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Sedimentology of Upper Jurassic Deposits in the Tembesi River Area, Central Sumatra

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Abstract: In the Tembesi River area, the Upper Jurassic crops out along two parallel NW-SE oriented lines. It consists of black, massive or bedded limestones interbedded with either black, more or less laminated shales or with more or less shaley sandstones.

The limestones include numerous Madreporaria which indicate an Upper Jurassic age.

Examination of the limestone microfacies leads to them being interpreted as mud-mounds of microbial origin (bioclasts encrusted with micrite and various algal structures, occurrence of filaments in the sparite, rhombohedrons of dolomite, bituminous stylolites, fenestrae, etc.).

The study of the clay minerals contained both in the marls, the shales, the sandstones and in the mud-mounds themselves, indicates a close shore deposit with sporadic influx of terrigenous sediment coming periodically from the continent.

INTRODUCTION

Up to now, the Jurassic of Sumatra has been poorly known and Jurassic corals and coral formations have not been subject to special studies. Fontaine, *et al.* (1984) recognised for the first time the importance of Upper Jurassic reef formations in the country. In 1983, a field trip organized with the participation of the CCOP-ESCAP (Bangkok), the GRDC (Bandung), the French oil company CFP and the CNRS (Paris), allowed the authors to begin more detailed studies of these formations.

The Upper Jurassic of Sumatra is reliably known in four areas (Figure 1): The Atcheh area (North Sumatra), the Padang area (West coast), the Tembesi River area (Central region) and the Gumai Mountains (South Sumatra).

The Upper Jurassic sediments comprise black, massive or bedded limestones interbedded either with more or less laminated black shales or with more or less shaley sandstones. These limestones were previously called "reef limestones" by Tobler (1923) due to the numerous corals occurring in these formations.

Coral species in the limestones indicate a Kimmeridgian age in the Padang area, and a Tithonian age in the Jambi area. The species recorded are known throughout the Tethysian

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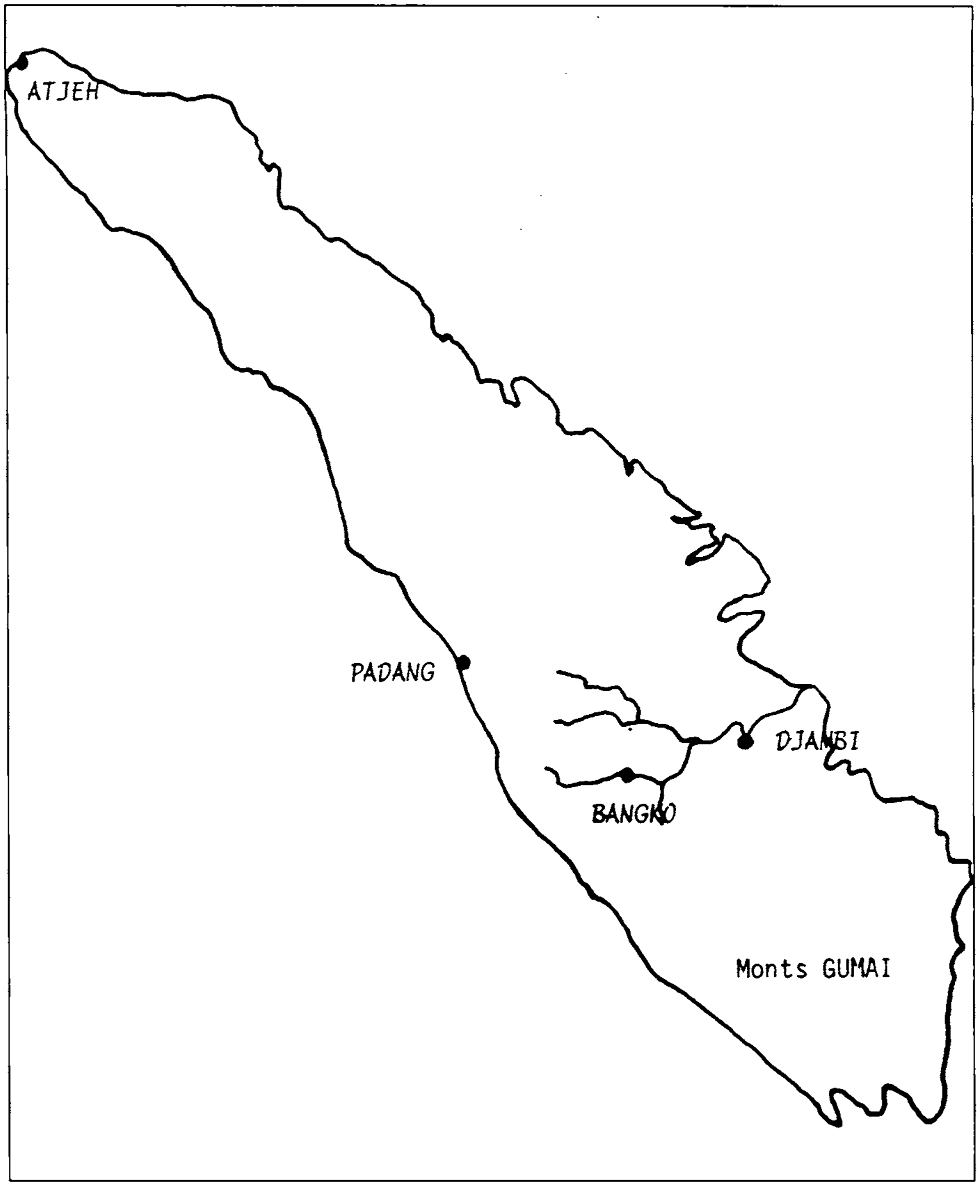

Figure 1: Map showing the Upper Jurassic areas of Sumatra

basin (France, Switzerland, Romania, Poland, Czechoslovakia) but they are smaller than the ones elsewhere known and they never built true reef frameworks. Thus, by comparison with living corals which change a lot in size and shape with their conditions of life, we can conclude that corals in the Jurassic of Sumatra did not grow in good environmental conditions to develop true reefs.

Sedimentological studies demonstrate those special conditions in life. The studies were made in the Tembesi River area: in the vicinity of Sungai Manao (along the Mesumai River), the surroundings of Pulau Bayur and along the Asai River. In this area, the Upper Jurassic crops out as two parallel elongate areas trending NW-SE. These areas are outlined by the outcrops of Sungai Manao, Pulau Bayur, Asai River and Mengkadai areas and by Bukit Bulan, Napalicin and Batu Brugo limestones (Bukit Radja Mounts) (Figure 2).

Microfacies studies

A. Sungai Manao area

On Ngalao Hill, 38 km west of Bangko, is found a massive, black limestone interbedded with black and laminated shales. This limestone, also found in Sungai Tengko Tengha, was interpreted as "reef limestone" by Tobler (1923). The same facies is observable throughout the Kampung Tengha and Benteng areas.

The microfacies consists of micrite with various and numerous bioclasts: Calcispherulidae, Sponge spicula, Urchin spines often corroded, encrusted by microbial organisms, Echinoderm fragments, recrystallized corals, Bryozoa, well preserved *Cladocoropsis mirabilis* (Pl. 1, Figure 1), Foraminifera and small gastropods. In some places, fragments are aligned parallel to one another as is observed in mud-mound flanks. Stylolites are abundant.

B. Pulau Bayur area

A large outcrop of black limestone is visible around Pulau Bayur, along the Tembesi River, from about one kilometre downstream up to approximately 1.5 km above the village. This limestone contains numerous Scleractinia and calcisponges. More than twenty species have been identified here (Beauvais, 1983).

The most typical microfacies observed in this formation are as follows:

1) in a level extremely rich in corals: one corallite of *Stylosmilia corallina* is coated with micrite and *Bacinella* structures (Pl. 2, Figure 7) and a fragment of coral is encrusted with *Lithocodium* and *Tubiphytes* structures (Pl. 2, Figure 1).

2) in the same level, two thin lamellar colonies of Mircosolenidae are arranged parallel to one another with the space between them being invaded by micrite organised into *Lithocodium* structure in the lower part, passing up into micrite of *Tubiphytes* type (central layer) and then to a cambered *Bacinella* (Pl. 3, Figure 2). Before the last laminated and flat micritic episode, a layer of sparite is visible which seems to be cavity filling. On the top of the flat micritic layer, a thin film of sparite wraps a pelloid. In the upper part, an episode of faecal pellets occurs.

