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A Triassic "reefal" limestone in the basement of the Malay Basin, South China Sea: Regional implications.

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Abstract: A palaeontological and sedimentological study was carried out on samples from a well, Sotong B-1, drilled in the southern part of the Malay Basin. This study was confined to the pre-Tertiary limestone basement rocks. This limestone has been assigned to the Late Triassic and displays characteristics similar to other Late Triassic limestones of the Tethyan realm. The age of the limestone suggests that a pre-Tertiary basement sequence ranging from the Lower Carboniferous to the Upper Triassic probably exists in the offshore areas of the Malay and Thai Basins.

INTRODUCTION

The Sotong structure which is located in the southern part of the Malay Basin is a seismically recognised, low relief domal feature which displays an unconformable relationship with the overlying relatively flat bedded sequence. The limestone studied in this paper has been penetrated by a well (Sotong B 1 = latitude 04°52'36.82"N, longitude 104°47'59.16"E) drilled on this structure and measures over 987 ft from a depth of 9,030 ft to the bottom of the well at 10,017 ft. It has been cored from 9.736 ft to 9,761 ft where it is gray in colour and from 10,000 ft to 10,017 ft where it is black. From 9,030 ft to 9,600 ft and from 9,990ft to 10,000 ft, it is known only by ditch cuttings (drill chips). From 9,600 ft to 9,736 ft and from 9,760 ft to 9,990 ft, no sample has been preserved (see figure 1)

The limestone is overlain by Oligocene shale and sandstone considered sediments of a lower deltaic plain and a Neogene sequence deposited in marine and brackish water. The contact of the limestone with the Tertiary sediments appears to correspond to an unconformity. The unconformity is not clear at the Sotong B1 well however, at another well (Sotong B2 = latitude 4°54'14.875"N, longitude 104°47'01.780"E; see Figure 1) which has also reached the limestone and has bottomed in it after penetrating only 40 ft, the Oligocene clastics are separated from the limestone by a dark red to purple sandy shale with green mottling, between 9,020 ft and 9,575 ft which suggests an emergence before the deposition of the Tertiary strata.

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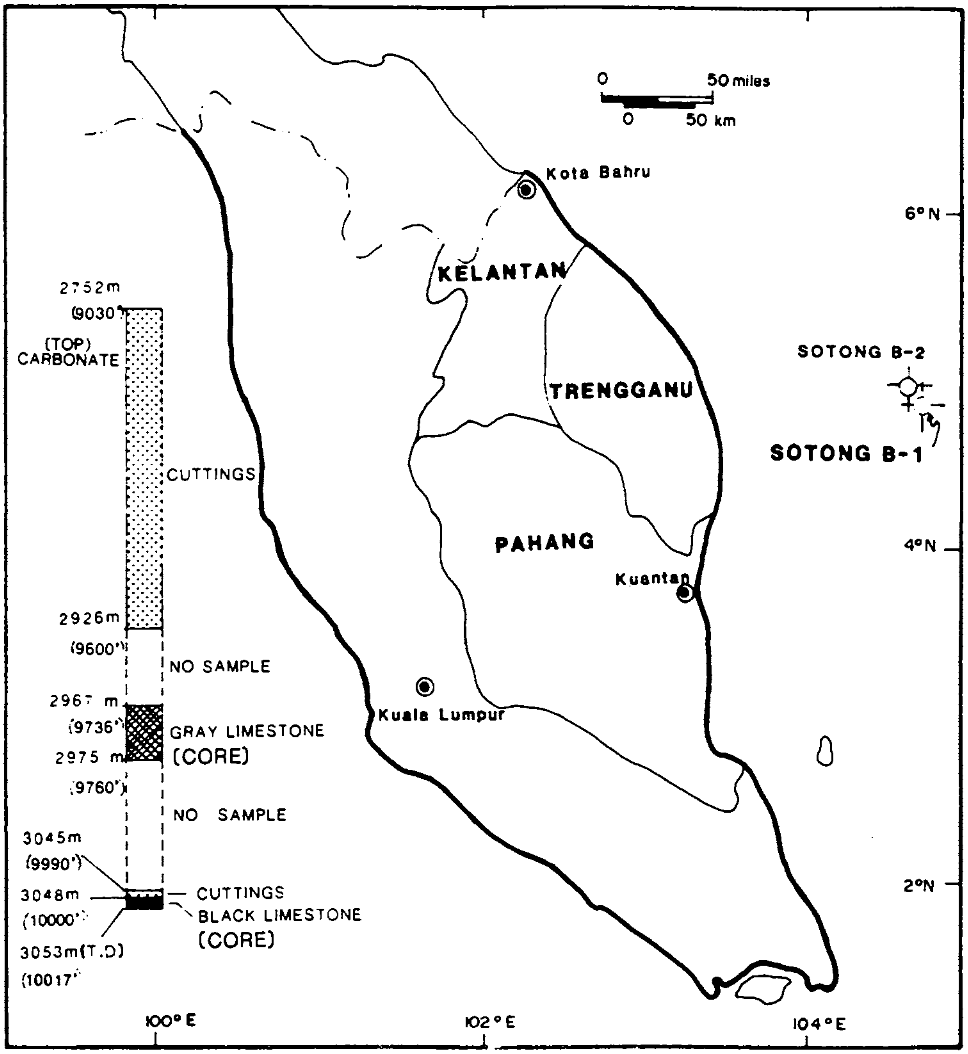

Figure 1: Location map of well Sotong B-1, South Malay Basin and distribution of sampled intervals

Prior to this study the stratigraphic position or age of this basement carbonate was unclear and various proposals gave ages varying from Permian to early Tertiary, The present study is aimed at better defining the age of the Sotong carbonate and to examine its implications with respect to the regional geology of South-east Asia.

THE SOTONG LIMESTONE AND ITS NATURE.

The Sotong limestone is compact with frequent stylolites. Cavities, at the time of deposition have been filled by one or more successive phases of infilling: the first phase may be represented by the growth of encrusting *Tubiphytes* or of encrusting foraminifera, followed by a micritic infilling or rarely and later on, by a calcite infilling. Core examination reveals the limestone is massive with no stratification planes visible.

Only about 300 m of the Sotong limestone was drilled and therefore its full vertical extension is not known. However, similar limestones facies are known, such as the Wetterstein limestone of Austria (Late Anisian to Early Carnian age), which locally reaches thickness of 1700 m (Bradner and Resch 1981). In Peninsular Malaysia the thickness of Triassic limestone are not accurately known, although the Kodiang limestone has been estimated to be more than 125 m thick (Khoo, 1983).

Broadly, the limestone can be distinguished into two types based on colour; a dark, black limestone and a lighter, gray limestone.

Black Limestone: The black limestone (10,000 ft to 10,017 ft) is a mud moderately rich in fossils and fossil fragments. Texturally it is a wackestone to packstone, and never an undebatable grainstone. A few oolites have been noticed at a depth of 10,007.50 ft and 10,008 ft; they are still more or less included in mud. Bioclasts are commonly micritized at their periphery (cortoids). A sessile foraminifera with a height seven times as large as its width (Pl. 5, Fig. 5) is perfectly preserved at a depth of 10,013 ft; because of its fragile nature, it could not resist wave shocks. In conclusion, the depositional environment was a quiet water, somewhat confined because fossils are not prolific and diverse.

