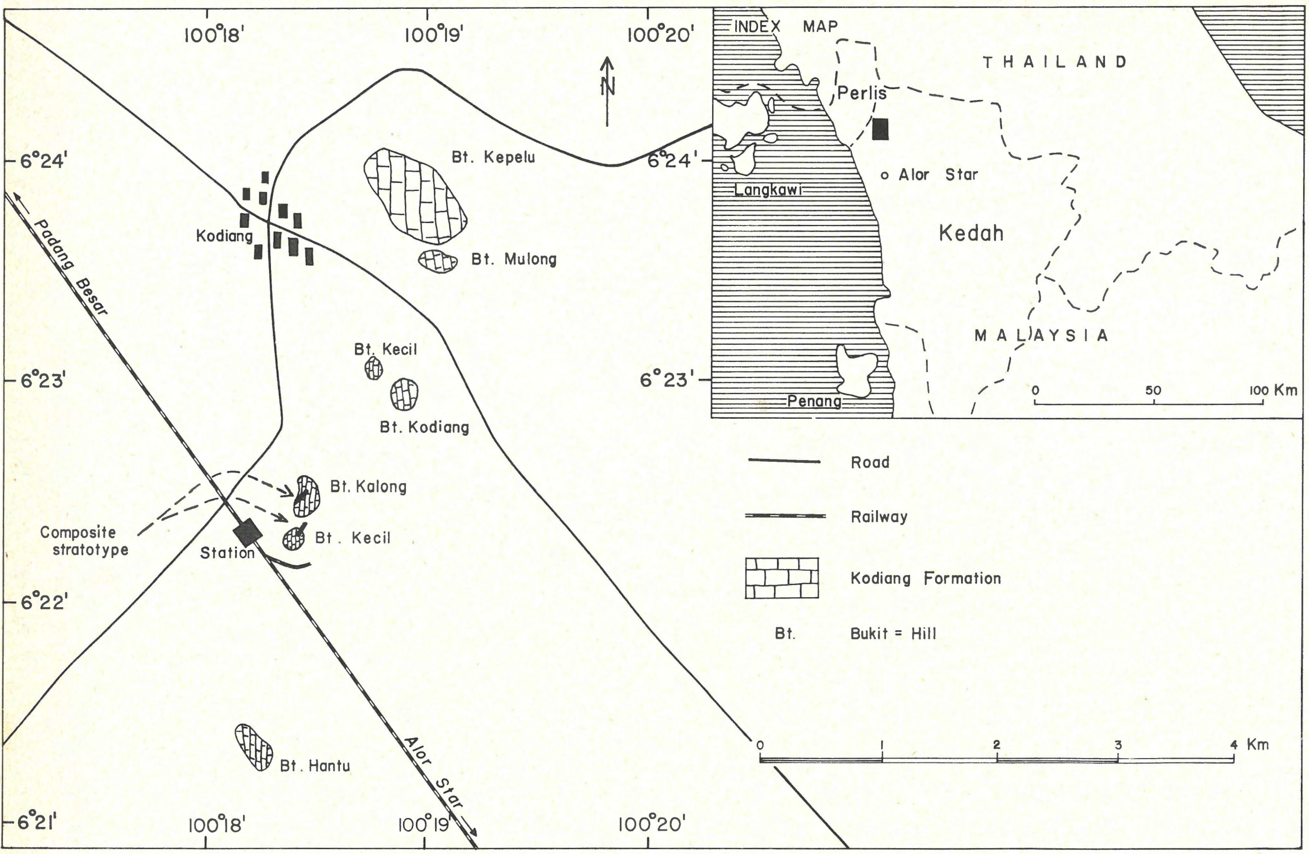

Fig. 1
Outcrop and index map of the Kodiang Limestone Formation.

the equidimensional calcite crystals. Macroscopically, irregular dome-shaped structures of about 50 cm wide and 20 cm high can be seen (fig. 3C). Locally the lamination is broken up into small chips of about 1 cm. The thickness of the laminae increases in unit 4 up to thin beds of about 2 cm thickness, that consist of graded calcite particles from fine silt to mud size, alternating with brown, dolomitic mudstone beds. Near the top of unit 4, the thin beds are occasionally found broken into fragments of about 5 cm, while underlying and overlying beds remain undisturbed (fig. 4A).

