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Stratigraphy and palaeontology of the Carboniferous sediments in the Panching area, Pahang, West Malaysia

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Abstract: A new lithostratigraphic subdivision for the Carboniferous sediments of the Panching area, Pahang is proposed as follows; Charu Formation (Viséan—basal Namurian), Panching Limestone (Namurian A) and Sagor Formation (?Late Carboniferous). These three formations are defined as constituting the Kuantan Group.

The Charu Formation consists predominantly of interbedded sandstones, siltstones and shales. Brachiopods, found abundantly at a number of localities indicate the formation is of Viséan—basal Namurian age. The sedimentary features and fossil assemblage suggest the formation was deposited in a shallow marine near shore environment.

The Panching Limestone consists of biomicrites, biosparites, biosparudites, oomicrites and recrystallised micrites. It contains a very rich macro- and microfauna which indicates a Namurian A age. The limestone is interpreted to have formed in a warm shallow marine reefal environment. Five penecontemporaneous facies are recognisable in the limestone: micritic facies, biomicrite facies, crinoidal facies, biosparite facies and carbonaceous limestone facies. The overall fauna of the formation represents a reefal pre-climax community. A new species of heterocoral, *Hexaphyllia concavia* sp. nov. is described from the Panching Limestone.

The Sagor Formation is a sequence of conglomerate, sandstone, shale, mudstone and radiolarian mudstone, with rare limestone lenses, deposited in a relatively shallow marine environment. The precise age of the formation is not known but is interpreted to be Late Carboniferous.

INTRODUCTION

The sediments of the Panching area, Pahang (Fig. 1), were divided by Fitch (1951) into a lower "Calcareous Series" of Carboniferous age and an upper unconformable "Arenaceous Series" of ?Triassic age. The "Calcareous Series" was subdivided by Fitch (1951) into an "Argillaceous Facies" and "Calcareous Facies". Alexander (1959) replaced the term "Calcareous Series" by "Kuantan Group". The "Kuantan Group" of Alexander was not defined in terms of formal formations but is here retained and formalised. The terms "Arenaceous Series", "Argillaceous Facies" and "Calcareous Facies" are unsatisfactory in terms of modern stratigraphic practice. The lithostratigraphy of the Panching area is thus in need of revision. In this paper, a new set of lithostratigraphic units is proposed for the Carboniferous sediments of the Panching area in accordance with the international code of stratigraphical nomenclature (Hedberg, 1976).

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PROPOSED LITHOSTRATIGRAPHY

The proposed lithostratigraphic subdivision for the Carboniferous sediments of the Panching area is as follows:-

Group	Formation	Thickness (m)	Age
Kuantan Group	Sagor Formation	c.1500+	?Late Carboniferous
	Panching Limestone	c.600	Namurian A
	Charu Formation	c.1600+	Viséan-Namurian A

The distribution of these formations is given in the geological sketch map (Fig. 1). The nature of the sediments underlying the Kuantan Group in unknown at present. In the Panching area the group is overlain by ?Triassic shallow water clastic marine sediments.

CHARU FORMATION

Description

This formation consists of interbedded sandstones, siltstones and shales of approximately 1600 metres known thickness. The sandstone beds are generally of 2–5 metres thick but occasionally occur up to 15 metres. They are medium grained and massively bedded and often grade upward into siltstone of up to 3 metres thickness. Both sands and silts show ripple marks, grading and cross bedding and are bioturbated. Interbedded shale beds are usually less than 1 metre thick. Occasional impersistent limestone lenses are recorded in this unit by Fitch (1951) who also reports volcanic tuffs in the Charu Formation exposed in Sungei Batu (Fig. 1). The formation is well exposed in road cuttings between the 17th and 19th milestones on the Kuantan-Sungei Lembing road (between GR250720 and GR215727) and these road cuttings are taken as the type locality for the formation (see Fig. 2 for lithological details). The name Charu Formation is derived from the Sungei Charu which is the nearest geographical feature to the type locality. The formation is conformably overlain by the Panching Limestone. The base is not seen and the nature of the underlying strata is unknown.

Palaeontology and Age

Muir-Wood *et al.* (1948), Fitch (1951) and Yanagida and Sakagami (1971) have described fossils from various localities in the Charu Formation. In addition fossils are reported from two other localities in this paper. For details of faunas and localities refer to Table 1.

Muir-Wood *et al.* (1948, pp. 17–18) discussed the age of the Sungei Terapai fauna and concluded it was probably of Lower Carboniferous (Viséan) age, a conclusion shared by Fitch (1951). Yanagida and Sakagami's fauna from near Sungei Lembing is similar to that described by Muir-Woor *et al.* and was also considered by them to be of Lower Carboniferous age. Faunas from the Sungei Balang, Sungei Chereh, Sungei Rangoi and the road cutting near the old Gakak Mine are also regarded to be of Viséan age (Fitch, 1951). The faunas reported in this paper from the type section and just southwest of Bukit Sagu also indicate a probable Viséan age. Since the Panching Limestone stratigraphically overlying the Charu Formation is of early Namurian age