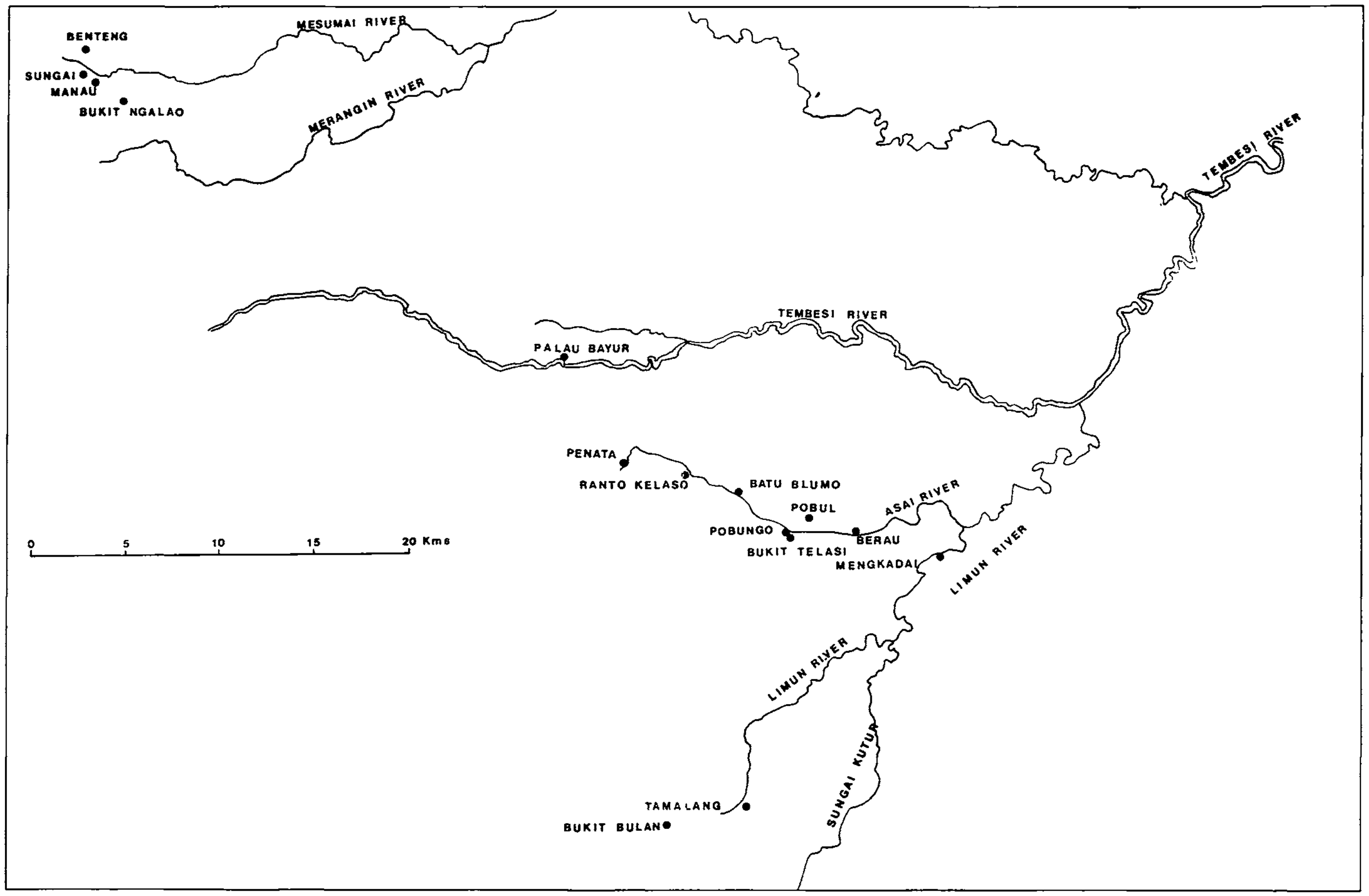

Figure 2: Map showing the Tembesi River, Sungai Manao and Asai River areas.

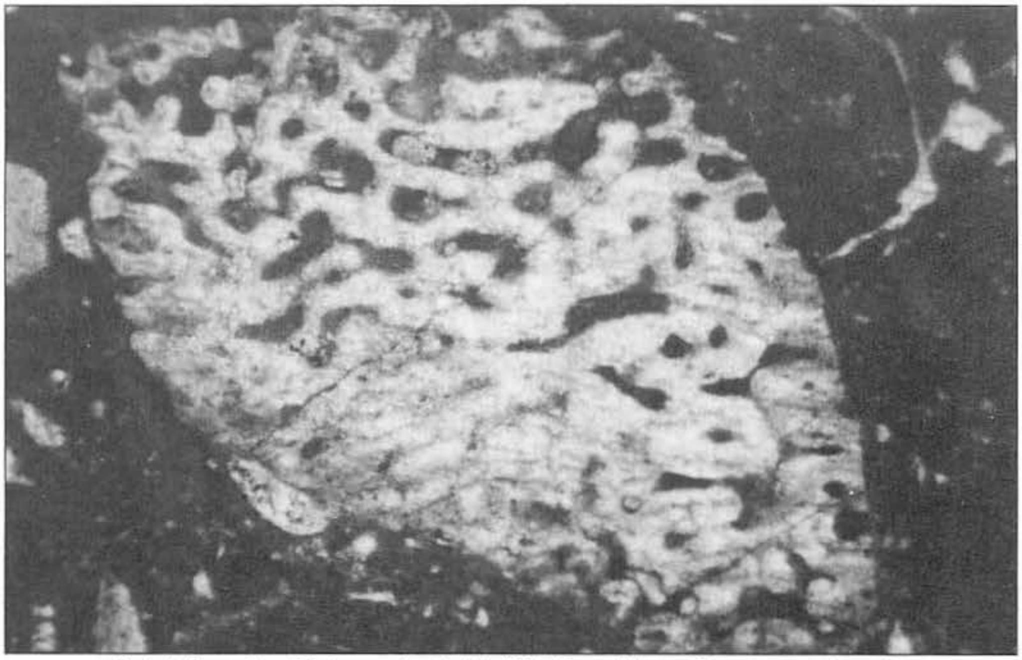

Plate 1 Figure 1: *Cladocoropsis mirabilis* Felix. Sungai Manao. Transverse section x 30.

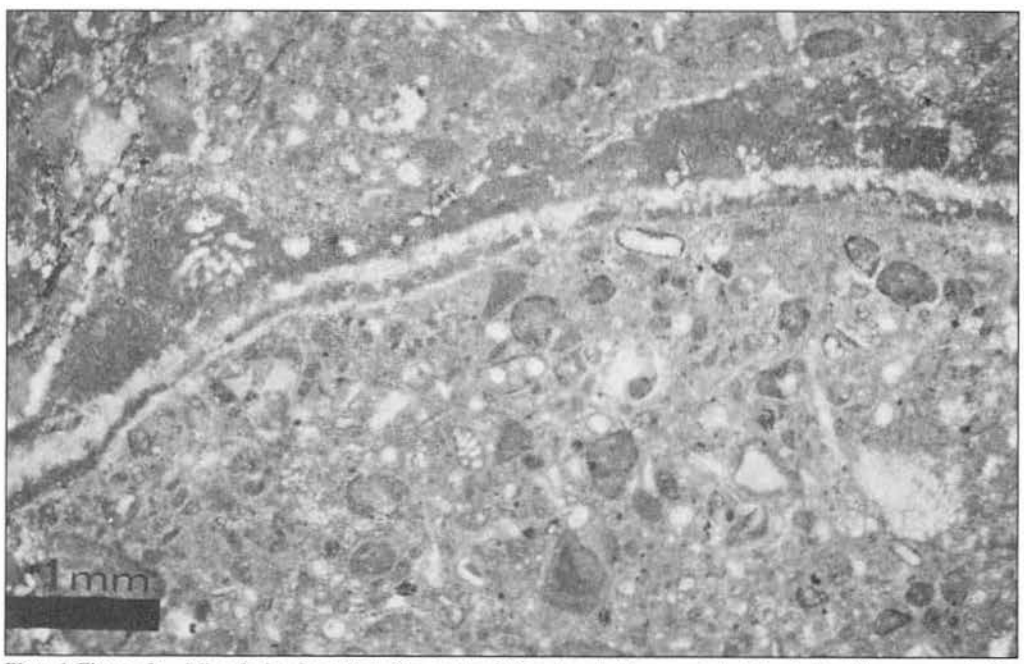

Plate 1 Figure 2: Microfacies from Batu Kauer (Asai River): a shell encrusted with micrite. The upper micritic plastering is bumpy and exhibits *Girvanella* tubes in ball arrangement?