Units 5, 9, and 12 are composed of black lime mudstone. The limestone shows a slight wavy bedding with beds of about 10 cm thickness, alternating with thin beds of black siliceous and carbonaceous shale. The abundant occurrence of chert nodules and chert beds is characteristic for these units. The mudstone contains only a few small foraminifers and ostracods, the cherty parts however, contain large quantities of radiolaria tests and some sponge spicules.

Units 6 and 8 are completely composed of angular lithoclasts up to 5 cm in diameter. The clasts consist of grey mudstone, showing similarities with the broken fragments of unit 4 (fig. 4A and 4B). The lithoclasts are embedded in a brown, dolomitic muddy matrix. This rock type is considered to be an intraformational breccia.

Unit 7 is rather recrystallised, but is probably of the same rock type as unit 1 to 4.

Unit 10 is composed of about 25 m light grey, graded limestone beds. The individual beds vary in thickness from 5 cm to about 1 m. Each bed typically contains a sequence of grainstone, packstone, wackestone and mudstone, successively from bottom to top (fig. 3D). A wide variety of grains are present. Most common are lithoclasts and bioclasts, but oöids and pellets also occur locally. Lithoclasts consist of mudstone, pelletal packstone, algal boundstone, and various bioclastic rock types. Among the bioclasts foraminifers, bivalves, gastropods, brachiopods, ostracods, radiolaria and algae are found. The mudstone at the top of several beds shows a clear lamination.

Unit 11 and 14 are composed of subangular to subrounded limestone fragments, from a few millimeters to several decimetres in size. Unlike the clasts of the intraformational breccia, these rocks contain a wide variety of limestone clasts, among which a few of the underlying and several exotic rock types can be found. The clasts are floating