Sponges are the most common fossils; they are frequently encrusting and had a prominent role in binding the mud. Corals, not in life position, are restricted to the base of the limestone; they are rare and fragmentary and are not frame-building. Algae are absent with the exception of one horizon with rare red algae. *Tubiphytes*, a pseudo-algae, occurs generally at all the horizons without being abundant, except at the base. A few bryozoa have been noticed only at the base of the black limestone. Fragments of shells (brachiopods and bivalves) are not abundant. Ostracods are frequent. Foraminifera are not diverse; a part of them is encrusting. The others are small and not diverse.

The limestone is not metamorphosed and occasionally slightly dolomitized. However, because of diagenesis, microstructures of corals and other fossils has been destroyed. Pyrite is common and scattered in the limestone; it is more frequent along some veins. Stylolites are common, but widely scattered.

Grey Limestone: The gray limestone (9,736 ft to 9,761 ft) is commonly a packstone or a wackestone-packstone rich in fragments of sponges and bryozoa. Corals are abundant at a few levels. Dolomitization is more important than for the black limestone. Brecciation occurs at a few levels. Fractures are infilled by calcite and dolomite or by green and red mud.

Aside the colour, the gray limestone is different from the black limestone because it is more commonly a packstone. From a paleontological point of view, the abundance of sessile and encrusting foraminifera is remarkable (Fig.2). Bryozoa and corals are more abundant than in the black limestone. *Spongiomorpha* has been noticed at a depth of 9,737 ft.

PALAEONTOLOGY

This study is based on 86 thin sections, an important number which allows a sufficient study.

Black Envelopes.

Before dealing with fossils, the high frequency of "black envelopes" must be noted. It is due to two and probably three phenomena:

Some bioclasts are black at their periphery (cortoids; Pl.6,Fig.2) because of the production of micrite by boring activities of algae, bacteria and maybe fungi. These cortoids are abundant at some levels.

Tubiphytes (Pl. 4, Fig.6,4) an organism which is black when looking at thin section under the microscope, encrusts many organisms or bioclasts. It presents commonly one or two canals and then is easy to recognize.

On the other hand, when there is no canal and when the thin section is a little thick, it is difficult to rule out the presence of an oncolitic wrapping; such an envelope is produced by blue green algae.

Tubiphytes, a pseudo-algae, is abundant in the Sotong limestone. This genus, known from the Upper Carboniferous to the Upper Jurassic, played a prominent role in frame-building and binding during the Permian and the Triassic. After the Triassic, it never again regained its previous importance. In the Sotong limestone, *Tubiphytes* is commonly of the *T. obscurus* - type and occasionally of the *T. carinthiacus* - type with a less tight skeleton.

According to our observation, cortoids and *Tubiphytes* are very frequent; the presence of oncolites is possible.

Actual algae are rare and small in size, with a diameter of less than two centimeters. They are represented mainly by red algae. Dasyclads are practically absent.

Bacinella. an algo-microbial structure, occurs occasionally. *Cayeuxia* has been noticed in a single thin section.

Another problematical alga: *Panormidella aggregata* (Pl.1 Fig. 1) Senowbari-Daryan 1984 is present only in the black limestone at a depth of 10,015 ft. This species is known in Peninsular Malaysia at Bukit Chuping and at Kota Jin (Fontaine *et al.,* 1988).

Foraminifera.

Foraminifera are not abundant; figure 7 of plate 1 is exceptional in showing several foraminifera in a thin section of some ditch cuttings. Foraminifera may be free; then, they are small and resemble *Sigmoilina* (Pl.1, Figs. 4,5,6,), *"Endothyra"* (Pl.1, Fig. 8,9,10), *Opthalmidium, Frondicularia, Tetrataxis* (Pl.2, Fig. 1). *Aulotortus* maybe present: some sections might belong to this genus, but they are very recrystallized. Foraminifera may be attached to a substratum (mainly bioclasts); they are simple (*Calcivertellinae*; Pl.2, Fig. 3) or more complicated and resembling *Alpinophragmium perforatum* (Pl.3, Figs. 1,2,3; Pl. 5 Fig. 5) (Flugel 1967). These last sessile foraminifera are very few in the black limestone, but abundant in the gray limestone; they were living commonly in relatively protected cavities.

Calcisponges.

Calcareous sponges (Pl. 4. Figs. 1,2; Pl. 5 Fig. 1) are abundant at many levels of the black and gray limestones. Some of them are encrusting and have contributed to sedimentation by their binding. Calcareous sponges consist of two types : non-segmented sponges and sphinctozoa (or segmented sponges). Non-segmented sponges are the most common; their skeleton is more or less thick, indicating the possible presence of several species and probably also diverse reactions to environment. Sphinctozoa are not abundant; they belong to two species of *Colospongia.*

Spongiomorpha, a genus attributed to sponges or hydrozoa according to the authors, is rare and has been noticed only at the top of the gray limestone (9,737 ft); it suggests a Middle Triassic or younger age. Spongiomorphs appeared during the Ladinian. Sphinctozoa were prolific during the Late Triassic and were severely decimated by the mass extinction of the end of the Triassic; they experienced a slight resurgence during the Lower Jurassic (Hettangian-Sinemurian) followed by a decline.

In conclusion, sponges indicate an overall Middle Late Triassic age.

DEPTH (FT)	RED ALGAE	TUBIPHYTES	FORAMINIFERA A	FORAMINIFERA F	CALCISPONGES E	CALCISPONGES C	CORALS S	CORALS CM	CORALS CF	GASTROPODS	BRYOZOA	OSTRACODS	ECHINODERMS	OOLITES	PYRITE	FACIES	PROBLEMATICA	SHELL FRAGMENTS	PELOIDS	SED FEATURES	CORTOIDS	DOLOMITIZATION
9030.00																						
9055.00				○		●																
9085.00			○	●																		
9115.00			○	●																		
9145.00				○		○					○											
9175.00			○	●																		
9195.00				■		●																
9225.00			●	●									●									
9265.00				●																		
9295.00				●														○				
9325.00				●																		
9355.00																						
9385.00				●																		
9415.00												○						○				
9736.50						●	○						○			W						
9737.00				○	○	○																
9737.50																						
9738.00													○					○				
9739.00											●	○						●				
9740.00	○		○			■					●	○	○			W-P		○			○	
9741.00						■						○	○			W						
9742.00					○	■			○				■			W-P						
9743.00						■							●			P						
9744.00									■							P		●				
9745.00	○								■							P						
9745.50						○			■							W-P						
9746.00																						
9747.00			○		●	●						○				W-P						
9748.00				○		●				○		○				W		○				
9749.00			○			●					■	○	○			W-P		●				
9750.00		○	○	○		■					■	○	○			P						
9751.00			■	●		●					●					W-P				BC		

KEYS

1) FORAMINIFERA
A - ATTACHED
F - FREE

2) CALCISPONGES
E - ENCRUSTING
C - COLUMMAR AND FRAGMENTS

3) CORALS
S - SOLITARY
CM - COMPOUND MASSIVE
CF - COMPOUND FASCICULATE

W - WACKESTONE
P - PACKSTONE
G - GRAINSTONE
BC - BRECCIATED
⊡ - DITCH CUTTINGS

● - FEW
○ - RARE
♦ - PRESENT
■ ABUNDANT

Figure 2: Paleontological data sheet of the Sotong limestone Note the predominance of sessile or encrusting foraminifera and corals in the gray limestone (9736'-9760') compared to the black limestone (10000' -10017').