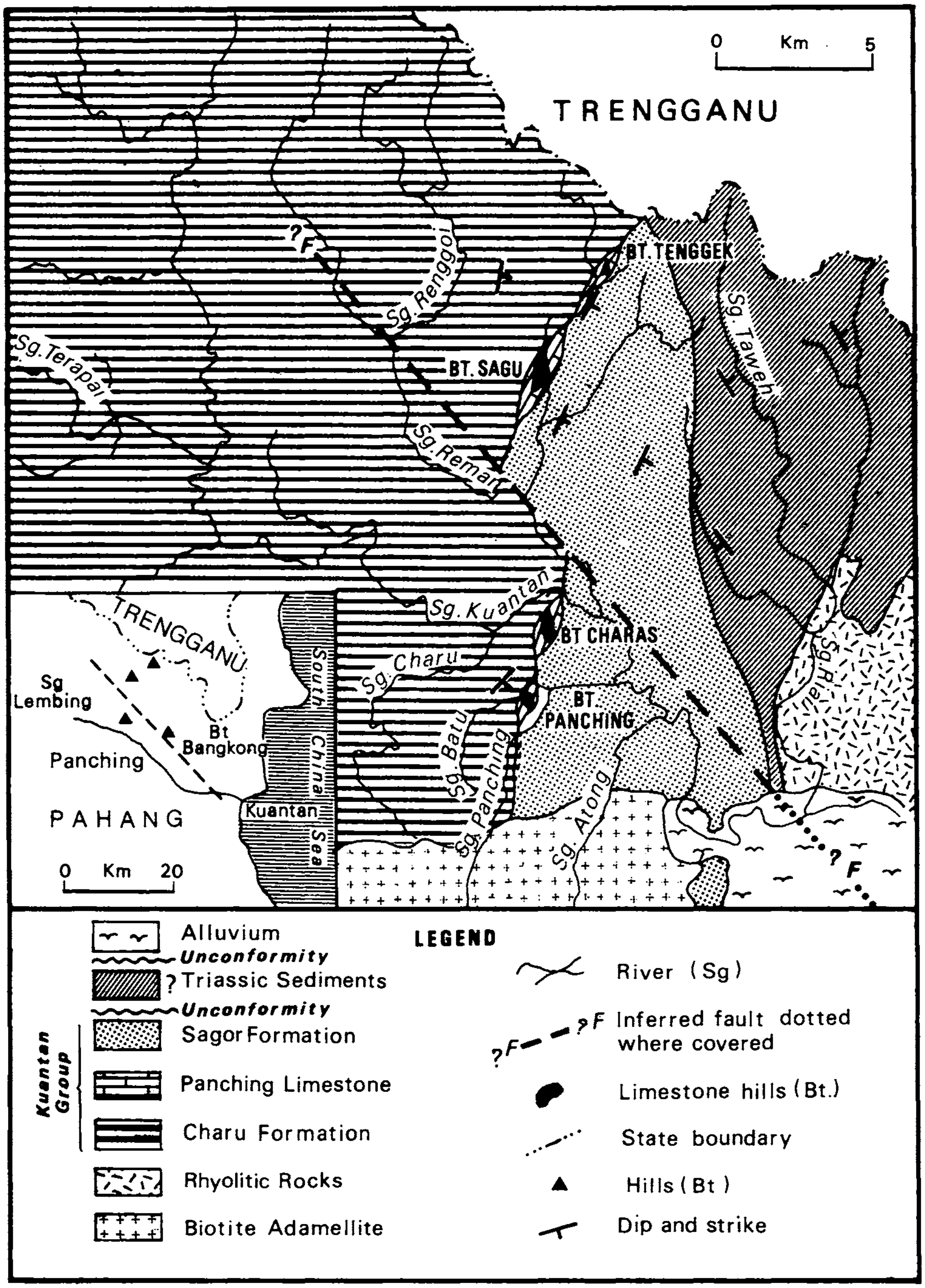

Fig. 1. Geological sketch map of the Panching area showing the distribution of the proposed Carboniferous formations. Based on Fitch (1951), Tan (1972) and Stauffer (1976).

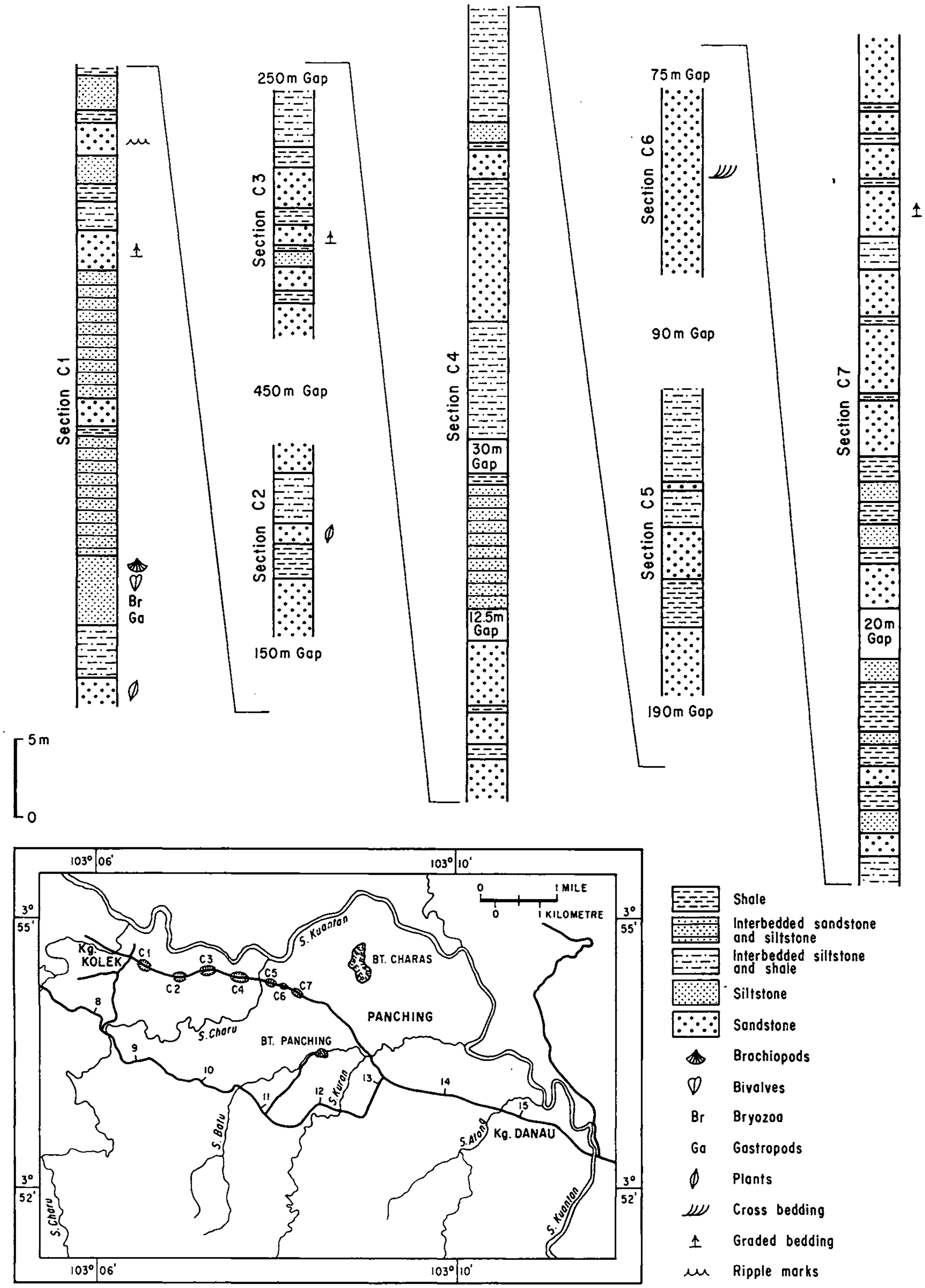

Fig. 2. Measured sections of Charu Formation of the type locality.

TABLE 1.

SPECIES RECORDED FROM THE CHARU FORMATION.