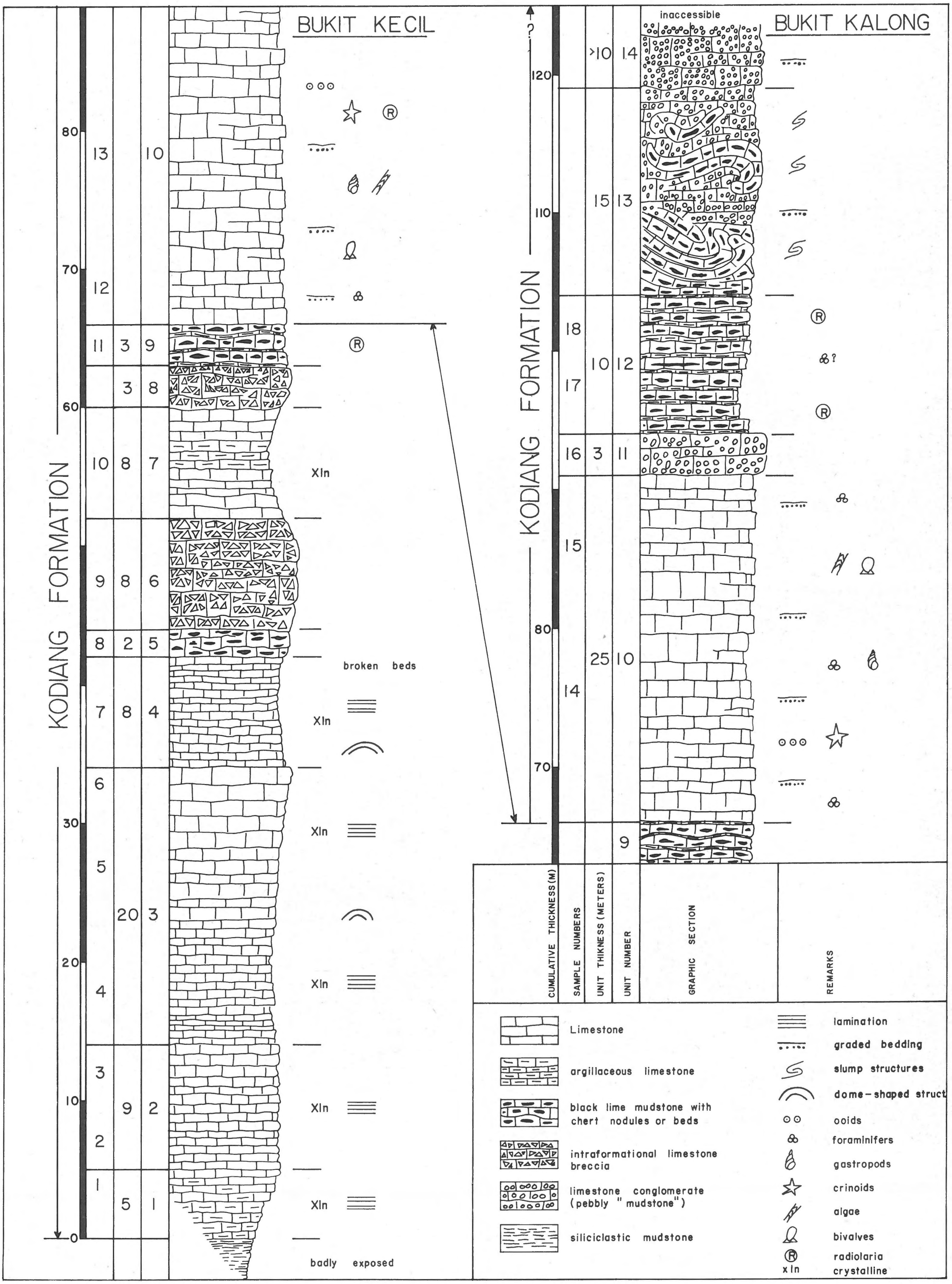

Fig. 2 Stratotype of the Kodiang Limestone Formation.