DEPTH (FT)	RED ALGAE	TUBIPHYTES	FORAMINIFERA		CALCISPONGES		CORALS			GASTROPODS	BRYOZOA	OSTRACODS	ECHINODERMS	OOLITES	PYRITE	FACIES	PROBLEMATICA	SHELL FRAGMENTS	PELOIDS	SED FEATURES	CORTOIDS	DOLOMITIZATION
			A	F	E	C	S	CM	CF													
9751.50			●			●					●					W-P				BC		
9752.00			■			○			○		■	○	○			W-P		○		BC		
9753.00		○		○		●			○	○	●	○	○			W-P		○				
9753.50		○	●	○		●			●		●	○	○			P		○				
9754.50			○	○					●		○	[illegible]	○			W-P		●				
9755.00			■	○		●			●							W-P						
9755.50						●					■											
9756.00			●	○					■							P				BC		
9757.00			●			○					■					W-P				BC		
9757.50			●	●		○					○					W				BC		
9759.00						○			■							W-P				BC		
9759.50						■					●	○	○			P		○				
9760.00	○	○	●		○	■					●		○			P					○	
10000.00																				BC		
10001.00				○		■						○	○		◆	W-P		○			■	
10002.00		●		●	●	○							○			W		○			●	
10003.00				○								○	●		◆							
10004.00															◆							
10004.50			○							○						W						
10005.00			○			●			○	○	○	○				W-P		●			■	
10006.00		○		○	●	○						●	○			W-P		○				
10007.00		●		○	■	○				○		●	●		◆	W-P		○	■		●	
10007.50		○	○	○	■	●	○		○	■				◆		W-P		○	■		■	
10008.00	●	○	○		■		○			○	○	○	○	◆	◆	P-G					■	
10009.00		○				■					○				◆	P					■	
10010.00																				BC		
10010.50	○					○														BC		
10012.00		○		○	■	■				○	○	●	●		◆	W-P		○	○	BC		
10013.00	○	○	○		●	■							○			W						
10014.00	○		○		●	■				○						W-P						
10014.50		○	●			■							○			W-P		●				
10015.00	○	○				■										W-P	◆					
10016.50	○	■	○	●	●	■	○	○		○	●	○	○			W-P				BC	■	

KEYS

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Figure 2 (cont'd): Paleontological data sheet of the Sotong limestone Note the predominance of sessile or encrusting foraminifera and corals in the gray limestone (9736'-9760') compared to the black limestone (10000' -10017').

PL. 1

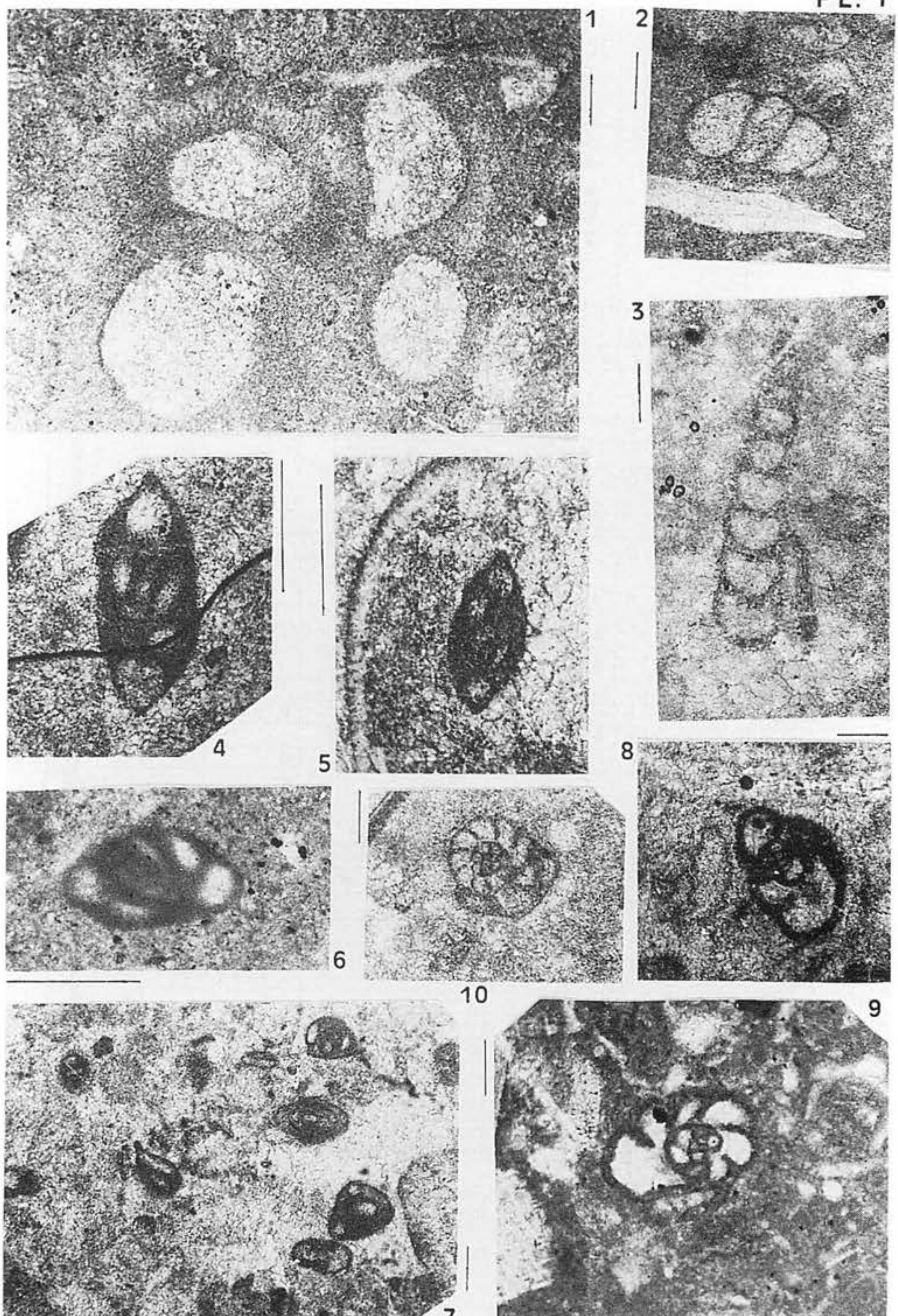

PLATE 1

Scale bar = 0.2 mm

Figure 1: *Panormidella aggregata* Senowbari - Daryan 1984. From the black limestone at a depth of 10,015 feet. In association with sponges and Bryozoa.

Figure 2: "Incertae sedis" which had been described in Permian limestone (Tien in: Fontaine *et al.,* 1986) and which is found here in the gray limestone at depth of 9750 and 9748 feet. It has been noticed also in the ditch cuttings (drill chips) at a depth of 9195 feet. Consequently, this genus ranges at least from Middle Permian to Upper Triassic (see also Pl. 6, Fig. 4).

Figure 3 – Nodosariidae from the gray limestone at a depth of 9,757.5 feet. This horizon is rich in fossils.

Figures 4, 5 & 6 – *Sigmoilina* – like foraminifera. From the ditch cuttings (drill chips) at depths of 9445 feet (Fig. 4), 9295 feet (Fig. 5) and 10,012 feet (Fig. 6).