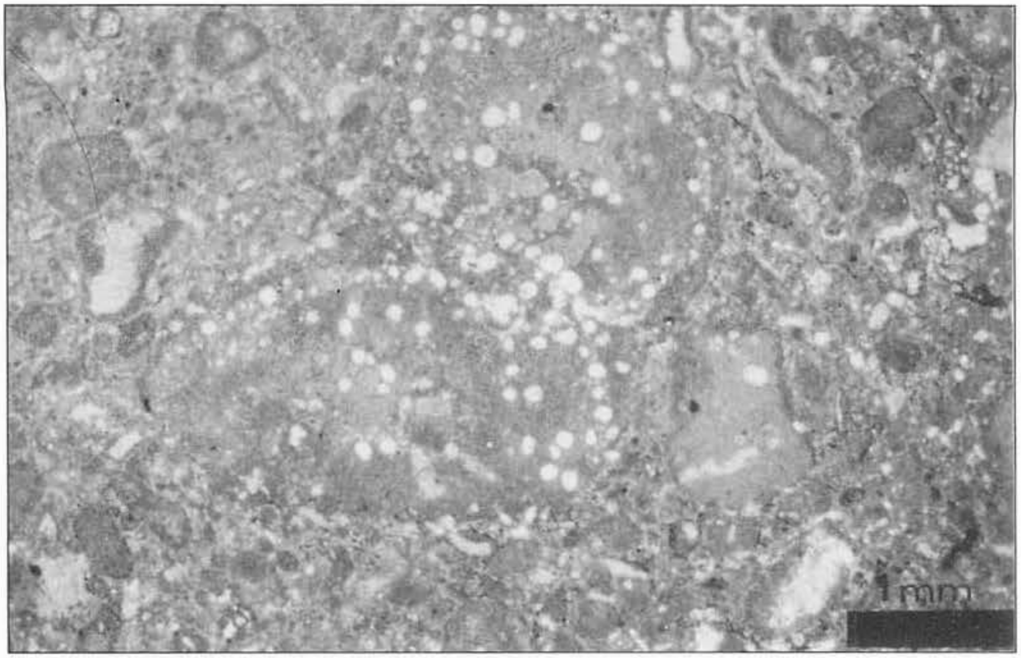

Plate 1 Figure 3: Microfacies from Batu Kauer (Asai River): aggregates of micritic pelloids in which we can see sections of *Girvanella* concentrically arranged.

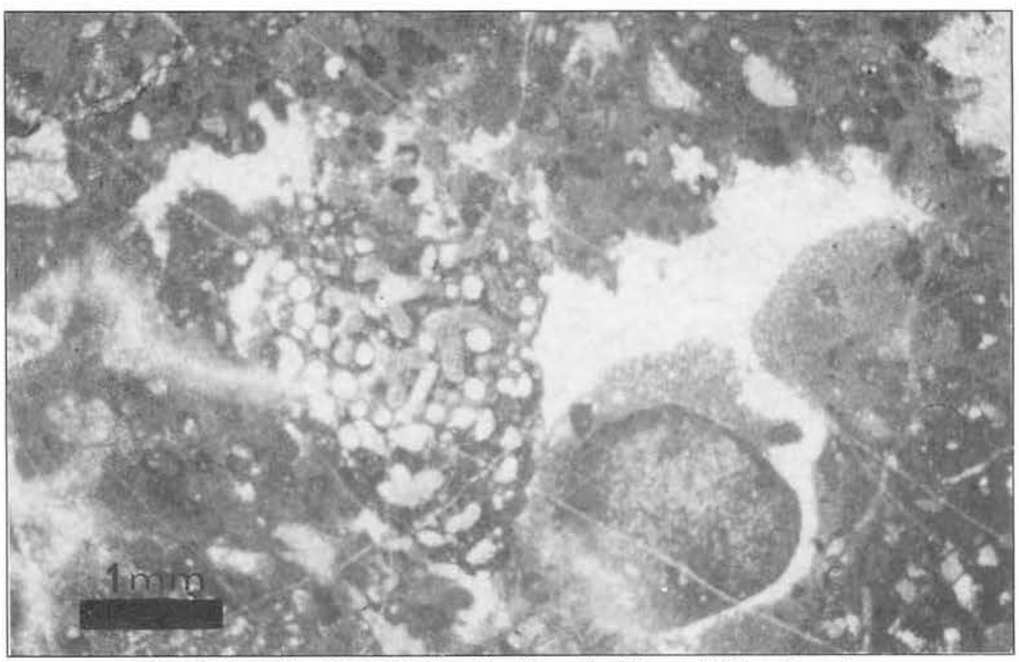

Plate 1 Figure 4: Microfacies from Batu Kauer (Asai River): infilling of a cavity.

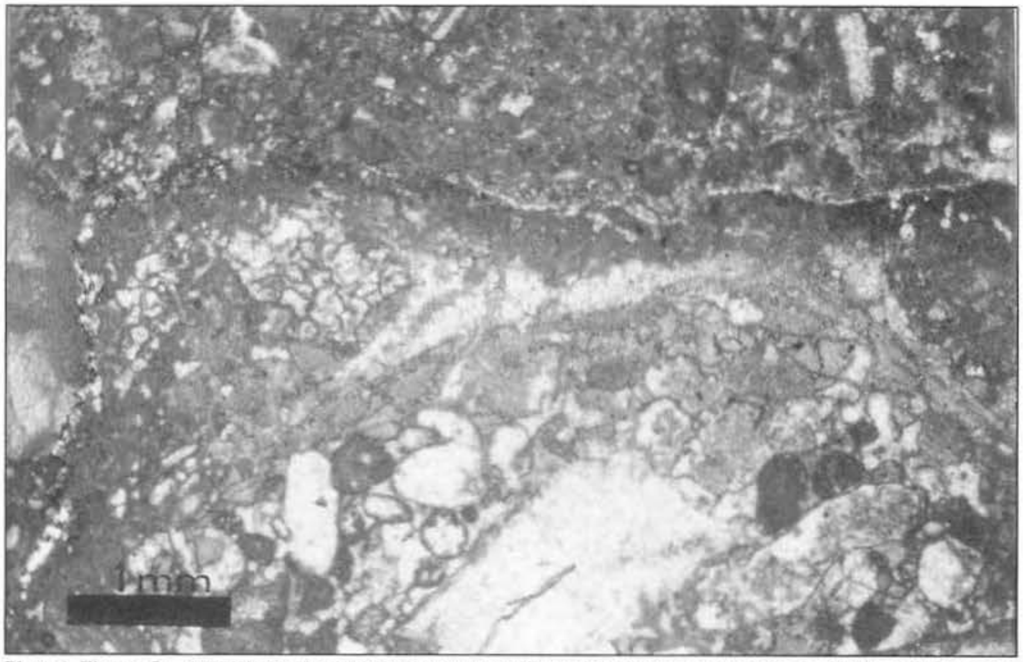

Plate 1 Figure 5: Microfacies from Batu Kauer (Asai River): *Bacinella* encrusted in a micritic pelloid matrix exhibiting micritized grains.