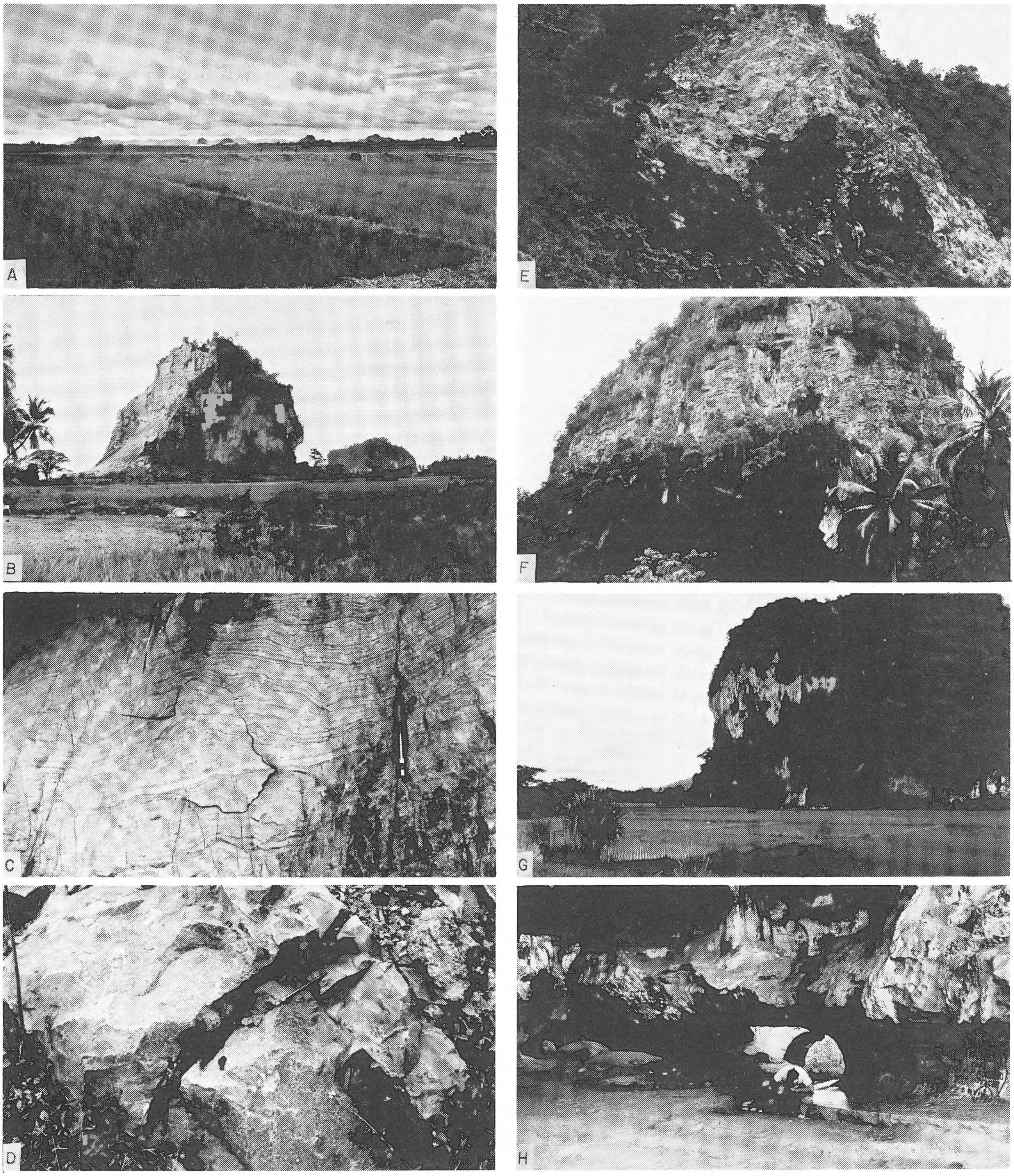

Fig. 3
A) Type locality of the Kodiang Formation. View from the south. From left to right (W-E): Bukit Hantu, Bt. Kecil, Bt. Kalong, Bt. Kodiang, and Bt. Kepelu. B) Lower component stratotype of the Kodiang Formation in Bukit Kecil. At the right hand side Bukit Hantu can be seen. C) Dome-shaped structure in stromatolitic limestones of Bukit Kalong. D) Graded bedded limestone bed in Bukit Kalong. Grainstone at the bottom (left) to laminated mudstone at the top (right). Pen has a length of 13 cm. E) Slumps high in the upper component stratotype of Bukit Kalong. F) Slump interval in Bukit Kodiang. G) Collapse cavern in Bukit Kepelu. Note the sea level notch at the foot of the hill. H) Smooth polished sea level notch at the foot of Bukit Kepelu.