		This work		Muir-Wood (1948)	Yanagida & Sakagami (1971)	Fitch (1951)			
		Type Locality	S.W. of Bukit Sagu	Sungei Terapai	5 km east of Sungei Lembing	Sungei Balan	Sungei Chereh	Gakak Mine	Sungei Rangoi
Brachiopods:	*Setigerites* sp.	x			x				
	Antiquatonia sp.	x			x				
	Streptorhynchus sp.	x							
	Punctospirifer sp.	x			x				
	Schellwienella ? sp.	x							
	Orthothes ? sp.	x							
	Streptorhynchus cf. *ruginosum* (Hall and Clark)				x				
	Camarotoechia ? sp.				x				
	Pugnax cf. *asiaticus* Muir-Wood				x				
	Linoproductus sp.				x	x			
	Schizophoria sp.			x		x		x	
	Leptaena cf. *analoga* (Philips)			x					
	Chonetes sp.			x		x		x	
	Dictyoclostus cf. *parvus* (Meek and Worthen)			x					
	Echinoconchus elegans (M'Coy)			x		x			
	Productina cf. *margaritacea* (Philips)			x					
	Hustedia cf. *radialis* (Philips)			x					
	Punctospirifer pahangensis Muir-Wood			x		x		x	
	Productus (s.s) sp.					x		x	
	Pustula sp.					x			
	Dictyoclostus sp.					x		x	
	Eomarginifera sp.					x			
	Echinoconchus sp.					x			
	Krotavia aculeata (Martin)					x			
	Avonia sp.					x			
	Plicochonetes cf. *buchiana* (de Konick)					x			
	Buxtonia sp.							x	
	Hustedia cf. *carbonaria* (Phillips)							x	
	Crurithyris ? sp.							x	
	Balanochoncha sp.		x						
	Sedenticellula sp.		x						
Bivalves:	*Myalina* sp.	x							
	Aviculopecten sp.	x							
	Aviculopinna sp.	x							
	Bakevellia ? sp.	x							
	Strehlochondria ? sp.	x							
	Anthraconeilo aff. *taffiana* Girty			x					
	Parallelodon cf. *bistrialus* (Portlock)					x			
	Scaldia sp.					x			
	Edmondia sp.					x			
	Posidonia sp.					x			
	Edmondia cf. *sulcata* Phillips.		x						
Gastropod:	*Euomphalus* sp.					x		x	
Trilobites:	*Linguaphillipsia terapaiensis* Stubblefield			x					
	Phillipsia sp.			x					
Crinoids:	*Poteriocrinus* sp.			x		x	x	x	
Bryozoa:	*Fistulipora* sp.			x					
	Fenestella cf. *angustata* (Fischer and Waldheim)			x	x				
	Fenestella cf. *tenax* Ulrich			x	x	x			
	Fenestella cf. *polyporata* (Philips)			x					
	Fenestella aff. *plebeia* M'Coy			x		x			
	Cystodictya sp.			x					
	Fenestella sp.	x			x	x		x	
	Yunnanis sp.							x	
Echinoid:	cf. *Melonechinus*					x			
Algae:	*Koninkopora* sp.								x
Forams:	*Hemigordius* aff. *harltoni* Cushman and Waters								x
	Archaediscus karreri Brady								x
	Endothyra aff. *bowmani* Brady								x
	Millerella ? sp.								x
	Cribrostronium sp.								x
Plants:	*Lepidodendron* sp.			x					
	Stigmaria sp.			x					

(see below), a Viséan age for the major part of the Charu Formation is indicated. The Viséan-Namurian boundary is therefore most probably located in the uppermost part of the Charu Formation.

Depositional Environment

The presence of symmetrical ripple marks and medium scale cross bedding in alternating sandstones and siltstones with interbedded shales suggests deposition in a shallow marine near shore environment. This is supported by the presence of much plant debris and a shallow marine fauna of brachiopods, bivalves, crinoids, trilobites and bryozoa.

PANCHING LIMESTONE

Description

The Panching Limestone is a massive, partly recrystallised, fossiliferous limestone of approximately 600 metres maximum thickness. Exposures occur as four limestone hills, from south to north, Bukit Panching, Bukit Charas, Bukit Sagu and Bukit Tenggek (see Fig. 1). The outcrops of this limestone appear to be lenticular in nature but confined to one stratigraphic level. Bedding is rarely observed in the limestone and is confined to coquinas and shaley limestone. Cavity fill structures are common and possible penecontemporaneous boulder beds occur in Bukit Sagu. The limestones are highly fossiliferous with a varied shallow marine fauna, indicative of a reefal environment (see below).

Bukit Charas, which appears to give an almost complete stratigraphic section, is taken as the type locality. The name Panching Limestone is derived from Bukit Panching (GR253706) situated near Panching Village.

Petrology of the limestones

Five limestone types are recognised in the Panching Limestone (based on Folk's 1954 classification with a minor modification in raising the lower limit of rudites to 2mm as prefered by most workers).

1. *Biomicrite* (Pl. 1, Fig. A)

Most of the allochems coarser than 0.0625 mm are crinoid columnals, bryozoan fronds, shell fragments and tests of foraminifera. Other coarse fragments consist of anhedral calcite mosaics, possible organic debris now reorganised to or replaced by crystalline calcite. Anhedral calcite crystals of average diameter 0.5 mm are found scattered in the micritic matrix, many of them showing bent twinning planes indicating diagenetic deformation.

2. *Biosparite* (Pl. 1, Fig. B)

This consists of angular to rounded organic fragments of diameter 0.0625 mm to 2 mm set in a granular mosaic sparry calcite matrix. Fragments larger than 2 mm are occasionally present and are usually crinoid columnals. A crinoid biosparite is occasionally observed with up to 60% crinoid fragments.

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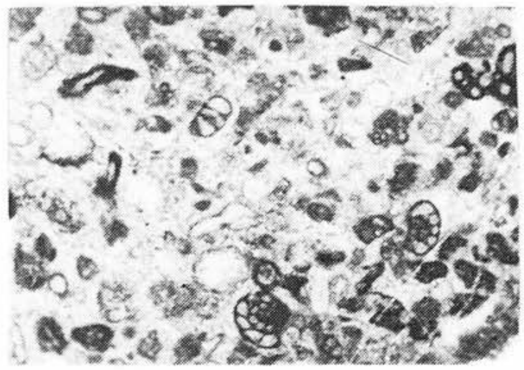

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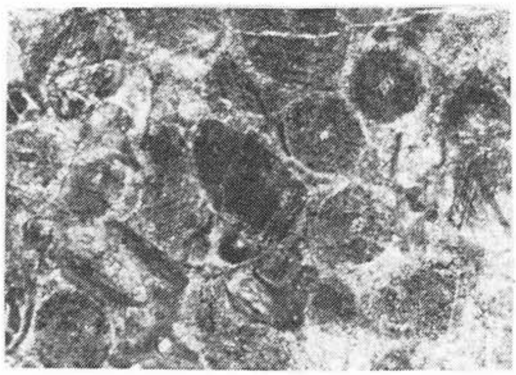

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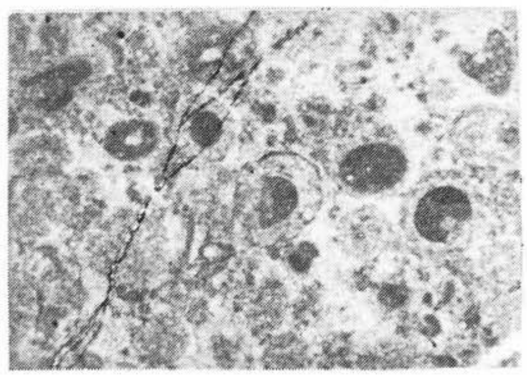

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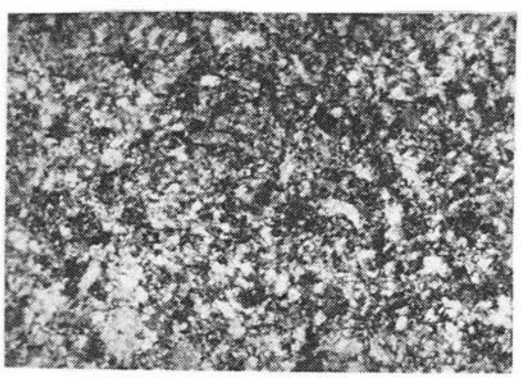

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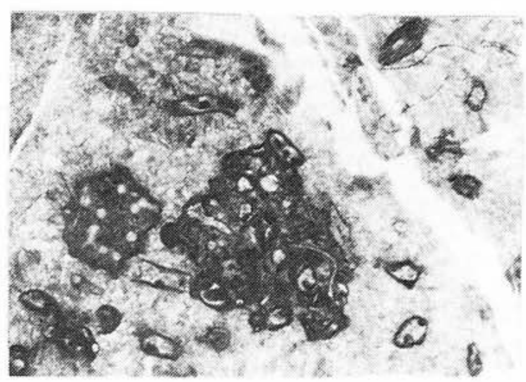

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Explanation of Plate I

Photomicrographs of Panching Limestone taken using plane polarised light.