Figure 7 – A limestone fragment from ditch cuttings (drill chips) at a depth of 9,115 feet, particularly rich in foraminifera.

Figures 8, 9 & 10 – *"Endothyra"*. From the black limestone (10,016.5 feet, 9), from the gray limestone (9,752 feet, fig. 10) and from the ditch cuttings (drill chips) (9,225 feet, fig. 8).

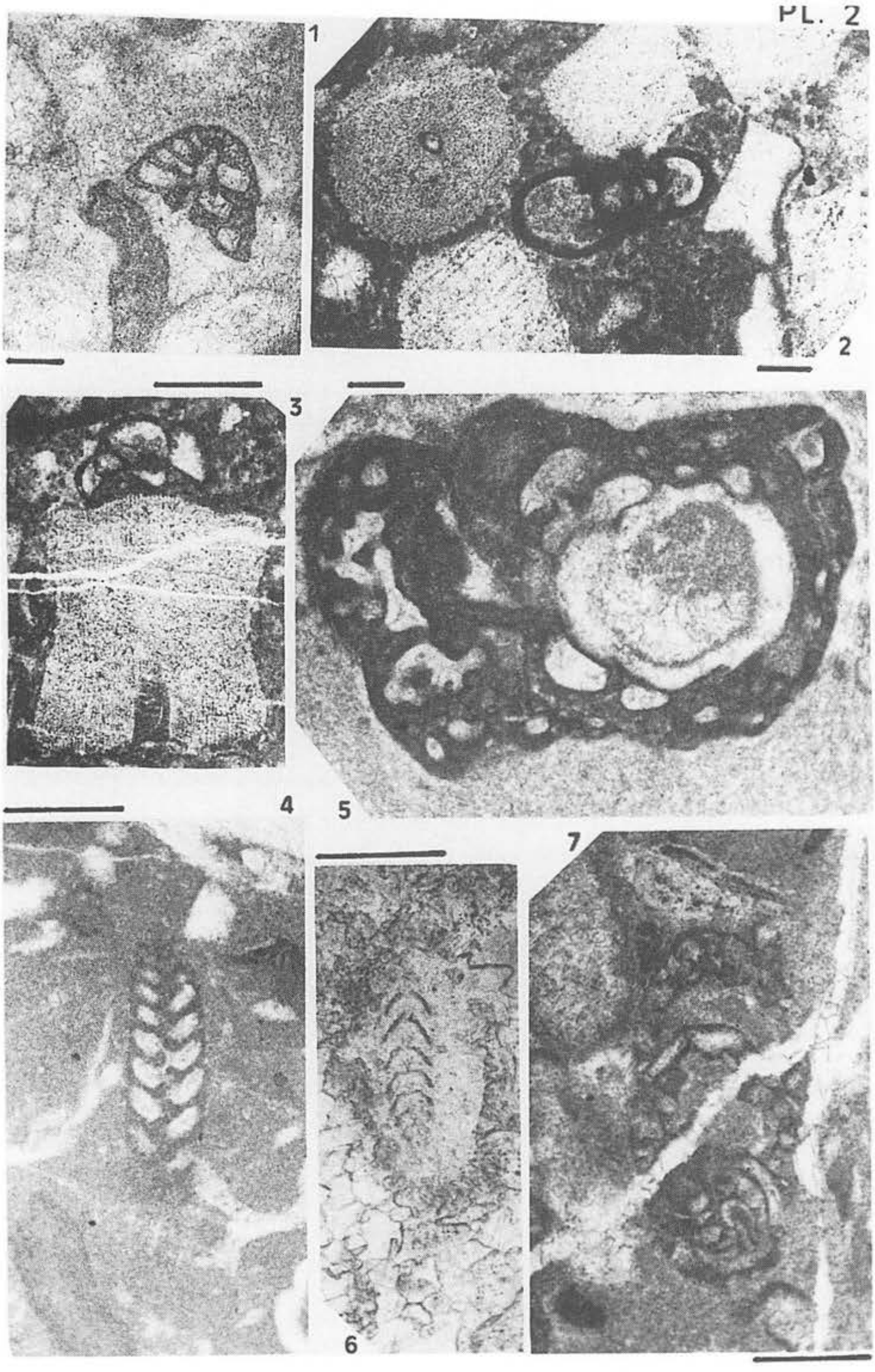
PL. 2
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PLATE 2

Scale bar = 0.2 mm

Figure 1 – *Tetrataxis*. Two specimens have been recognised in the gray limestone at a depth of 9760 feet. Another specimen has been found at a depth of 9757.5 feet. This genus is also probably present at a depth of 9759.5 feet. Accordingly, it appears that it is restricted to a narrow horizon between 9757.5 and 9760 feet.

Figure 2 – *"Endothyra"*. From the black limestone at a depth of 10016.5 feet. Another specimen has been found at the same level (see Pl. 1, Fig. 9).

Figure 3 – Sessile foraminifera (Calcivertellinae?) attached to an echinoderm fragment in the black limestone at a depth of 10016.5 feet.

Figure 4 – *"Palaeotextularia"*. From the gray limestone at a depth of 9759.5 feet.

Figure 5 – Foraminifera encrusting a bioclast. Gray limestone at a depth of 9760 feet.

Figure 6 – *Austrocolomia?* Gray limestone at 9759.5 feet.

Figure 7 – Foraminifera. Gray limestone at 9759.5 feet.