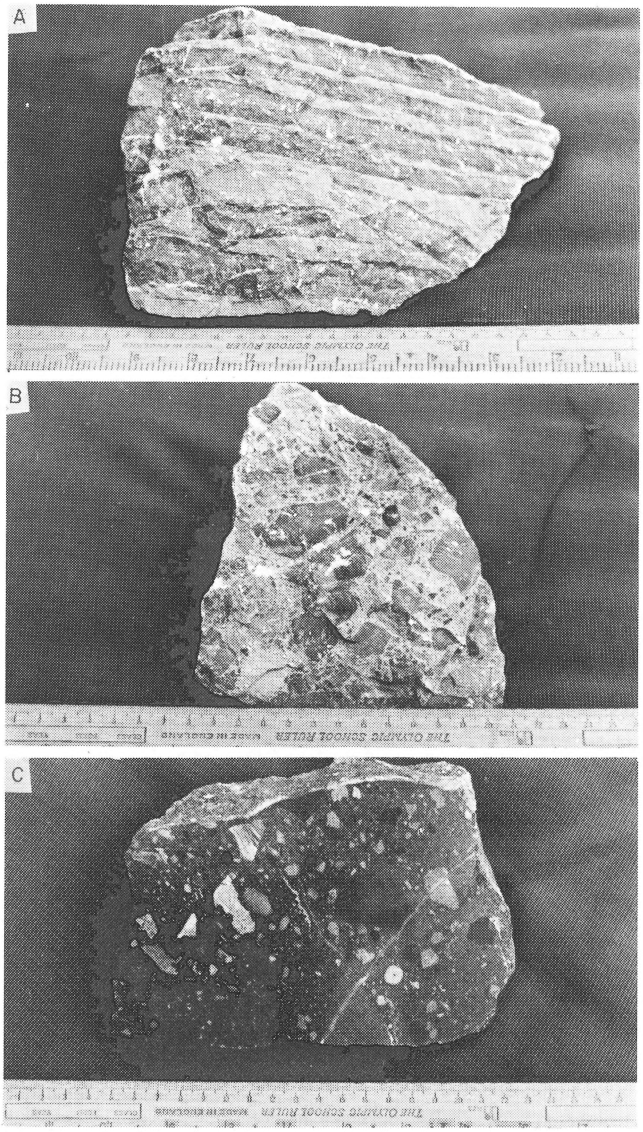

Fig. 4
A) Broken beds from the upper part of unit 4 in Bukit Kecil. B) Intraformational breccia from unit 6 in Bukit Kecil. Note the monomict composition of the clasts. C) Limestone conglomerate from unit 11 in Bukit Kalong. Note the polymict composition of the clasts. Ruler shows centimeters in the upper half and inches in the lower half.

in a dark coloured muddy to sand size matrix (fig. 4C). This rock type is considered to be a limestone conglomerate. It might even be called a pebbly lime "mudstone", in analogy with some siliciclastic equivalents, but it is not a mudstone in the sense of the Dunham classification (1962).

The black mudstones and shales of unit 12 grade into a thick unit which is completely composed of large masses of folded black limestone beds, from a few decimetres to several metres in size, embedded in between limestone conglomerate. Complete sets of alternating black mudstones and shales of the same type as in unit 12 are found, folded within the conglomerate. From a distance this unit appears to be a recumbent fold (Gobbett & Tjia, 1973, plate 20), but a closer look reveals that it is more probably composed of sedimentary slumps (fig. 3E). Similar phenomena, even more spectacular, were observed at about the same level in Bukit Hantu and Bukit Kodiang (fig. 3F).

The slump interval grades into unit 14, which, as already pointed out, is composed of limestone conglomerate. Unit 14 also marks the presently highest known part of the Kodiang Formation, since it forms the top of Bukit Kalong.

The composite section as measured here comprises about 125 m, giving the minimum thickness of the stratotype of the Kodiang Formation.

PALEONTOLOGY

Fossils can be found in rather large quantities in the Kodiang Limestone. They occur mainly in the coarse part of the graded limestone beds, but, though in smaller quantities, are also encountered in other parts of the Formation. Only the lowermost part, consisting of laminated recrystallised limestones is completely devoid of recognizable fossils. The organic remains were studied mainly in thin sections, since it was very difficult to extract fossils from the hard limestones and cherts (except the conodonts). Due to this fact, and because recrystallization obscures most of the internal structures of the fossils, precise identification was difficult. The following groups were observed: radiolaria, foraminifers, sponge spicules, trepostomate bryozoans, brachiopods, bivalves, gastropods, crinoid ossicles, echinoid spines, ostracods, algae, and conodonts.

The radiolaria occur mainly in the cherty parts of the Formation, in combination with siliceous sponge spicules. The radiolaria appear as thin-walled, spherical or oval bodies, sometimes cone-shaped and chambered. Frequently the outher surface is ornamented with spines.

The sponge spicules are of the hexactinal type and appear as stick-like and cross-like bodies in the thin sections.

Foraminifers occur widely in the Kodiang Formation. They are of a relatively simple type and belong probably to the subfamilies Nodosinellinae, Endothyrinae, Fischerininae and Ophthalmidiinae. Identification could only be done by studying the gross shape of the test, because wall structures and fine internal structures are rather obscured due to recrystallization. However, several specimens could be identified with reasonable certainty as *Lynucammina* sp., *Nautiloculina* sp., and *Ophthalmidium* sp. Up to now, no Triassic foraminifers have been described from the Malay Peninsula.