A. Carbonaceous biomicrite, Bukit Panching, slide BP1, X 20.
B. Biosparite, Bukit Charas, slide BC12, X 20.
C. Biosparudite, Bukit Sagu, slide BS93, X 20.
D. Oomicrite, Bukit Sagu, slide BS39, X 20.
E. Recrystallised micrite, Bukit Tenggek, slide BT18, X 20.
F. Biosparudite with limestone intraclasts, Bukit Tenggek, slide BT5, X 10.

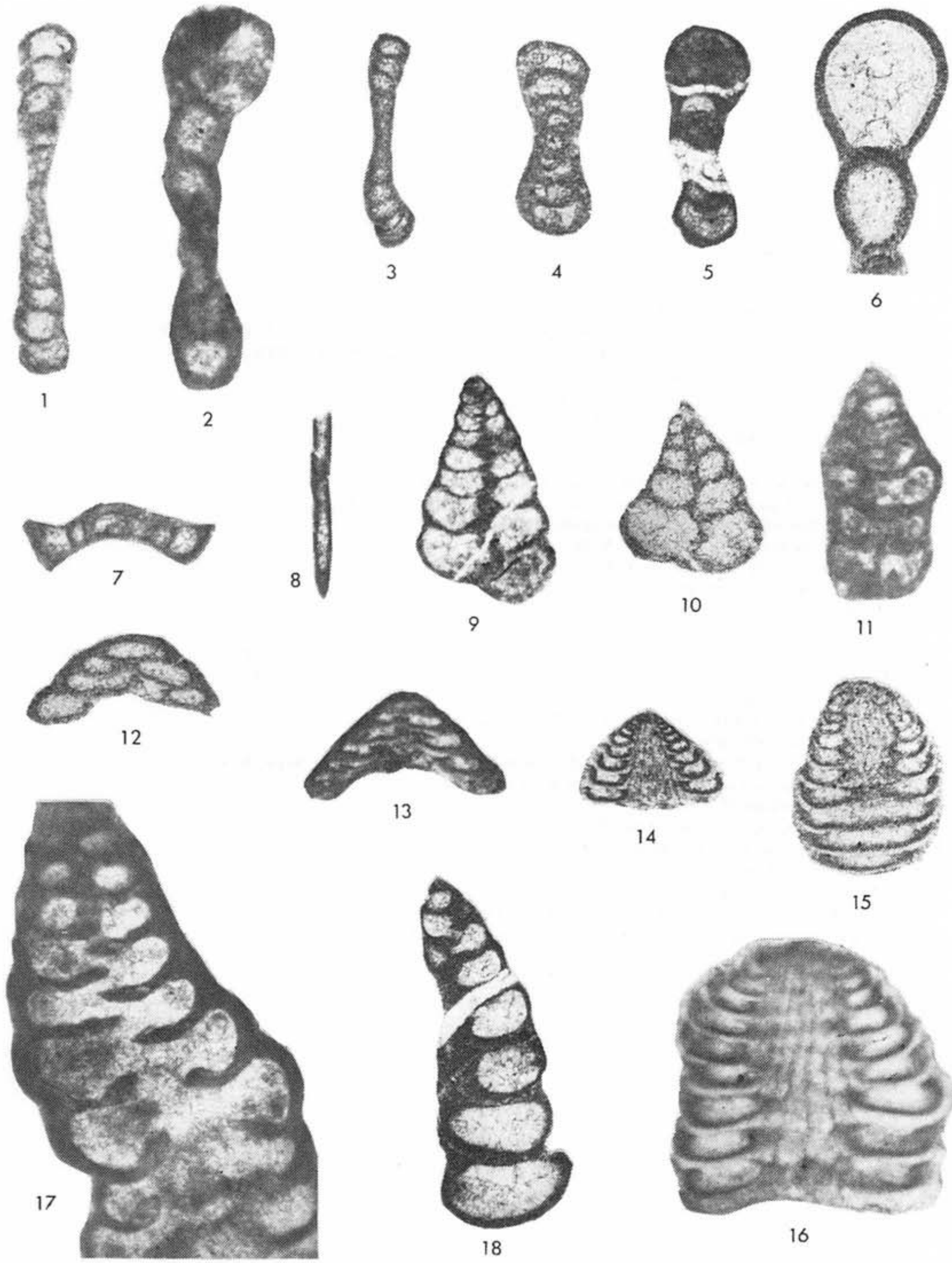
Explanation of Plate 2

Figs. 1, 3. *Monotaxinoides transitorius* Brazhnikova & Yartseva
  1. Axial section, slide BT9, X 100.
  3. Axial section, slide BT4, X 60.

Fig. 2. *Forschia* sp., axial section, slide BS21, X 40.
Fig. 4. *Seminovella elegantula* Rauzer & Chernosova, axial section, slide BS4, X 60.
Fig. 5. *Quasiendothyra* cf. *aljutovica* Reytlinger, axial section, slide BS2, X 60.
Fig. 6. *Tubertina* cf. *collosa* Reytlinger, axial section, slide BC10a, X 60.
Fig. 7. *Turrispiroides* sp., axial section, slide BP15, X 60.
Fig. 8. *Earlandia* cf. *perparva* Cummings, longitudinal section, slide BC7, X 27.
Figs. 9, 10. *Palaeotextularia grahamensis* Cushman & Waters.
  9. Axial section, slide BC47, X 27.
  10. Axial section, slide BC4, X 40.

Fig. 11. *Climacammina antiqua* Brady, axial section, slide BC3, X 20.
Fig. 12. *Tetraxis minima* Lee & Chen, axial section, slide BC3, X 27.
Fig. 13. *Tetraxis conica* Ehrenberg, axial section, slide BT12, X 33.
Figs. 14–16. *Howchinia bradyina* (Howchin).
  14. Axial section, slide BC10, X 40.
  15. Tangential section, slide BC10, X 40.
  16. Axial section, slide BT13, X 90.