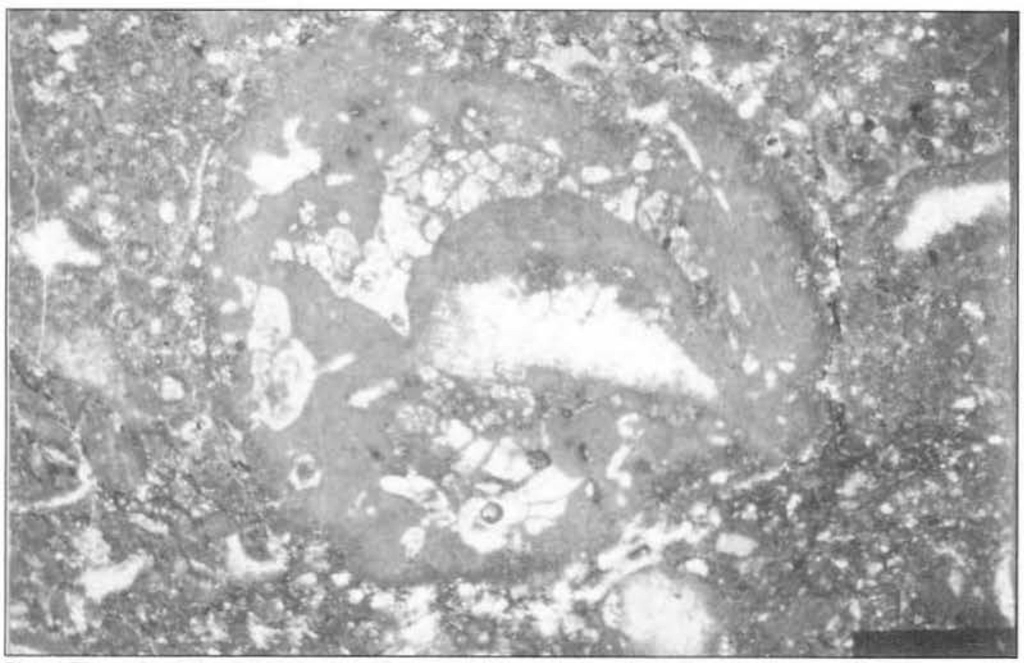

Plate 1 Figure 6: Microfacies from Batu Kauer (Asai River): one onchoid looking like a stromatolite. We can see the nucleus packed in a laminated micrite which exhibits *Bacinella* structures.

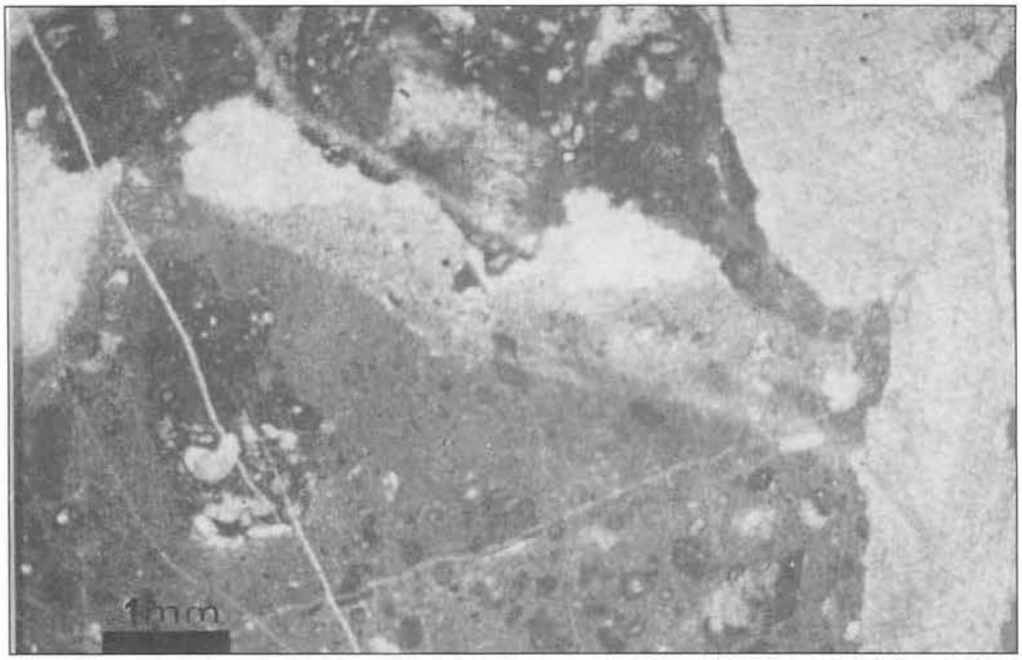

Plate 1 Figure 7: Microfacies from Batu Kauer (Asai River): a cavity infilled with geopetal crystal silt and tufts of micrite projecting down from the ceiling.

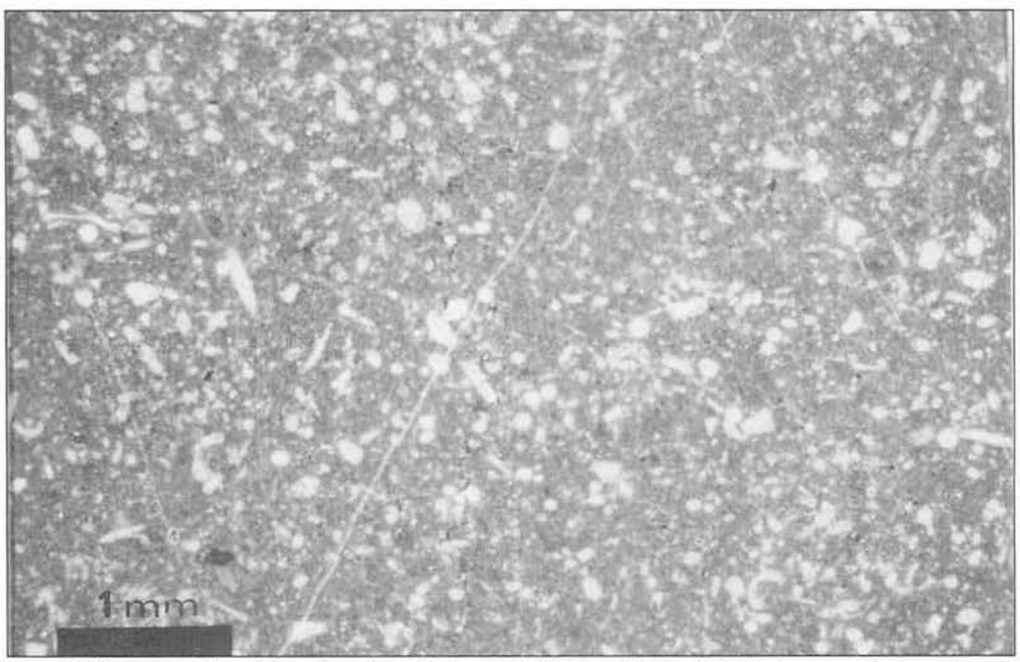

Plate 1 Figure 8: Microfacies from Batu Blumo (Asai River): micrite with Calcisponge spicula and small recrystallized bioclasts.

3) always in the same place, stromatolites may be observed (Pl. 2, Figure 4). Thus, in this stromatolite making a ferruginous protuberance, we can see a fragment of coral packed in a millimetric layer of *Bacinella* micrite and on this micrite, microsparite with girvanelloid tubes closely jointed occurs.

4) in the same limestone, a small digited tuft, laminated, made of *Girvanella* and *Bacinella* micrite is present (Pl. 3, Figure 1).

C. Asai River area

At Batu Kauer, in a limestone containing numerous fragments of gastropods, bivalves, echinoderms, sponge spicules, Foraminifera and corals, we find the following microfacies:

1) Corroded shell fragments encrusted with a micritic film (Pl. 1, Figure 2). On the underside of the shell, we can see a thin micritic layer on it, a thicker bumpy plaster showing tubes of *Girvanella* arranged in balls.

2) Onchoids (Pl. 1, Figure 6): this micritic ball, poorly laminated, looking like a stromatolite exhibits a nucleus which is a fragment of pelecypod test, packed with laminated micrite. *Bacinella* are present on both sides, wrapped again with micrite exhibiting tubes and *Bacinella* structures.

3) Aggregates of pelloids (Pl. 1, Figure 3): in the same limestone balls with sections of *Girvanella* concentrically arranged can be observed.

4) Cavities (Pl. 1, Figures 4 & 7): Throughout this outcrop we can see (Figure 7) a cavity in a pelloid micrite with, on the top, small tufts of micrite looking like stalactites. The cavity is infilled with geopetal crystal silt, the ceiling being colonized with biomicrite tufts protruding down.

This second cavity (Figure 4) exhibits a first infilling which is a micritic ball, turning into microsparite and to somewhat radiated pallissade, prior to a last mosaic cement. The angular patch of micrite with tubes has been punching downwards through the last void.

At Batu Blumo, a micrite with calcisponge Spicules and various sparitized fragments of shells occurs (Pl. 1, Figure 8).