PL. 3

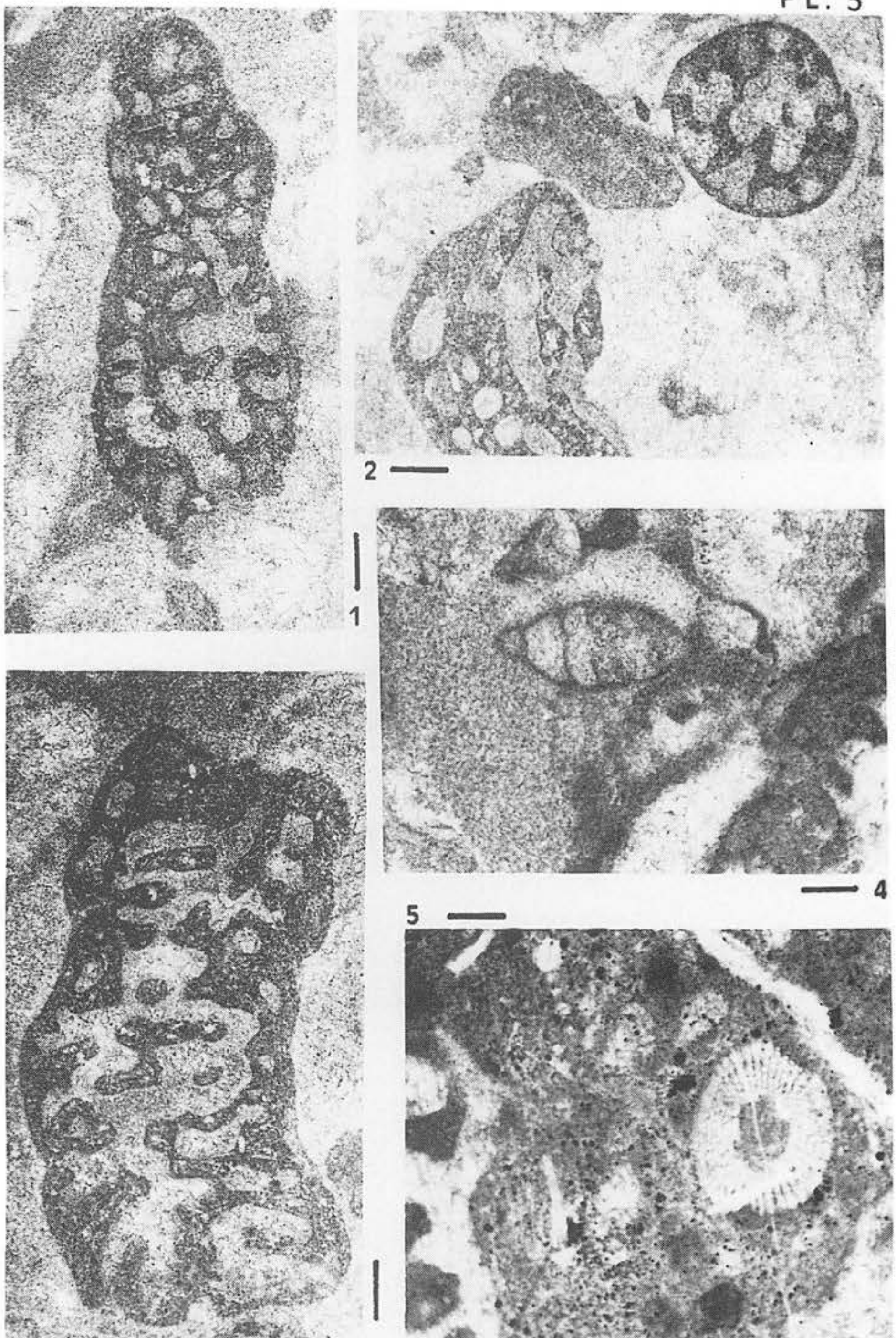

PLATE 3

Scale bar = 0.2 mm

Figures 1, 2 & 3 – Sessile foraminifera common in the gray limestone and very abundant at a depth of 9760 feet, where 17 specimens have been found in a single thin-section. This foraminifera is also present in the black limestone where it is rare.

Figure 4 – Foraminifera from the gray limestone at a depth of 9760 feet.

Figure 5 – Echinoderm fragment in the black limestone (wackestone) at a depth of 10015 feet. Note also the sponge fragment.

PL. 4

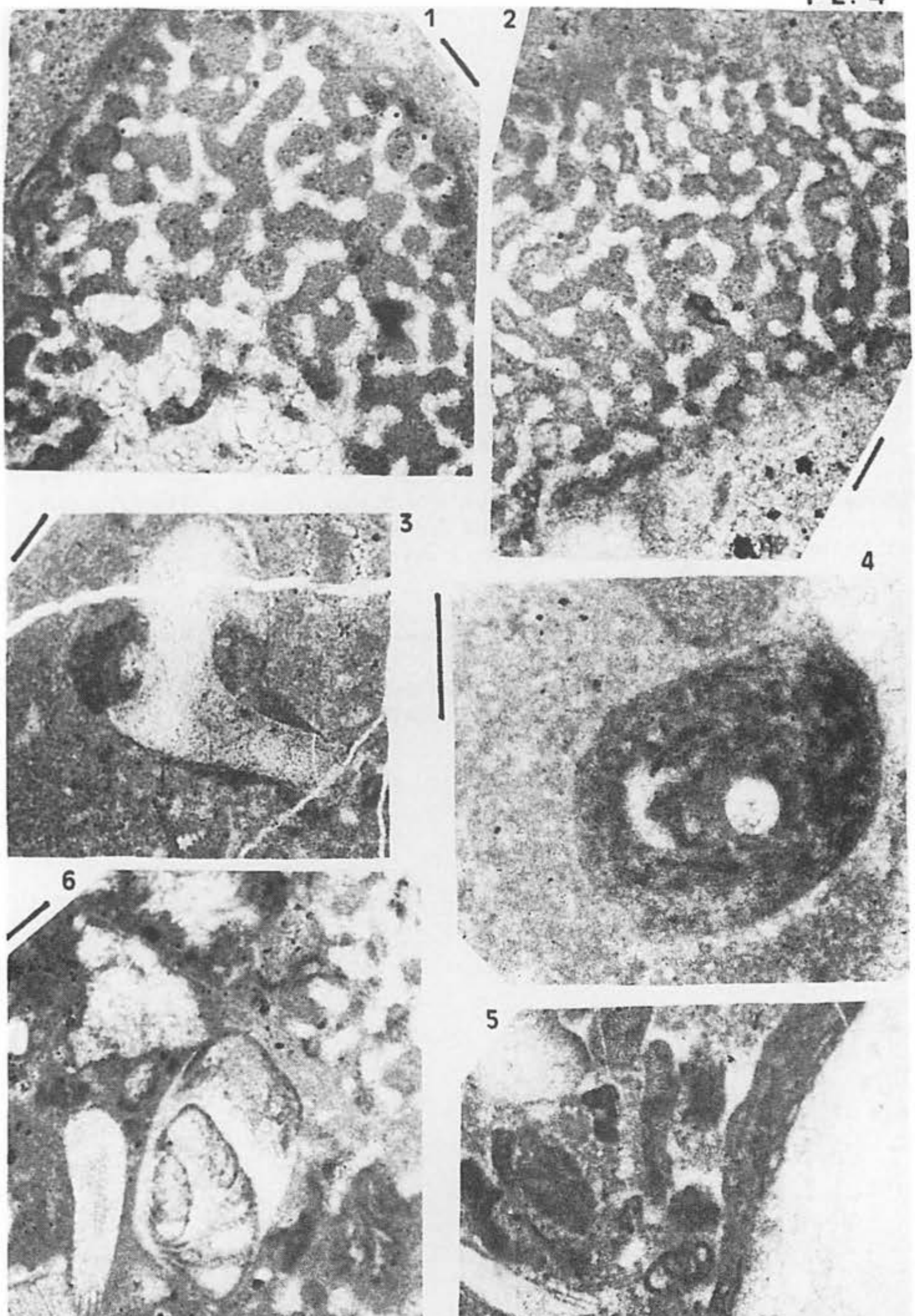

PLATE 4

Scale bar = 0.2 mm

Figures 1, & 2 – Calcareous sponges. Black limestone at 10012 feet (Fig. 1) and 10008 feet (Fig. 2). The sponge of Fig. 1 is partly encrusted by a "black envelope".

Figure 3 – *Tubiphytes* encrusting a fragment of echinoderm. Black limestone at 10016.5 feet.

Figure 4 – Transverse section of a *Tubiphytes* branch. Black limestone at 10016.5 feet.

Figure 5 – Fragment of a coral entirely recrystallized and coated by a "black envelope" (*Tubiphytes* ?). Wackestone-packstone of the base of the black limestone at 10016.5 feet.

Figure 6 – Foraminifera, sponge and echinoderm fragments from the black limestone at 10006 feet.