Clear branch-shaped trepostomate bryozoans, belonging to at least two genera, have been observed in the thin sections. In contrast with most other fossils, their state of preservation is fairly good. Tangential, transverse and longitudinal sections could be studied. Triassic trepostomes are very rare, therefore this material will be described by the second author in a subsequent paper. The specimens are restricted to one horizon in the slump interval.

Brachiopods are identified as punctate and impunctate types. They occur in most parts of the Formation as small fragments.

Bivalves were difficult to recognise in thin sections due to recrystallization. However, concentrations of them were observed in a rock sample from the coarse part of a graded limestone bed. The specimens are small, 3 to 4 mm in length, and elongated. Hinge and adductor scars were not visible.

Gastropods are relatively rare. They are very small, a few millimetres in length, very slender and trochospiral. The shell is possibly unornamented and the protoconch is dome-shaped.

Crinoid ossicles occur in large quantities throughout the entire fossiliferous part of the Formation, often in combination with echinoid spines.

Ostracods occur in fairly large quantities. Large accumulations of valves were observed within some of the radiolarian cherts. In most cases only one valve was present, but sometimes complete specimens were seen.

Algal stromatolites are probably present throughout the entire lower part of the Formation. Above this level scattered algal fragments were encountered in most of the thin sections.

The conodonts were described by Ishii and Nogami (1966), and Koike (1973).

AGE

A Triassic age for the Kodiang Limestones, based on conodonts, has been proposed by Ishii and Nogami (1966), and Koike (1973). Ishii and Nogami obtained two conodont faunas: the *Gladigondolella c.f. abneptis* fauna from Bukit Kecil, and the *G. tethydis* fauna from Bukit Kalong. Koike obtained conodont faunas from Bukit Kecil and Bukit Kodiang.

According to Koike's recent paper (1973), important age indicators in Bukit Kecil are the following elements: *Epigondolella mungoensis* (Upper Ladinian), *Gladigondolella tethydis* (Lower Anisian – Upper Ladinian – Upper Carnian), *Paragondolella polygnathiformis* (Upper Ladinian – Upper Carnian), *Didymodella alternata* (Lower or Upper Anisian – Ladinian), and *Hindeodella multihamata* (Lower or Upper Anisian – Ladinian). Based on these conodont species, Koike proposed an Upper Ladinian age for the fauna of Bukit Kecil.

An important age indicator in Bukit Kalong, according to Ishii and Nogami (1966), is *Gladigondolella tethydis* (Lower Anisian – Upper Ladinian or Lower Carnian).

In Bukit Kodiang Koike (1973) distinguished two faunas, but their stratigraphic position was not indicated. The first fauna yielded a predominant occurrence of *Paragondolella polygnathiformis* (Upper Ladinian – Upper Carnian). The fauna does not contain the Upper Ladinian species *Epigondolella mungoensis*, which occurs abundantly in the fauna of Bukit Kecil. Therefore, Koike assumed this fauna to be of a younger age than that of Bukit Kecil. The second fauna yielded abundantly *Neogondolella aegaea* (Lower or Middle Anisian), *Gladigondolella tethydis* (Lower Anisian – Upper Ladinian or Lower Carnian), and *Paragondolella excelsa* (Anisian). Koike reported also one species of *Neogondolella mombergensis* (Lower Anisian – Ladinian). According to this fauna, Koike concluded to a Lower or Middle Anisian age.

The foraminifers, which were identified by the present authors as *Lunucammina* sp. and other species possibly belonging to the subfamilies Nodosinellinae and Endothyrinae, are pointing to a Permian age at most. Those identified as *Nautiloculina* sp. are pointing to at least a Jurassic age. The foraminifers identified as *Ophthalmidium* sp. range from Upper Triassic to Recent. Since foraminifers of the Triassic are still rather incompletely known, it is very well possible that the range of some subfamilies, or even genera, presently unknown from Triassic rocks, should extend into the Triassic.