At Rantau Kelaso, Madreporaria become more abundant: we found colonies of *Adelocoenia corallina*, branches of *Stylosmilia corallina* binded by algal structures (*Bacinella* structures, Pl. 2, Figure 7), *Clausastraea sp., Montlivaltia sp.,* fragments of Stromatoporoids and numerous other bioclasts. Pelecypod shells may be infilled with micrite containing faecal pellets (Pl. 2, Figure 5). In a level containing numerous corals, we found micritic stromatolites in a tuft arrangement (Pl. 2, Figure 2). Over the micrite, laminated microsparite occurs with a tube in the microsparite. The micritic central tuft is cluttered, and hence a *thrombolite* (i.e. a stromatolite not laminated but with a cluttered structure).

In another thin section of this coral limestone, we can see (Pl. 2, Figure 6), from the base to the top: sparite, micrite with *Tubiphytes*, microsparite with *Girvanella* tubes, a sparitic

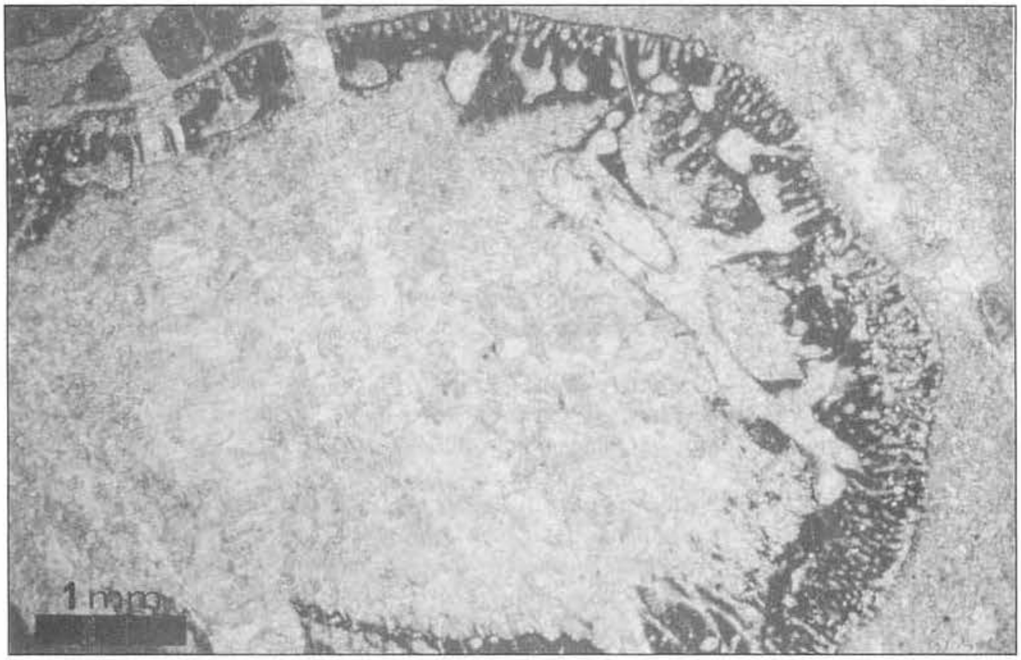

Plate 2 Figure 1: Microfacies from Pulau Bayur: fragment of sparitized and coral encrusted with micrite in *Lithocodium* and *Tubiphytes* structures.

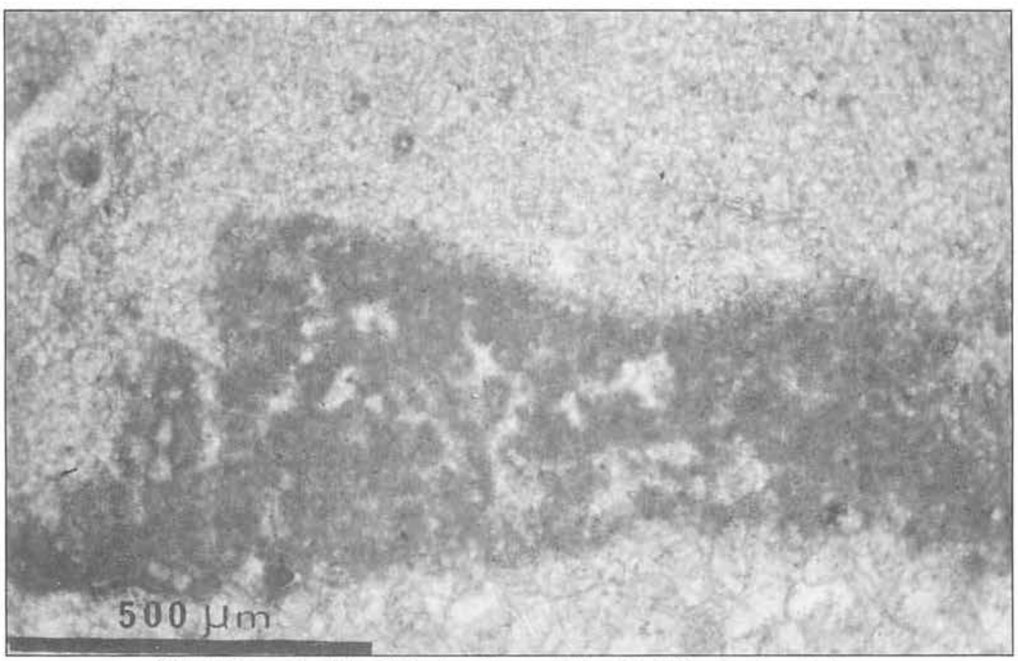

Plate 2 Figure 2: Microfacies from Rantau Kelaso (Asai River): a thrombolite.

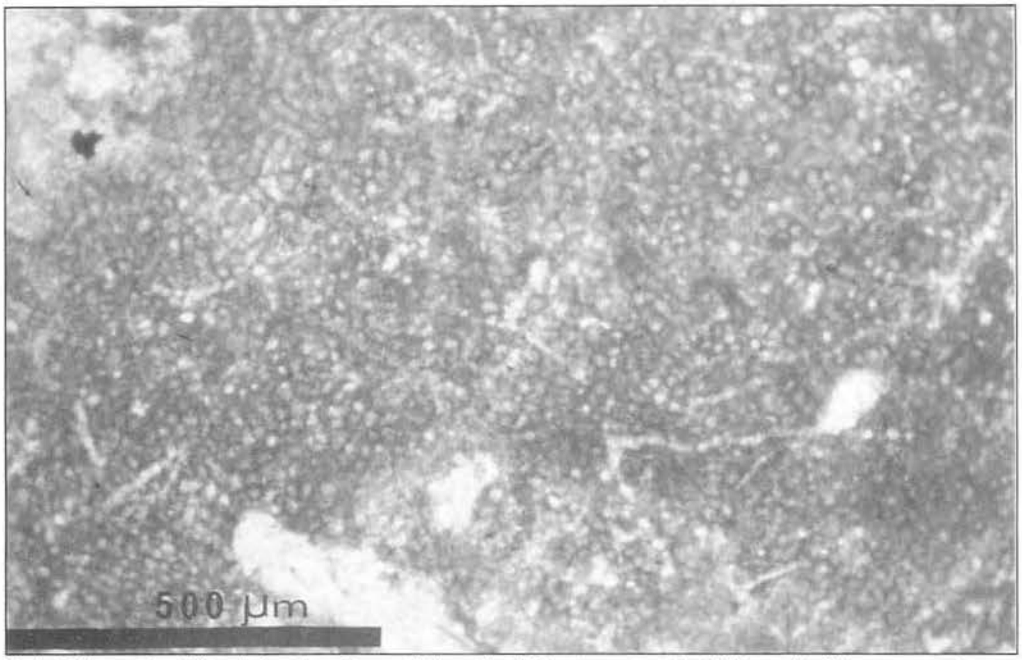

Plate 2 Figure 3: Microfacies from Rantau Kelaso (Asai River): a pure tuft of *Girvanella*. We can see at the top longitudinal sections of the filaments.