Figs. 17, 18. *Climacammina textulariforme* Moeller.
  17. Axial section, slide BT21, X 37.
  18. Axial section, slide BC7, X 37.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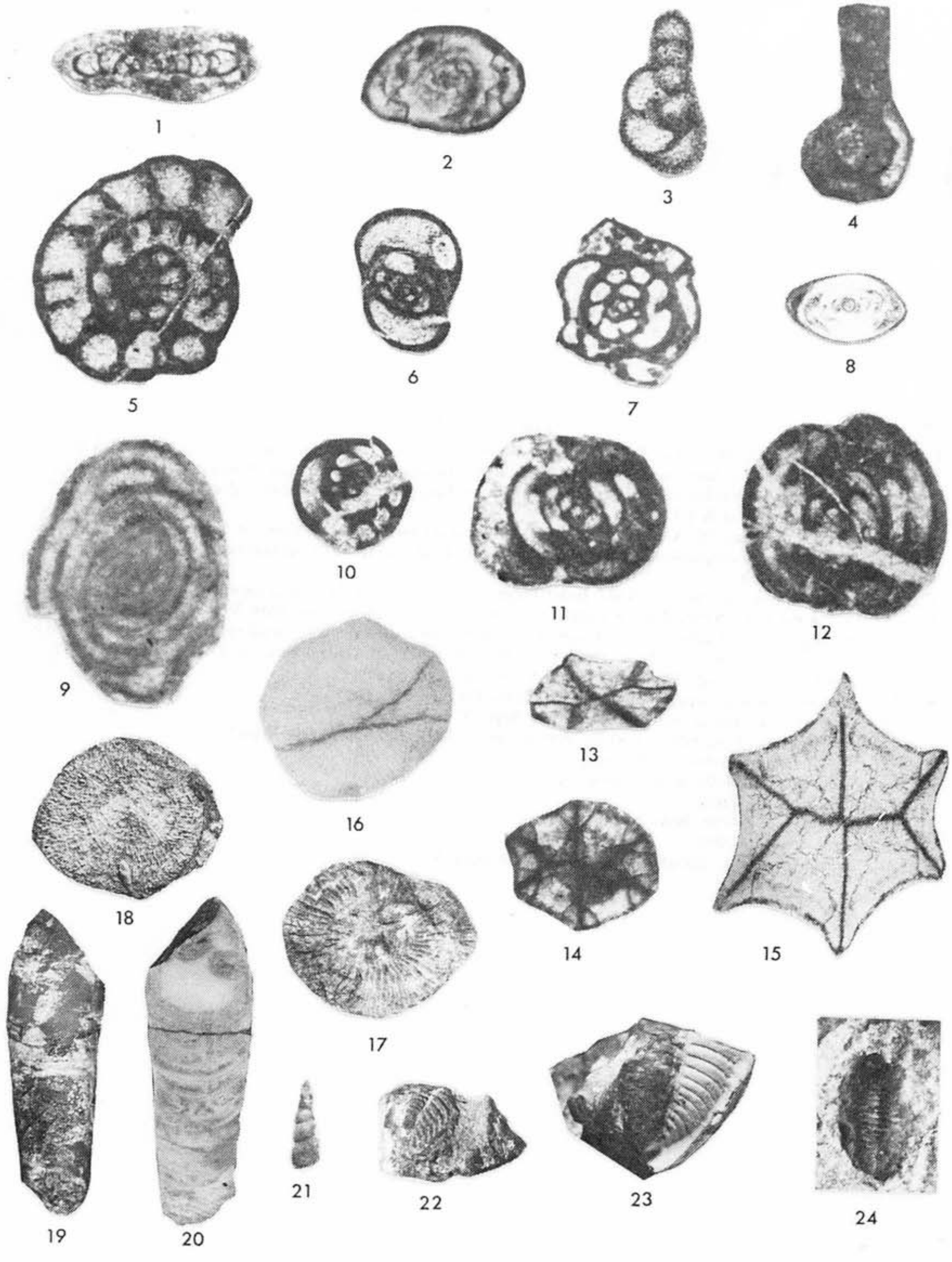
Explanation of Plate 3

Fig. 1. *Archaediscus ulmeri* Mikhaylov, axial section, slide BT23, X 60.
Fig. 2. *Archaediscus bashkirius* Krestovnikov & Teodorovitch, axial section, slide BS66, X 60.
Fig. 3. *Endothyranella* cf. *armstrongi* Cushman & Waters, axial section, slide BSla, X 60.
Fig. 4. *Glomospiroides* sp., axial section, slide BC29, X 37.
Fig. 5. *Quasiendothyra* cf. *aljutovica* Reytlinger, saggital section, slide BT21 X 66.
Figs. 6, 7. *Yanischewskina* cf. *typica* Mikhaylov.
6. Axial section, slide BC7, X 27.
7. Saggital section, slide BP2, X 27.
Fig. 8. *Permodiscus vetustus* Dukevitch, axial section, slide BC17, X 17.
Fig. 9. *Brunsia* cf. *pulchara* Mikhaylov, axial section, slide BT22, X 107.
Figs. 10–12. *Endothyranopsis* cf. pseudoglobulus Reytlinger.
10. Tangential section, slide BC17, X 20.
11. Oblique section, slide BC80, X 30.
12. Oblique section, slide BC17, X 30.
Figs. 13, 15. *Hexaphyllia concavia* sp. nov.
13. Transverse section, slide BC47, X 13.
15. Holotype, transverse section, slide BC17, Bukit Charas, Namurian A (H_1), Panching Limestone, X 40.
Fig. 14. *Hexaphyllia prismatica* Struckenberg, transverse section, slide BS66, X 58.
Figs. 16, 17. *Koninkophyllum* sp.
16. Tranverse section (polished) of A422, Bukit Charas, X 0.67.
17. A422 before polishing, X 0.67.
Fig. 18. *Palaeosmilia* cf. *murchisoni* Milne-Edwards & Haime, A423, Bukit Sagu, X 0.67.
Figs. 19, 20. *Hesperoceras* cf. *laudoni* Miller & Youngquist.
19. External surface of A420, X 1.
20. Longitudinal section (polished), X 1.
Fig. 21. *Meekospira* sp., A421, Bukit Charas, X 1.
Figs. 22, 23. *Paladin* sp.
22. Pygidium, dorso-lateral view of A424, Bukit Tenggek, X 2.
23. Pygidium, latero-dorsal view of A477, Bukit Tenggek, X 2.
Fig. 24. *Paraphilipsia* sp., dorsal view of A99, Bukit Sagu, X 1.3.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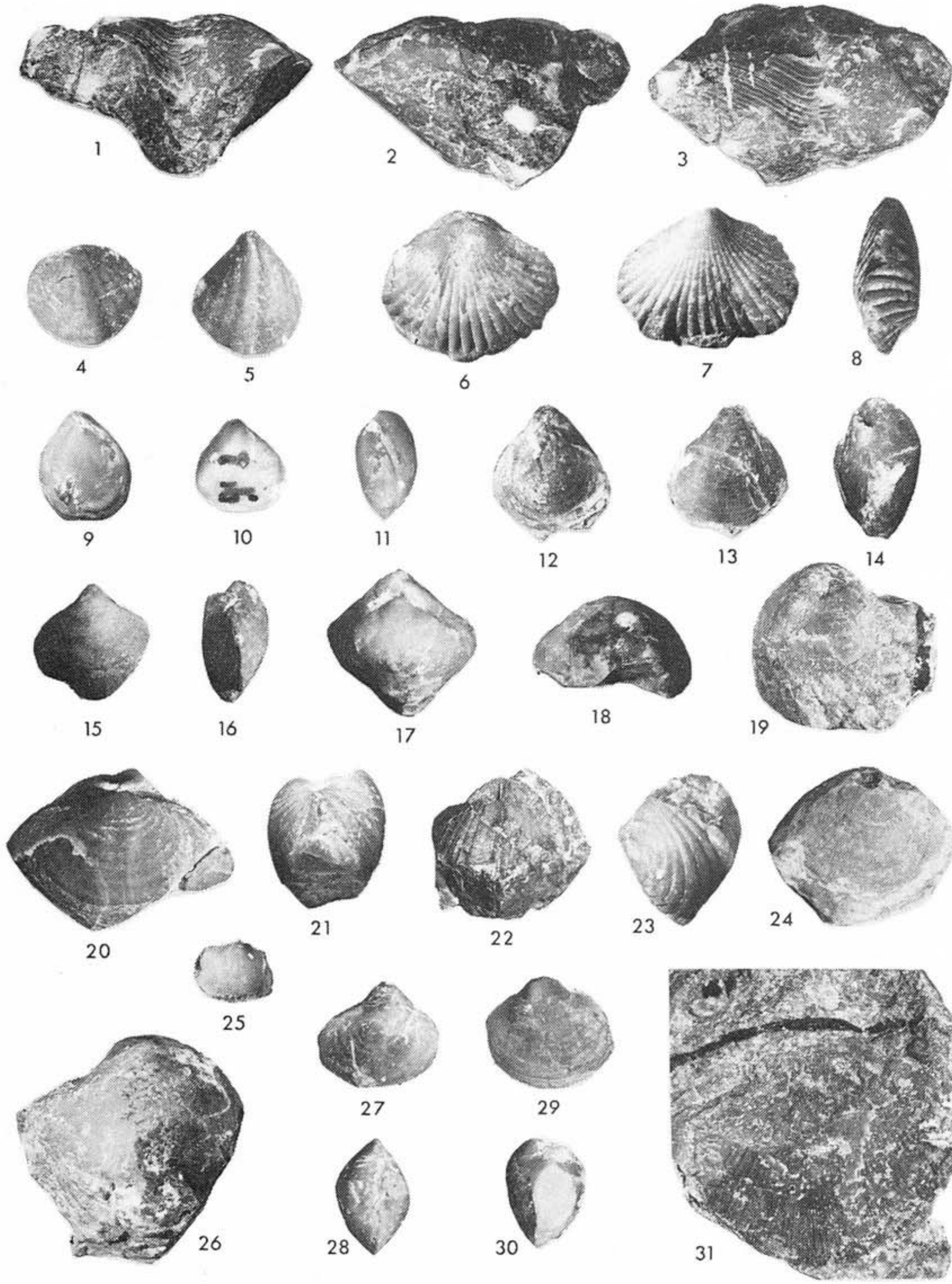
Expalanation of Plate 4