PL. 5

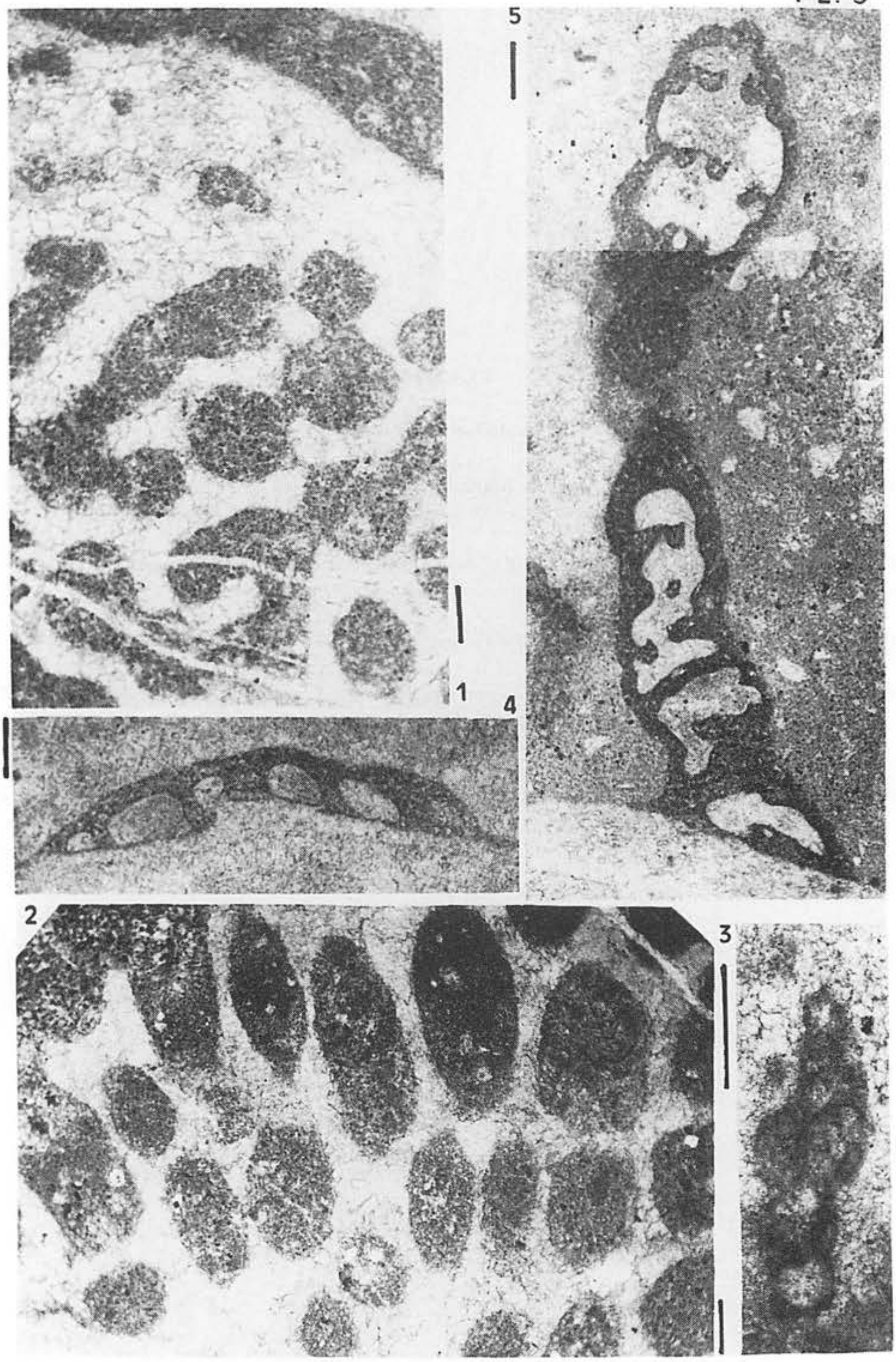

PLATE 5

Scale bar = 0.2 mm

Figure 1 – Calcisponge. This specimen displays a thicker skeleton than the two samples of Pl. 4 (Fig. 1 & 2). Similar examples are found in the black and in the gray limestone.

Figure 2 – Bryozoa/Tabulozoan which is frequent in the gray limestone but rare in the black limestone.

Figure 3 – Small foraminifera (*Reophax* ?) found in the black limestone at a depth of 10012 feet.

Figure 4 – Encrusting foraminifera. Gray limestone at 9760 feet.

Figure 5 – Sessile foraminifera, *(Alpinophragmium perforatum)*. Black limestone at 10013 feet.

PL. 6

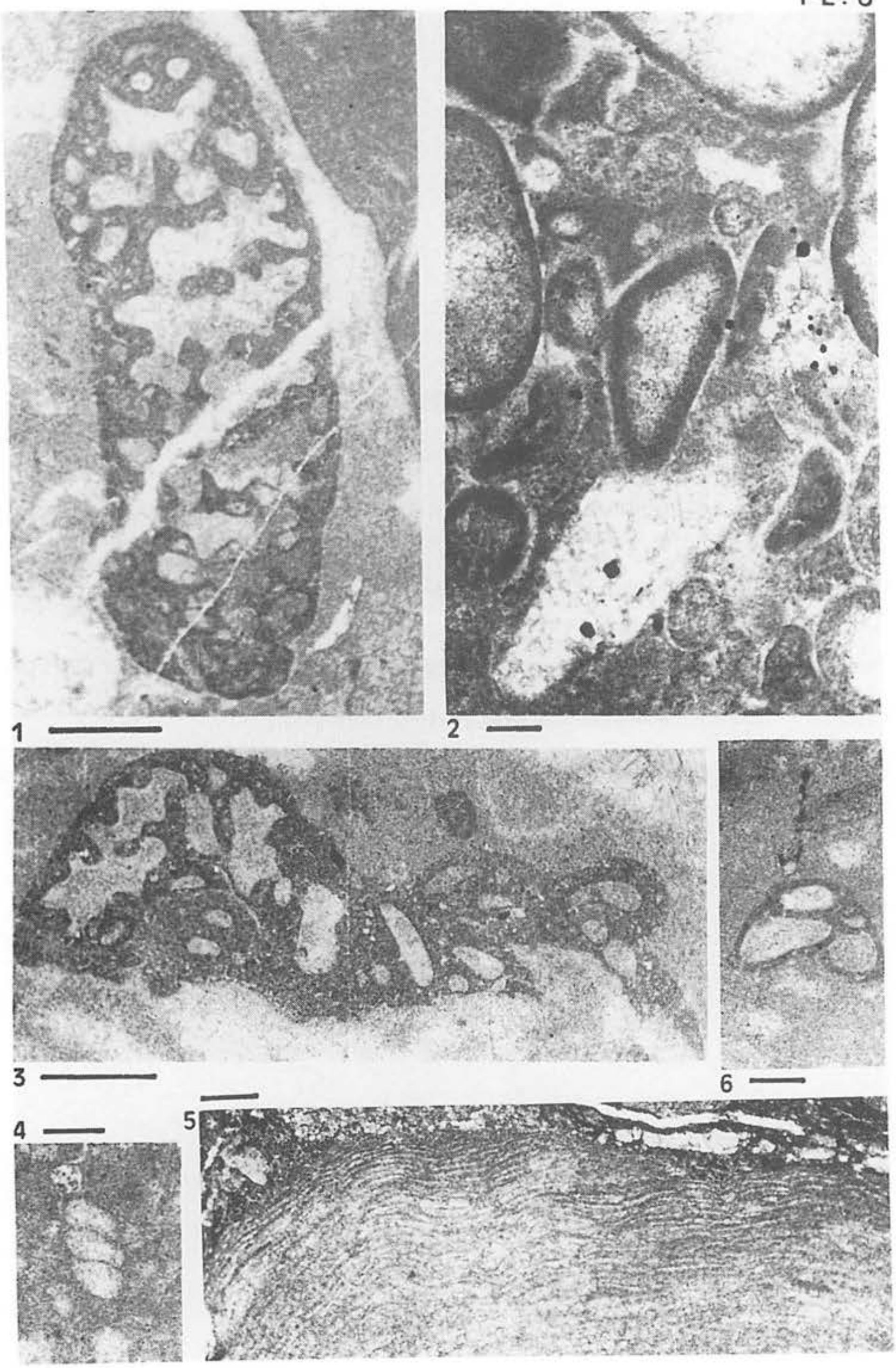

PLATE 6

Scale bar = 0.2 mm

Figure 1 – Foraminifera fragment.
(Alpinophragmium perforatum). Gray limestone at 9759.5 feet.