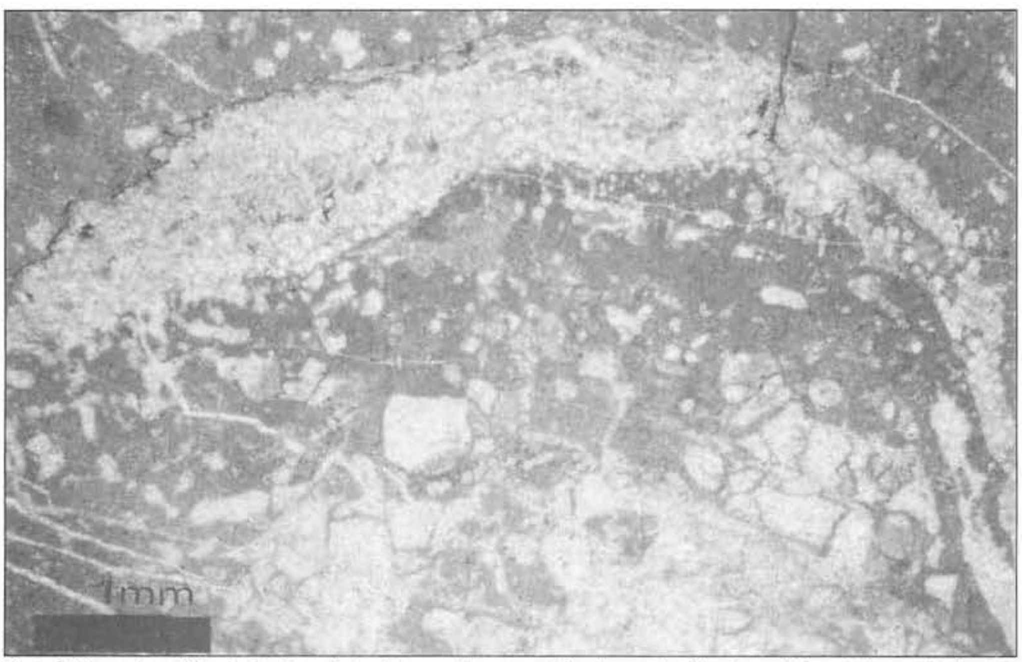

Plate 2 Figure 4: Microfacies from Pulau Bayur: a fragment of Coral coated with a first millimetric layer of microtite exhibiting *Bacinella* structures and tubes, then with a microsparite layer made of *Girvanella* tubes; all the thin section seems like a stromatolite making a ferruginous protuberance.

Plate 2 Figure 5: Microfacies from Rantau Kelaso (Asai River): a Pelecypod shell infilled with faecal pellets.

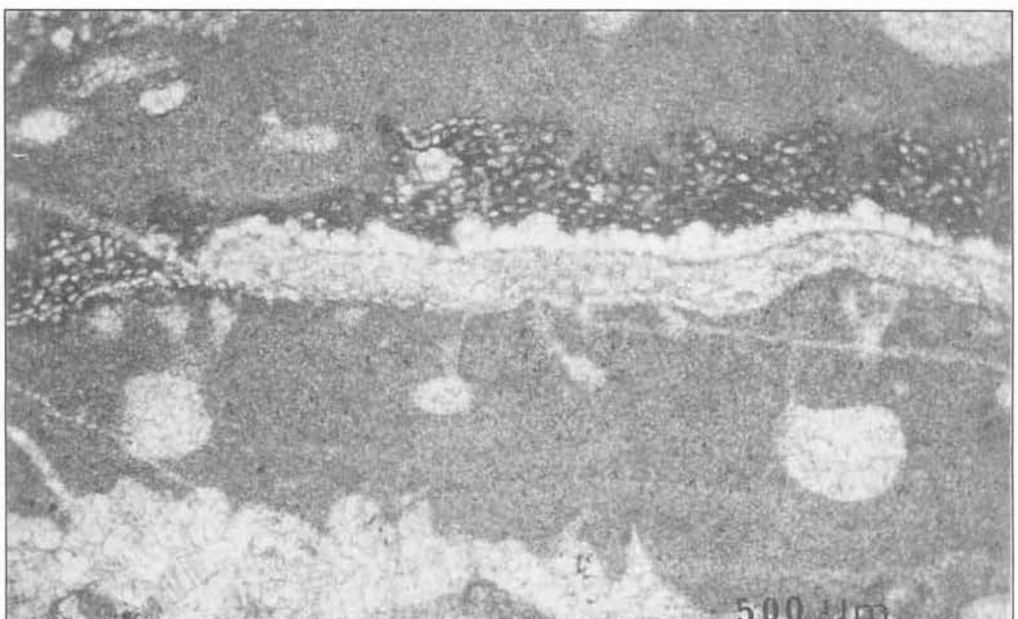

Plate 2 Figure 6: Microfacies from Rantau Kelaso (Asai River): complex encrustings: from the bottom to the top: sparite, micrite with *Tubiphytes*, microsparite, a horizontal layer of white sparite seeming like a cavity, an encrusting of true *Girvanella* rich in organic matter and arranged in tufts, and, lastly, micrite with *Tubiphytes*.

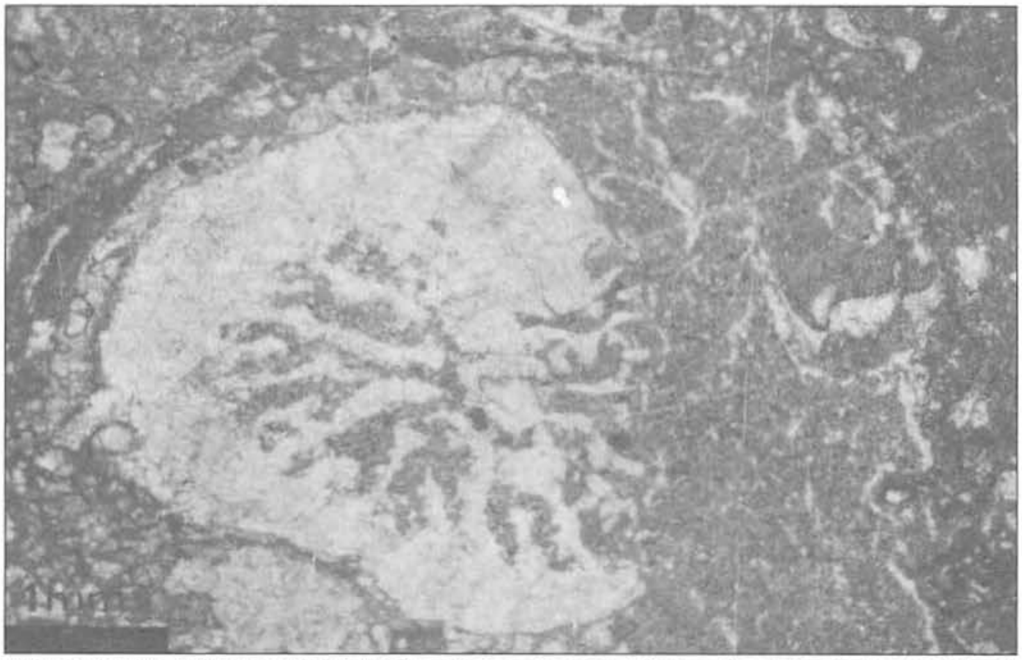

Plate 2 Figure 7: Microfacies from Pulau Bayur: Transverse section of *Stylosmilia corallina* Koby encrusted with laminated micrite and *Bacinella* (on the left).

white layer representing a horizontal cavity, an encrusting of true *Girvanella* more or less crushed, very rich in organic matter, in tufts arranged and, again, micrite with *Tubiphytes*. The flat cavity may have been formed after the upper *Girvanella* encrusting owing to a shrinkage phenomena.

Interpretation

All the above microfacies have already been described in various sedimentary formations from Ordovician up to the present which represent mud-mounds.

What is a mud-mound?

The definition of such a mud-mound was made by Bernet-Rollande, Maurin and Monty (1982). We call mud-mounds accumulations of micrite of microbial origin. The carbonate mud is produced by microorganisms: decomposition of organic substances can induce the production of very fine grained carbonates. Monty (1965) explains that algae and bacteria change the environmental conditions by reducing CO_2 to organic carbon compounds, thus shifting the solubility equilibrium toward inorganic precipitation of carbonates. Deelman (1975) demonstrated also the precipitation of aragonite through the activity of sulfate reducing bacteria.

The fenestrae result from gas produced by bacterial decay of the organic substances present in the mud.