DEPOSITIONAL ENVIRONMENT OF THE CARBONATE SEDIMENTS

Five main rock types can be distinguished in the stratotype of the Kodiang Formation: laminated limestones, intraformational breccias, black cherty lime mudstones alternating with black carbonaceous shales, graded clastic limestones, and limestone conglomerates. Each of these rock types represents a specific depositional environment of the carbonate sediments.

The laminated, but slightly recrystallised limestones, some showing dome-shaped structures, are rather similar to recent algal stromatolites (for example, Davies, 1970). Stromatolites are generally believed to occur predominatly in a shallow marine or tidal environment (Logan et al., 1964). Playford (1972) however, compared the recent stromatolites of Shark Bay, Australia, with Devonian stromatolites from the Canning Basin in Western Australia and showed that some forms grew to depths of at least 45 m and some probably more than 80 m below sea level. Hoffman (1974) found stromatolites in shallow water as well as in deepwater facies of Lower Proterozoic rocks in Canada. When the descriptions of the above-mentioned authors are compared, it seems that the rather regular flat stromatolites occur more abundantly in shallow than in deeper water. Consequently it seems likely that the Kodiang stromatolites were deposited in a shallow marine environment. The thickness of 42 m of stromatolitic limestones indicates that during a considerable time the conditions were rather stable in the area of deposition. The locally disturbed laminations might be explained by temporary exceptional rough conditions, like storms.

Higher in the stromatolitic sequence the conditions tended to change, since the thickness of the laminations increases to thin beds and becomes slightly graded. This indicates a decrease in algal growth, while inorganic processes of deposition became more important. There are two explanations for such a change, either the supply of sediment became so high that the algae were killed, or the water became too deep to permit algal growth. Probably both factors have played a part, although under favorable conditions these algae can grow down to 80 m. The disappearance of stromatolites is associated with the appearance of thin but slightly graded beds, indicating a higher supply of sediment, and with occasionally broken beds, indicating unstable, possibly slope conditions.

Unstable conditions certainly must have prevailed during the deposition of the intraformational breccias. Lithified beds are broken and redeposited. The broken beds could not have been transported very far from their original place of deposition since most fragments are angular and monomict. The limestone clasts are surrounded by the same brownish coloured mud which is found also in between the thin beds of unit 4. This mud might have facilitated the transport of the clasts.

The black siliceous lime mudstones with interbedded black carbonaceous shales occur characteristically below and above the graded bedded clastic limestone and conglomerate interval. A mudstone-shale association indicates a quiet environment that was sufficiently calm to allow the fine material to settle. Such environments occur either in shallow protected areas, or in relatively deep water below the effective wave base. A high organic content in muddy carbonate sediments is found more in deep than in shallow water, because deeper waters contain less oxygen than the typically better aerated shallow waters (Wilson, 1969; Heckel, 1972). The occurrence of large amounts of radiolaria tests in the cherty parts of the mudstones supports the idea that these sediments were deposited in a deeper water environment. The abundance of radiolaria in the cherts might indicate simultaneous volcanic activity elsewhere in the basin.

The graded clastic limestones show many similarities with the allodapic limestones of Meischner (1964), which were considered being deposited by turbidity currents. The high variety of bioclasts, various types of lithoclasts and even pellets and oöids indicate the diverse provenance of these sedimentary particles. In view of the stratigraphic position of these graded limestones, in between deeper water black mudstones and shales, it seems very probable that they were deposited by density currents transporting material from the shelf into the basin.

The limestone conglomerate, which looks very much like the carbonate equivalent of a siliciclastic pebbly mudstone, indicates mass transport of coarse and fine material. Stanley and Unrug (1972) considered pebbly mudstones diagnostic slope indicators. This interpretation is confirmed high in the succession of the Kodiang Limestone, where limestone conglomerates surround large sedimentary slumps. Measurements in several localities indicate slumping directions from west to east. This means that the highest part of the slope was located to the west (the shelf side), and the lowest part to the east (the basin side).