Figure 2 – Cortoids abundant at a horizon of the black limestone at 10007 feet.

Figure 3 – Encrusting foraminifera *(Alpinophragmium perforatum)* from the gray limestone at 9757.5 feet.

Figure 4 – "Incertae sedis" of Tien 1986. From the gray limestone at a depth of 9748 feet.

Figure 5 – Red algae. Gray limestone at a depth of 9745 feet.

Figure 6 – Small foraminifera (*Tetrataxis* ?) from the gray limestone at a depth of 9759.5 feet.

Corals

Corals (solitary and massive colonies) are few and fragmentary in the black limestone; moreover, they are restricted to the base of this limestone, with the exception of one fasciculate coral found at 10,005 ft and 10,007.5 ft. This fasciculate coral is known only by a longtudinal section with three corallites, 2.5 mm in diameter and with slightly arched tabulae about 1 mm apart; it seems to belong to *Pinacophyllum* Frech 1890, an Upper Triassic genus.

In the grey limestone, corals are abundant at some levels; they are mainly fasciculate colonies. They are very poorly preserved, being commonly entirely recrystallized; it is even difficult to know whether they belong to different species or not, for instance at depth 9744 ft and 9745.5 ft. At depth 9759 ft, they are a little less recrystallized; their corallites are 4 mm to 6 mm in diameter. They may belong to *Thecosmilia*. They are commonly not in life position.

Bryozoa/Tabulozoa.

The organisms of this group are commonly recrystallized; it is difficult to separate them. For sake of simplications, they are mentioned under the name "Bryozoa", they are rare in the black limestone and abundant at some levels of the gray limestone (Pl.5, Fig. 2), where some of them are encrusting corals, for example at depths of 9745 ft and 9753 ft. The Bryozoa belong to the Trepostomata, a group once thought extinct at the end of the Permian, but which actually survived the mass extention event of Permian -Triassic boundary and reinvaded shallow shelf settings during the Triassic (Stanley, 1988) Fenestellidae, a Paleozoic group, are lacking even though environment was favourable to them; this absence suggests a Mesozoic age, restricted to the Triassic by the presence of Trepostomata.

Brachiopods.

Brachiopods are rare.

Molluscs.

Gastropods are frequent and small in size, with the exception of one specimen which has been found at the base of the black limestone and which is moderately large (about 2 cm in height).

Pelecypods are represented by some fragments of shells which are never abundant.

Echinoderms.

Fragments of echinoderms are frequent and include many echinoid spines.

Worms.

Tubes of worms (serpulids) are occasionally present.

Ostracods.

Ostracods are scattered in the Sotong limestone: their valves are still connected.

PALEOENVIRONMENT.

In the preceding paragraphs, constructors, bafflers and binders have been mentioned. Moreover, they are included in a large scale build-up, more than 300 m thick. Accordingly, the Sotong limestone appears to correspond to a reef at least in the broadest sense of this term. It is apparently a moundlike structure organically controlled, probably lacking a recognizable organic framework; instead, it is rich in binding and to some extent baffling organisms. However, it should be stated at the onset that the observations and conclusions drawn are based on limited data obtained from a single cored well. As such the interpretations of the depositional environment of the Sotong limestone may not reflect its true nature. Occurrence of fragments of sponges, Bryozoa and echinoderms at some levels are due to taphonomic processes.

Corals do not play a predominant role as compared to the role of calcisponges. Their size is small and apparently in the small volume of the core, they are commonly not in their original growth position.

Other organisms are not large; their skeleton is not particularly strong and densely packed. No special vigorous growth is noticeable. There is no conclusive evidence of a wave resistant rigid framework coupled with a high energy nature of the associated carbonate rocks. There is no winnowed grainstone. A few levels are rich in grains and even a few oolites may be present; they are very restricted and not well washed by waves. The Sotong 'reef' is dominated more by binding than frame-building organisms; because of that winnowing has been limited. Many organisms are rather fragile and most suited to live within relatively quiet water environments. The frequency of *in situ* organisms is commonly not high; some sponges and foraminifera have been noticed in growth position and ostracods with their connected valves.

A comparison between the faunal association of the gray and black limestones suggest a more binding and frame-building character in the gray limestone (Fig. 2). This is especially evidenced in the gray limestone between 9749 ft and 9761 ft, with the predominance of encrusting foraminifera, bryozoans and some corals. Possibly the gray limestone was formed in environments with relatively shallower water and/or less restricted conditions compared to the more euxinic-looking black limestone.

On the other hand, the nature of the gray limestone is partly altered by a strong dolomitization obliterating the bioconstruction. The dolomitization occurs in two modes; as small rhombs dispersed in the microsparitic or micritic matrix and as vein-filling. Some parts of the cores, especially the upper part of the gray limestone, has fairly pervasive dolomitization. The earlier phase of matrix associated dolomitization could have resulted during an early burial stage, followed by a later phase of deep burial, fracturing and dolomitization by basinal fluids.

At present, it is impossible to compare this type of bioconstruction with limestones exposed onshore. Some Ladinian limestones like the Kota Jin limestone in Pahang, central Peninsular Malaysia (Fontaine *et al.*, 1988) or the limestone of Khoa Cha Ang On (southeast Thailand) appear to be similar; they have not been studied from a sedimentological point of view. The study of the Sotong limestone must be an impetus for future studies onland.

The Sotong limestone displays affinites with some limestones of Austria in its facies and in its floral and faunal content; however, the Sotong limestone is different from some limestones of the Late Norian of Austria which contain an equal number of calcareous sponge and coral species (Schafer and Senowbari - Daryan 1981). The Sotong limestone corresponds to a subtidal environment (lagoonal or back-reef).

STRATIGRAPHIC POSITION

Permian limestones are widespread in Southeast Asia (Fontaine *et al.*, 1986); consequently, when limestones have yielded poorly preserved fossils difficult to identify, they have generally been assigned to the Permian on a lithological basis. In pervious studies, the Sotong limestone has been treated in the same way, even though it contains no typical Permian or even Paleozoic fossils as fusulines, Fenestellidae and others.

The fossils of the Sotong limestone are dominated by calcisponges and bryozoans; *Tubiphytes* and corals are also present. These assemblages have been described in the Triassic of the Tethyan realm. In addition to the type of community, fossils also indicate separately a Triassic age. Sponges and corals suggest a Middle-Late Triassic age, and all the focus is more indicative of a Late Triassic age.