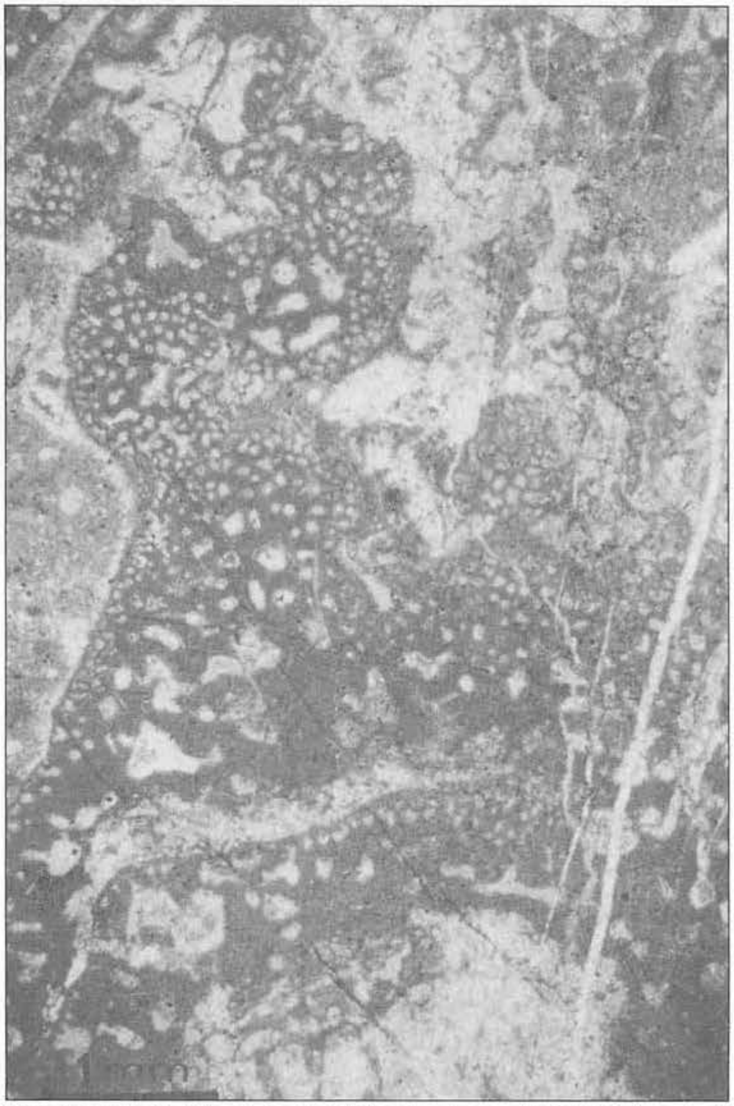

Plate 3 Figure 1: Microfacies from Pulau Bayur: a small digited tuft made of *Bacinella* and *Girvanella* micrite.

Plate 3 Figure 2: Microfacies from Pulau Bayur: two vertical sections of colonies of Microsolenidae encrusted with micrite organized into *Lithocodium* structure (lower layer), micrite with *Tubiphytes* (central layer), passing to a cambered *Bacinella*, then, to a layer of sparite, then, to a thin film of micrite. The upper part exhibits an episode of faecal pellets.

Mud-mounds possess consistent lenticular shapes throughout their known stratigraphic range. Sizes are variable from 10 m up to one km vertical or more in some cases.

Generally these mud-mounds charge themselves with dolomite.

We can see it is the case in the limestones of Sumatra: we find this dolomite with the following characteristics (Pl. 3, Figure 3): loosely packed rhombohedrons, always surrounded with organic matter, dirty, possibly zoned, often with black points, associated with micrite, and also associated with pyrite which sometimes constitute dissociated framboids.

Black centres of rhombohedrons are reminiscent of biological dolomite created within cyanobacterial mucilages. Such material is under investigation by our team.

Thus, we can see that micrite, organic matter and dolomite are closely associated and we conclude an organic microbial origin of the dolomite.

From another outcrop, between Batu Blumo and Rantau Kelaso, along the Asai River, we can observe dolomite under two aspects (Pl. 3, Figure 4): well formed rhombs and globules more or less micritic, representing incompletely formed dolomite in which we can see alternations of dolomite and micrite.

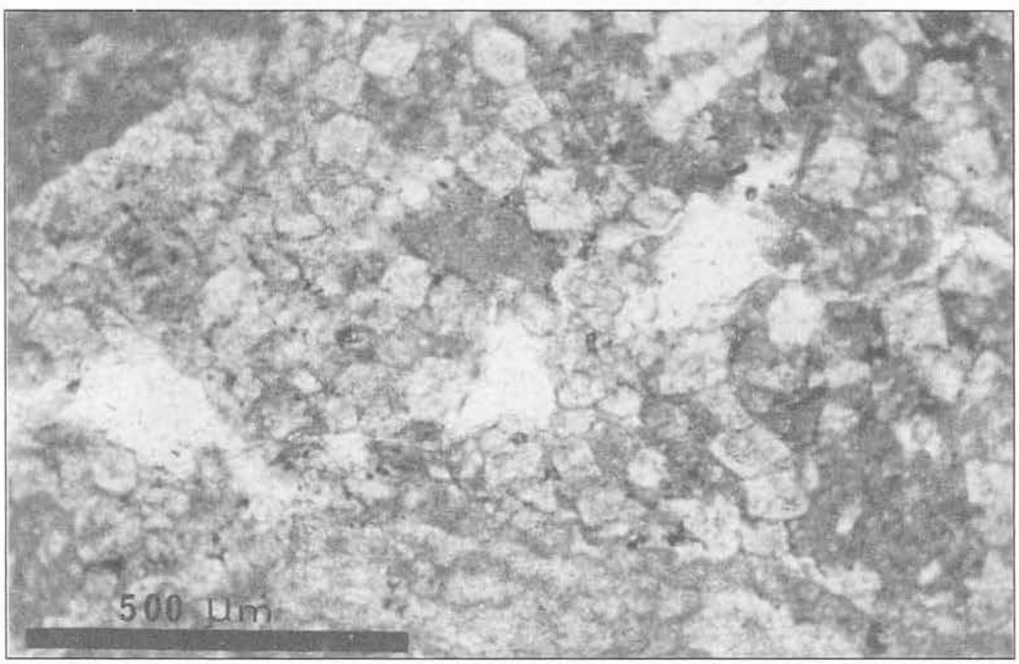

Plate 3 Figure 3: Microfacies from Pulau Bayur: loosely packed rhombohedrons of dolomite, surrounded with organic matter, zoned, with black points (on the left), associated with dissociated framboids (on the right upper corner).

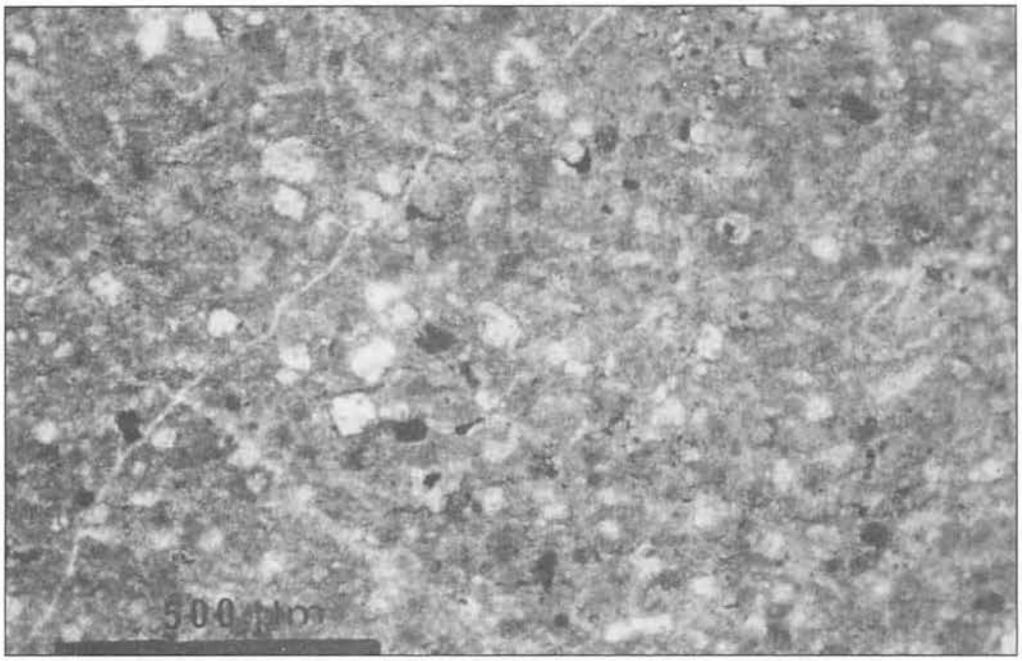

Plate 3 Figure 4: Microfacies between Batu Blumo and Rantau Kelaso (Asai River): dolomite may be seen under two aspects: well formed rhombs and zoned globules.