Figs. 1–3. *Georgethyris*? sp., A402, Bukit Tenggek. 1, posterior view; 2, anterior view; 3, dorsal view; all X 0.67.
Figs. 4–5. *Brachythyrina chouteauensis* Weller, A390, Bukit Tenggek. 4, ventral view; 5, dorsal view; both X 2.
Figs. 6–8. *Hemiplethorhynchus fallax* Tournais, A403, Bukit Tenggek. 6, ventral view; 7, dorsal view; 8, lateral view; all X 1.3.
Figs. 9–11. *Cleiothyridinia* sp. A395, Bukit Tenggek. 9, ventral view; 10, dorsal view; 11, lateral view; all X 1.3.
Figs. 12–14. *Composita subquadrata* Hall, A396, Bukit Sagu. 12, dorsal view; 13, ventral view; 14, lateral view; all X 1.
Figs. 15, 16. *Composita sulcata* Hall, A397, Bukit Tenggek. 15, dorsal view; 16, lateral view; both X 0.67.
Figs. 17, 18. *Athyris* sp., A387, Bukit Tenggek. 17, ventral view; 18, lateral view; both X 1.
Figs. 19, 26. *Daviesiella* cf. *llangollensis* Davidson. 19, Dorsal view of A399; 26, dorsal view of A399a; both X 0.67.
Figs. 20, 21. *Reticularia imbricata* (Sowerby), A409, Bukit Tenggek. 20, ventral view; 21, lateral view; both X 2.
Fig. 22. *Brachythyris* cf. *ovalis* Phillips, dorsal view of A391, Bukit Tenggek, X 1.
Fig. 23. *Camarotoechia* sp., lateral view of A393, Bukit Tenggek, X 1.3.
Fig. 24. *Setigerites* sp., dorsal view of A414, Bukit Sagu, X 0.67.
Fig. 25. *Rhipidomella* cf. *michelinia* Leveille, dorsal view of A410, Bukit Tenggek, X 0.67.
Figs. 27–30. *Reticularia imbricata* (Sowerby).
27. Ventral view of A409a, Bukit Charas, X 0.67.
28. Lateral view of A409a.
29. Dorsal view of A409b, Bukit Sagu, X 0.67.
30. Lateral view of A409b.
Fig. 31. *Schellwienella* sp., dorsal view of A412, Bukit Sagu, X 1.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3. *Biosparudite* (Pl. 1, Fig. C)

The biosparudite comprises angular to subrounded fragments greater than 2 mm in diameter set in a matrix of lime sand/mud. Fossil fragments constitute the main framework and include shell debris, crinoid plates and columnals, bryozoan fronds, corals, trilobites, echinoid and brachiopod spines, sponge spicules and foraminiferal tests. In addition, fragments of pre-existing limestone (?reef debris) are also present (Pl. 1, Fig. F).

4. *Oomicrite* (Pl. 1, Fig. D)

The oomicrite consists of well sorted spherical to ellipsoidal oolites set in a micritic matrix. The nuclei of the oolites are composed of dark micritic material. The concentric laminae of the oolites are of impure lime mud and/or crystalline calcite. Some of the oolites containing lime mud layers are squashed or ruptured probably due to compaction whilst in a plastic state.

5. *Recrystallised Micrite* (Pl. 1, Fig. E)

Bedded limestones exposed at Bukit Tenggek include recrystallised micrites consisting mainly of micritic calcite grains with scattered occurrences of anhedral sparry calcite (diameter 0.5 mm). There is a marked absence of fossil fragments. Ghost structures interpreted as representing fossils now recrystallised to micrite are occasionally observed.

Palaeontology and Age

A rich macro- and microfauna is known from the Panching Limestone. Table 2 gives species recorded to date from the four limestone hills exposing this formation.