A worldwide marine regression is known at the end of the Carnian after an eustatic maximum high sea-level stand during the Ladinian and the Carnian. Whereas sea reinvaded some other parts of the world during the Norian, there was only a small renewed expansion of sea in Southeast Asia, restricted to a few areas and limited commonly to Lower and more rarely Middle Norian; however, in Sarawak, the Philippines, Timor and Seram Islands, the Upper Norian has been documented. Because Carnian strata are widespread around the Gulf of

Thailand (Thailand, Vietnam, Peninsular Malaysia), the Sotong limestone belongs probably to Middle and Late Triassic age.

REGIONAL SETTING AND IMPLICATIONS

The Upper Triassic corresponds to the youngert marine strata known in East Thailand, Peninsular Malaysia and a great part of Vietnam, Laos and Cambodia. In the southern part of Vietnam, Laos and Cambodia, marine sediments include locally Lower Jurassic beds. Middle-Upper Jurassic beds have been found only in West Thailand, Sumatra, Borneo, the Philippines and East Indonesia. By the end of the Triassic, many areas emerged because of the Indosinian orogeny. The discovery of the Upper Triassic in the Malay Basin suggests that one may expect to find, within the Sunda Shelf areas of the South China Sea, the whole sedimentary sequence known onshore elsewhere in the region.

In southeast and peninsular Thailand, the Carboniferous, the Permian and the Triassic have been documented; in west peninsular Thailand, even the Lower Paleozoic has been evidenced, but there, it is another terrane. In central Peninsular Malaysia, a sedimentary sequence ranging from the Lower Carboniferous to the Carnian is well exposed in the Kelantan and Pahang states (= Central Basin of Fig. 3). In Sumatra and Sarawak, Carboniferous to Cretaceous marine sediments are known. In the eastern part of the Gulf of Thailand, the Carboniferous has been described at the Pirates Archipelago; the Permian is widespread from Ha Tien in south Vietnam to south Cambodia; the Triassic has been evidenced at Hon Nghe, an island south-east of Ha Tien. These strata disappear towards the west below a thick continental sequence (similar to the Gagau Group of Malaysia) exposed in south-west Cambodia (Cardamones and Elephant Mts.) and extending to some islands of the Gulf of Thailand (Phu Quoc) down to Pulau Panjang, where it has yielded abundant fossil wood.

From all these data, a sequence ranging from the Lower Carboniferous to the Upper Triassic may be expected as probably subcropping in the Gulf of Thailand and Malay Basin.

However, Terengganu state raises a problem (Fontaine and Khoo, in press); the Permian and particularly the Triassic are poorly represented in this state, suggesting an emergence. Fossil plants, Permian in age, have been mentioned at Pulau Redang (Khoo *et al.*, 1988). In comparison, Kelantan and Pahang states present a thick sequence of marine sediments and many stages and substages of the Carboniferous, Permian and Triassic have already been strongly evidenced. Whereas subsidence was active in Kelantan and Pahang states during the Carboniferous-Triassic interval, Terengganu remained a high (maybe because of a paleo Lebir-Fault?), especially after the Middle Carboniferous. After the discovery of Triassic limestone in the Malay Basin and the possible presence of older marine strata, the Terengganu state appears to have been a horst block between two subsiding basins for a long time.

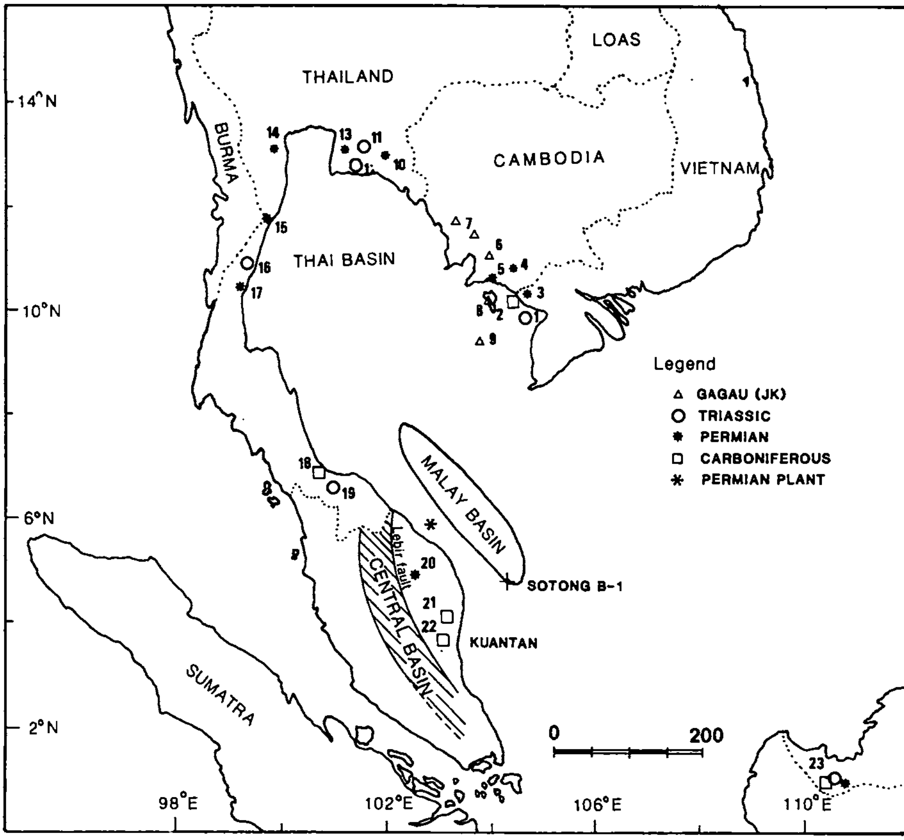

Figure 3: Regional map of part of Southeast Asia showing the offshore Malay and Thai Tertiary sedimentary basins as well as locations of onshore Carboniferous to Trassic outcrops. The numbers 1 to 24 refers to the following localities:

1. Hon Nghe;
2. Pirates Archipelago;
3. Ha Tien;
4. Kompong Trach;
5. Kampot
6. Elephant Mts.;
7. Cardamomes Mts.;
8. Phu Quoc;
9. Pulau Panjang;
10. North of Chanthaburi;
11. Khao Cha Ang On;
12. Klaeng;
13. Liewadi Lake near Sri Racha;
14. Ratburi;
15. Prachuabkirikan;
16. Khao Lak (possibly includes Lower Jurassic) ;
17. Chumphon;
18. Songkla (Carboniferous);
19. Songkla (Triassic)
20. Bukit Biwah - Bukit Taat;
21. Sungai Simpang (south Terengganu)
22. Bukit Panching, Bukit Charas (east Pahang)
23. west Sarawak with Terbat Formation (Middle Carboniferous to Lower Permian) and Sadong Formation (Triassic);
24. Pulau Redang.

Note: The Central Basin of Peninsular Malaysia has an extensive sedimentary sequence of Carboniferous to Triassic age.

The discovery of a Triassic limestone in the Malay Basin leads to another remark. The Triassic limestone exposed on land in peninsular Malaysia has been dated by studies of diverse fossils (Fontaine *et al.*, 1988); they have not been thoroughly described by depicting their floral and faunal assemblages as well as their sedimentology. Accordingly, it is difficult to compare the Sotong limestone, poor in good stratigraphic markers, with a similar limestone exposed on land.

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