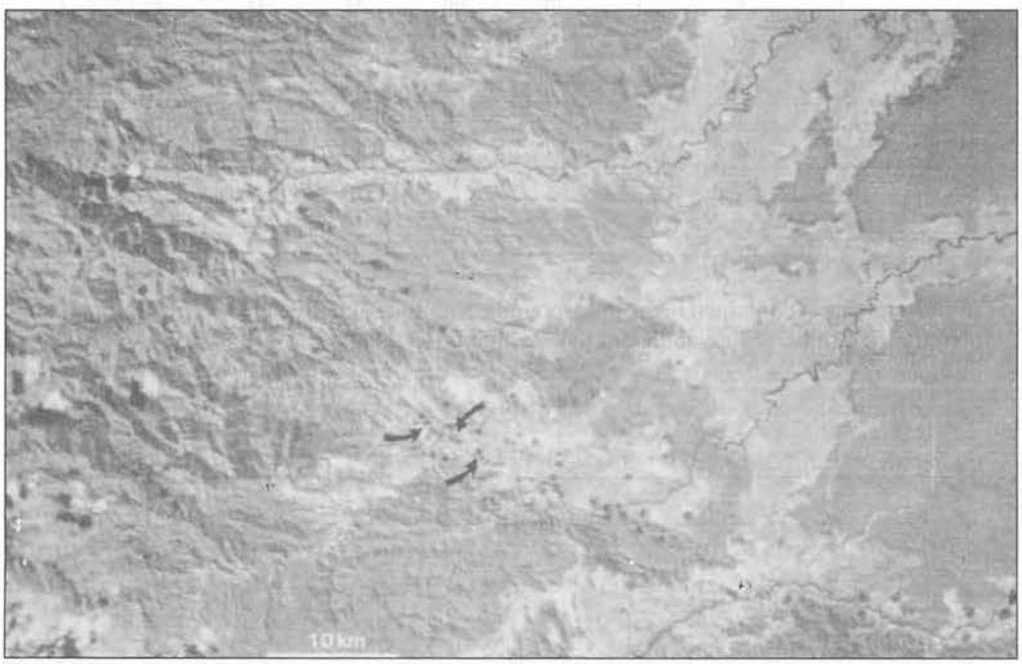

Plate 3 Figure 5: Satellite picture of the Asai River and Pulau Bayur areas exhibiting clusters of mud-mounds. The arrows point out the studied outcrops.

Conclusions

The Upper Jurassic limestones of Sumatra contains many corals which do not build true reefs. Their microfacies are smilar to those occurring in mud-mounds known all over the world from Ordovician up to the present. These mud-mounds appear on the satellite photographs (Pl. 3, Figure 5). We can see they are grouped into clusters and it is another character of the mud-mounds to occur in clusters: "you find one and you have more" wrote in a previous paper Bernet-Rollande, Maurin and Monty (1982). Echosounder, research in present seas shows morphological anomalies which fit perfectly with such fossil arrangements; they are located in the 100 metres range.

Clay minerals studies

A. Sungai Manau area (Table 1)

Chlorite does not occur in the limestone, it is only present in the shales. Kaolinite is poorly represented throughout the area. Illite is present and abundant in all levels. Interstratified clay minerals (12-14 A°) seem to be less important than smectite, indicating an early stage of evolution. Zeolite occurs both in shales and in limestones. Quartz is of neoformation and of diagenetic origin, dolomite and feldspar also occur.

TABLE 1

SUNGAI MANAO AREA

	C	K	I	Int.	Sm.	Q	D	Z	F
378	0	0	8	0	2	+	+	89	+
380	0	15	85	0	0	0	0	0	0
381 marnes	6	13	60	6	3	+	0	12	0
383	0	0	57	27	16	+	0	0	0
384	0	0	50	0	50	+	+	0	0

B. Pulau Bayur (Table 2)

No chlorite is contained in the mud mounds. Kaolinite and illite are relatively abundant. Interstratified minerals are abundant too. Zeolite is detected.

TABLE 2

PULAU BAYUR

	C	K	I	Int	Sm.	
518	0	73	12	10	5	
512	12	4	21	18	15	Q
533	0	26	32	30	13	Z
493	0	24	28	0	48	
483	0	9	33	37	23	Q

C. Asai River area (Table 3)

As in Sungai Manau, the evolution of phyllitous minerals reaches to the stage of interstratified minerals, except in scarce levels where smectite only is present. Kaolinite is relatively abundant. Quartz of neoformation and of diagenetic origin occurs. Feldspar is more or less abundant and often related to the presence of chlorite. Chlorite is scarce, and tends to be located in the terrigenous levels. Zeolite also occurs.

TABLE 3

ASAI RIVER AREA

	C	K	I	Int.	Sm.	Q	D	Ż	F
388	0	26	26	28	20	+	0	+	0
393 Schistes	0	15	85	0	0	+	0	0	+
394 marnes	20	19	54	0	6	+	0	0	+
395 marnes	15	14	48	0	23	+	0	0	+
422	0	43	31	14	12	0	0	0	0
399	7	27	56	4	5	+	0		+
430	3	19	16	0	3	+	+	52	0
398 Grés	0	72	10	0	18	+	+	0	0
399 marnes	0	40	40	0	19	+	+	0	0
404	27	40	14	0	19	+	0	0	0
405	0	88	6	0	6	+	+	0	0
406	0	50	0	0	50	+	+	0	0
415 grés	13	E	49	20	18	+	0	0	+
411	21	21	18	18	18	+	0	0	0
413 schistes	23	0	76	0	20	+	0	0	0

D. Bukit Bulan Area (Table 4)

We can note here are abundance of illite and scarcity of smectite and interstratified minerals. Zeolite is absent.

TABLE 4

BUKIT BULAN AREA

	C	K	I	Int.	Sm.	Q	D	Z	F
553	0	20	90	4	4	+	0	0	0
564	11	0	84	0	5	+	0	0	0

Interpretation

According to Millot (1964) kaolinite, illite and well recrystallised chlorite are not destroyed in a normal marine environment. Consequently, when they occur in limestones or shales, they have a detrital origin and come from adjoining continents. Kaolinite originates from a continental alteration during tectonically quiet periods. Thus an abundance of kaolinite in the mud-mounds indicates they were edified during quiet periods.

Kaolinite is more abundant in Pulau Bayur and in the Asai River areas, while the quantity of illite is larger in the vicinity of Bukit Bulan and of Sungai Manao. If we consider the schematic distribution of clay minerals given by Millot (1964, Figure 29) we can see that the predominance of the kaolonite may indicate a nearer proximity of a shore line than illite does.

Quartz of neoformation and dolomite are found mainly in the mud-mounds. This fact is consistent with the conclusion made from microfacies observations, that these minerals originate from bacterial activity.

Well crystallized illite is more abundant in the clastic sediments in which feldsparth and chlorite also occur exclusively. Thus it seems to that these minerals are directly derived from the degradation of a nearby continent.

Smectite is everywhere present; interstratified minerals are everywhere present too, but less abundant in the limestones, while zeolite is preferently present in the limestones. These facts seem to indicate that volcanism did not affect mud-mounds and terrigenous sediments in the same way, owing to their initial differences in chemical composition.

CONCLUSIONS

Corals are very abundant in the Upper Jurassic of Sumatra but did not thrive owing to the sporadic deposits of terrigenous sediments coming from a nearby continent. Thus, they did not build true reefs, but they contributed to edification of mud-mounds which were developed due to an intensive activity of microorganisms (microalgae, bacteria) in quiet environment, not more than 100 metres deep.

The alternance of limestones with shales and shale sandstones coming from a nearby continent allows us to think that the model of alluvial sequences passing laterally to marine facies observed by Hayward (1983) in a Miocene reef of South West Turkey, where clastic sediments were deposited as an alluvial fan prograding into a marine area may be applied here.

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