Muir-Wood *et al.* (1948) compared the rich macrofossil fauna of the Panching Limestone with Carboniferous forms elsewhere and concluded they were most closely related to British Carboniferous Viséan forms and suggested a correlation with the D coral brachiopod zone (now = Asbian and Brigantian Stages). A re-examination of Muir-Wood *et al.*'s fauna shows that in fact the evidence for this correlation is rather poor. The only species Muir-Wood *et al.* describe that is indistinguishable from British forms is *Reticularia imbricata* (Sowerby) and this form is typically found in reefal facies limestones in Britain and is considered unreliable as a precise stratigraphic indicator. The other macrofossil species described by Muir-Wood *et al.* are subject to one or another form of open nomenclature and are only compared superficially with British Viséan forms. No diagnostic Asbian or Brigantian species have been recorded from the Panching Limestone and a correlation with those Stages cannot be upheld. Igo and Koike (1968) described a conodont fauna from Bukit Charas which contained *Idiognathoides noduliferus* (Ellison & Graves). In Europe and the U.S.A. this species appears above the base of the Namurian and Igo and Koike suggested that their fauna was of Lower Namurian age. Mamet and Saurin (1970) listed foraminifera from Bukit Sagu and Bukit Charas (Table 2). The Bukit Sagu fauna was considered to be of late Viséan (V3c) age since it contained an association of *Bradyina*, *Howchinia*, *Neoarchaediscus*, *Planospirodiscus* and *Valvulinella*. However, these forms are now known to persist into the lower Namurian (R. Conil, pers. com.) and therefore a basal Namurian age is also possible. The *Howchinia bradyina* (Howchin) that occur in the lower Namurian are slightly different from Viséan forms in that the axis is filled with a series of tube-like structures. The specimens of this species in the Panching Limestone exhibit this feature (see Pl. 2, Figs. 14–16) thus indicating a Namurian rather than a Viséan age. The fauna from Bukit Charas described by Mamet and Saurin contained abundant *Asteroarchaediscus* and this fact together with the absence of *Howchinia* and *Valvulinella* was taken to indicate a Namurian age. Ozawa (1975) described fusulinid foraminifera characteristic of the *Eostaffella-Millerella* Zone (late Viséan–early Namurian) from Bukit Charas. The presence of *Archaediscus krestovnikovi* Rauser-Chernousova, *A. maximus* Grozdilova & Lebedeva and *Howchinia gibba* (von Moller) in the fauna was taken to indicate a Viséan age. This conclusion appeared to be at variance with the foraminifera and conodonts from Bukit Charas described by Mamet and Saurin (1970) and Igo and Koike (1968). Ozawa suggested that the faunas described in the latter two works probably came from the southern end of the limestone hill suggesting that the limestones ranged in age from Viséan-Namurian. The species Ozawa uses to indicate a Viséan age are now known to extend into the Namurian and a definite Viséan age for Ozawa's faunas cannot be established.

A rich conodont fauna has recently been extracted from all four limestone hills of the Panching Limestone (Metcalfe, 1980a). The fauna of the limestone represents the *Idiognathoides noduliferus–Streptognathodus lateralis* conodont zone and is of Namurian A age. The fauna also includes *Rhachistognathus primus* Dunn and *R. muricatus* (Dunn) which are diagnostic of the Mississippian-Pennsylvanian boundary in the U.S.A., a level correlated with the Early Namurian of Europe. The conodonts indicate that the full stratigraphic range of the Panching Limestone falls in the Namurian A and a possible range in age of Viséan-Namurian suggested by Ozawa cannot be upheld. The presence of apparent 'Viséan' macrofossils in these limestones is interpreted to be due to facies control of the benthonic fauna in a reefal environment (Metcalfe, 1980b, pp. 15–16).

Depositional Environment

The Panching Limestone is here interpreted to have formed in a warm shallow marine reefal environment. The evidence for this is provided by it's faunal assemblages, lithological characters and sedimentological features. Five microfacies are recognised in the Panching Limestone as follows:-

1. *Micritic facies*

Thinly bedded shaley, micritic unfossiliferous limestones constitute this microfacies. It is only recorded at one locality, at Bukit Tenggek, where it is in fault contact with massive limestones. The relationship between this and other facies of the Panching Limestone is not known.

2. *Biomicrite facies*

Massive, poorly bedded or unbedded grey biomicritic fossiliferous limestones constitute this facies. The fauna consists predominantly of brachiopods and foraminifera. Corals, bryozoa and echinoderms are also present. This facies is interpreted to represent the "reef core". Cavity filled structures interpreted as possible *Stromatactis* (Bathhurst, 1959) are common and exclusive to this facies.

MACROFOSSILS

Muir-Wood *et. al.* (1948)

	Muir-Wood *et. al.* (1948)	Bt. C.	Bt. S.	Bt. T.
Corals:	*Caninia* near *C. gigantea* Michelin	x		
	Caninia sp.	x		
	Lithostrotion (Diphyphyllum) sp.	x		
	Amygdalophyllum sp.	x		x
Crinoid:	*Poteriocrinus* sp.		x	x
Brachiopods:	*Schizophoria mesoloba* (Yanishevsky)		x	x
	Buxtonia sp.		x	x
	Stenoscisma saquensis Muir-Wood		x	x
	Avonia cf. *davidsoni* (Jarosz)		x	
	Avonia weberi (Yanishevsky)	x	x	
	Buxtonia sp.		x	
	Dictyoclostus sp. *muricatus* group			x
	Dictyoclostus cf. *deruptus* (Romanowsky)			x
	Dictyoclostus sp.	x	x	x
	Eomarginifera sp.			x
	Gigantella cf. *latissima* (Sowerby)			x
	Krotavia cf. *keyserlingiana* (de Koninck)			x
	Krotavia multituberculata (Yanishevsky)	x	x	
	Linoproductus kokdscharensis (Grober)	x	x	
	Linoproductus yunnanensis (Loczy)		x	
	Proboscidella nana Muir-Wood		x	
	Sinuatella oreintalis Muir-Wood		x	x
	Linoproductus tenuistriatus (de Verneuil)	x		
	Brachythyris koksuensis Dikareva		x	x
	Brachythyris willbourni Muir-Wood	x	x	x
	Brachythyris ? *buckmani* Yanishevsky		x	
	Brachythyris sp.		x	
	Marginicinctus ? cf. *planus* (Yanishevsky)			x
	Pugnax asiaticus Muir-Wood			x
	Pugnax cf. *pugnus* (Martin)			x
	cf. *Chorisites* ? *humerosus* (Phillips)			x
	Neospirifer derjawini (Yanishevsky)		x	
	Spirifer cf. *condor* d'Orbingy		x	
	Spirifer scrivenori Muir-Wood		x	x
	Spirifer sp.	x		x
	Phricodothyris sp.		x	x
	Reticularia cf. *alexandri* George		x	
	Reticularia imbricata (Sowerby)		x	x
	Cleiothyridina sp.		x	
	Dielasma cf. *attenuatum* (Martin)		x	
	Dielasma sp.		x	
Molluscs:	*Pterinopectinella* cf. *granosa* (Sowerby)	x		
	Edmondia sp.			x
	Streblopteria sp.		x	x
	Streblochondria ? sp.			x
	Solemya ? sp.		x	
	Orthonychia ? sp.		x	
	Dentallium ? sp.		x	

Sakagami (1972)

Bryozoa:
- *Fistulipora* sp. indet.
- *Dyscritella* sp. indet.
- *Rhabdomeson* sp. indet. A.
- *Rhabdomeson* sp. indet. B.
- *Rhombopora tersiensis* Nekhc
- *Rhombopora charasensis* Saka
- *Nikiforovella pahangensis* Sak
- *Streblascopora superminor* Sa
- *Sulcoretepora malayensis* Sak
- *Fenestella* cf. *cellulosa* (Crock
- *Fenestella* cf. *kawadae* Sakag
- *Fenestella* cf. *compressa* Ulric
- *Fenestella* aff. *polyporata* Phi
- *Fenestella pahangensis* Sakag
- *Fenestella* sp. indet. A.
- *Fenestella* sp. indet. B.
- *Fenestella* sp. indet. C.
- *Polypora* aff. *elliptica* mut. El
- *Polypora* cf. *subtilis* Nekhoro
- *Penniretepora iwaii* Sakagami
- *Penniretepora* sp. indet. A.
- *Penniretepora* sp. indet. B.
- *Penniretepora* sp. indet. C.