REGIONAL ASPECTS

At the moment the Kodiang Formation is only known in the type locality and is exposed in the seven hills around Kodiang village (fig. 1). In the nearest limestone hill, Gunung Keriang just north of Alor Star, Paleozoic fossils were found and the rock types are completely different from those in the Kodiang Formation.

The geographic locality and stratigraphic position of the Kodiang Formation is remarkable. In northwest Kedah, in Langkawi and in Perlis we find a sequence of mainly Carboniferous fine grained siliciclastics, and Permian carbonates. In northeast Kedah Carboniferous coarse grained siliciclastics are unconformably overlain by Triassic flysch deposits. The type locality of the Kodiang Formation lies on the boundary between these two areas. The Triassic rocks of the (informal) Semanggol formation, which is composed of a thick sequence of flysch type sediments, cover large areas in northeast Kedah. The relation between the Semanggol formation and the Kodiang Limestone is not clear. The relatively thin Kodiang Limestone might be a lateral carbonate facies equivalent of the much thicker flysch sediments of the Semanggol formation.

It is unknown whether younger rocks have covered the Kodiang Formation. The rock types from the top of the presently known Kodiang Formation and the major orogenic events in Late Triassic times might point towards an unconformity.

The present day expression of the Kodiang Formation into seven separate hills is mainly due to intense tropical karst and ancient marine abrasion. Karst caves and collapse caverns are found in all the hills (fig. 3G). Sea level notches and the presence of Holocene marine shells indicate higher sea levels and abrasion activity a few thousand years before present (fig. 3G and 3H). The higher sea levels must have been two or three metres above the present padi fields. The coastal plain surrounding the limestone hills is covered with Quaternary sediments.

CONCLUSIONS

The carbonate sediments of the Kodiang Formation have been deposited in a shelf, a slope and a basin environment. During deposition there was an alternation of stable and unstable conditions. Generally, instability was increasing during sedimentation, indicating an increase in paleoslope due to the approaching diastrophism at the end of the Triassic, the so-called Thai-Malay or Malay-Yunan Orogeny. The paleoslope was dipping to the east, indicating that the

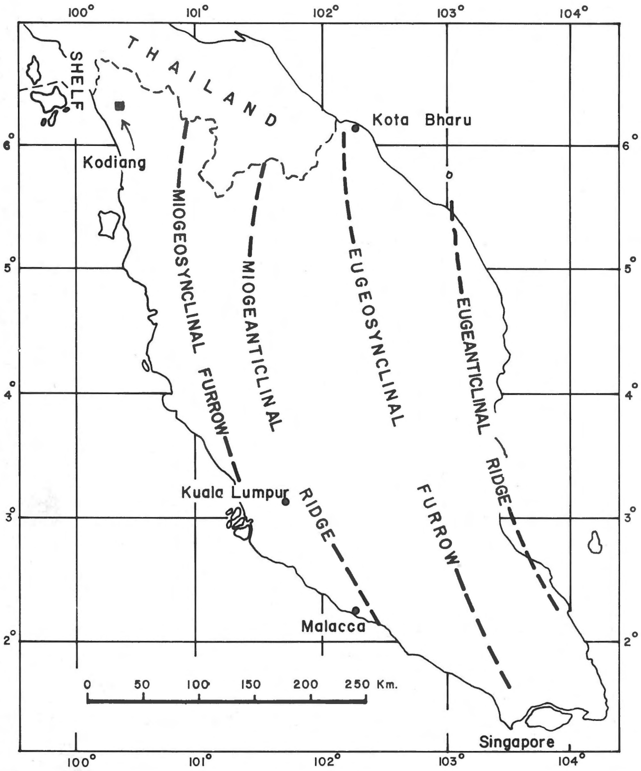

Fig. 5
Geosynclinal organization of the Malay Peninsula during Paleozoic and Lower Mesozoic times (after Burton, 1973).

shelf was located in the west, the basin in the east. This is conform the geosynclinal organization of the Malay Peninsula during Paleozoic and Lower Mesozoic times (fig. 5).

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