This Paper

Corals:
- *Koninckophyllum* sp.
- *Hexaphyllia prismatica* Struck
- *Hexaphyllia concavia* sp. nov.
- *Palaeosmelia* cf. *murchiso* Edwards and Haime

Brachiopods:
- *Athyris* sp.
- *Brachythyrina* cf. *strangwaysi*
- *Brachythyris chouteaunsis* We
- *Brachythyris* cf. *ovalis* Phillips
- *Camarotoechia* sp.
- *Cleiothyridina* sp.
- *Composita subquadrata* Hall
- *Composita sulcata* Hall
- *Crurithyris* cf. *planoconvexa* S
- *Daviesiella* cf. *llangollensis* Da
- *Georgethyris* ? sp.
- *Hemiplethorhynchus fallax* To
- *Rhipidomella* cf. *michelini* Lev
- *Rhynchotetra* sp.
- *Schellwienella* ? sp.
- *Setigerites* sp.

Molluscs:
- *Hesperoceras* cf. *laudoni* Youngquist
- *Meekospira* sp.

Trilobites:
- *Paladin* sp.
- *Paraphillipsia* ? sp.

TABLE 2.

SPECIES RECORDED FROM THE PANCHING LIMESTONE.

CONODONTS

)72)	Bt. P	Bt. C.	Bt. S.	Bt. T.
		x		
		x		
‥		x		
'.		x		
khoroshev		x		
Sakagami		x		
Sakagami		x		
· Sakagami		x		
Sakagami		x		
:ockford)		x		
kagami		x		
Jlrich		x		
Phillips		x		
kagami		x		
		x		
		x		
		x		
t. Elias		x		
oroshev		x		
ami		x		
‥		x		
.		x		
'.		x		
r				
		x	x	
ruckenberg	x	x	x	x
1ov.		x	x	
:hisoni Milne-				
			x	
				x
ysi de Ver.		x		
Weller		x	x	x
llips		x	x	x
				x
		x	x	x
all		x	x	x
		x	x	x
:a Shumard		x	x	x
· Davidson		x		
				x
· Tournais				x
Leveille				x
				x
		x	x	
		x	x	
i Miller and				
			x	
		x		
				x
			x	

Igo and Koike (1968)	Bt. P.	Bt. C.	Bt. S.	Bt. T.
Idiognathoides noduliferus (Ellison and Graves)		x		
Gnathodus bilineatus (Roundy)		x		
Spathognathodus campbelli Rexroad		x		
Ozarkodina sp.		x		
Hindeodella sp.		x		
Metcalfe (1980a)				
Apatognathus cuspidatus Varker		x		
Apatognathus libratus Varker		x		
Apatognathus scalenus Varker		x		
Geniculatus claviger (Roundy)	x	x		
Gnathodus bilineatus (Roundy)		x	x	x
Gnathodus commutatus (Branson and Mehl)	x	x	x	x
Gnathodus girtyi rhodesi Higgins		x		
Gnathodus girtyi simplex Dunn			x	
Gnathodus nodosus (Bischoff)		x		
Hibbardella acuta Murray and Chronic	x	x		x
Hibbardella geniculata Higgins		x		
Hibbardella pennata Higgins	x		x	x
Hindeodella ibergensis Bischoff	x	x	x	x
Hindeodella mehli Elias	x			
Hindeodella uncata Hass			x	
Hindeodella undata Branson and Mehl	x			
Idiognathoides noduliferus inaequalis Higgins	x	x	x	x
Idiognathoides noduliferus japonicus (Igo and Koike)		x		x
Idiognathoides noduliferus noduliferus (Ellison and Graves)		x	x	x
Kladognathus sp.	x	x		
Ligonodina roundyi Hass	x			
Lonchodina bischoffi Higgins and Bouckaert	x	x		
Lonchodina ponderosa Ellison		x		
Neoprioniodus scitulus (Branson and Mehl)	x	x		
Neoprioniodus singularis Hass	x	x	x	x
Ozarkodina delicatula (Stauffer and Plummer)	x	x	x	x
Rhachistognathus muricatus (Dunn)		x	x	
Rhachistognathus primus Dunn		x		
Spathognathodus campbelli Rexroad		x		
Spathognathodus scitulus (Hinde)		x		
Streptognathodus lateralis Higgins and Bouckaert	x	x	x	x
Subbryantodus subaequalis Higgins	x			
Synprioniodina microdenta Ellison		x	x	x

Archaedi
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Archaedi
Arçhaedi
Asteroar.
Asteroar.
(Krest
Biseriella
Bradyina
Calcisphe
Calcisphe
Climacar.
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Endothyr
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and R
Endostaf
Eostaffel
Helicospi
Howchini
Howchini
Mediocri
Monotax.
Neoarcha
Neoarcha
Palaeonu.
Palaeotex
Palaeotex
Parathur
Planospir
Planospir
Pseudoen.
Radiosph
Sacammi
Stacheia :
Stacheoia
Tetraxis
Tetraxis
Tuberitin
Trepeilop.
Valvuline
Vicinesph
Yanichew

MICROFOSSILS

FORAMINIFERA

Bt. T.	**Mamet and Saurin (1970)**	Bt. C.	Bt. S.	**Ozawa (1975)**
	Archaediscus sp.		x	*Mediocris mediocris* (Vissarionova)
	Archaediscus of the group *A. krestovnikovi* Rauzer-Chernoussova	x	x	*Eostaffella mosquensis* Vissarionova
	Archaediscus of the group *A. moelleri* Rauzer-Chernoussova	x	x	*Eostaffella toriyamai* Ozawa
	Archaediscus of the group *A. chernoussovensis* Mamet	x		*Millerella rossica* Rozovskaya
	Asteroarchaediscus sp.	x		*Pseudoendothyra* sp.
	Asteroarchaediscus of the group *A. baschkiricus*			*Howchinia gibba* (von Moller)
	(Krestovnikov and Teodorovitch)	x		*Archaediscus krestovnikovi* Rauzer-Chernousso
	Biseriella ? sp.	x		*Archaediscus* cf. *maximus* Grozdilova and Leb
	Bradyina rotula D'Eichwald		x	*Bradyina* cf. *rotura* (Eichwald)
	Calcisphaera laevis Williamson	x	x	*Palaeotextularia* sp.
	Calcisphaera pachyspaherica (Pronina)	x	x	*Cribrospira* cf. *panderi* Moller
	Climacammina of the group *C. patula* Brady		x	*Quasiendothyra* sp.
x	*Earlandia* sp.		x	*Endothyra* spp.
x	*Earlandia clavatula* (Howchin)		x	*Tournayella* sp.
	Earlandia elegans (Rauzer-Chernoussova)		x	*Monotaxinoides* sp.
	Earlandia vulgaris (Rauzer-Chernoussova and Reitlinger)		x	*Teraxis* cf. *conica* Ehrenberg
	Endothyra of the group *E. bowmani* Phillips	x	x	*Climacammina* sp.
x	*Endothyra* of the group *E. prisca* Rauzer-Chernoussova			*Deckerella* sp.
	and Reitlinger		x	*Tubertina* sp.
x	*Endothyra obsoleta* Rauzer-Chernoussova	x	x	*Glomospira* sp.
x	*Endothyra* of the group *E. similis* Rauzer-Chernoussova			
	and Reitlinger	x	x	**This paper**
	Endostaffella parva (von Moller)		x	
	Eostaffela sp.		x	*Turrispiroides* sp.
x	*Helicospirina* sp.		x	*Tuberitina* cf. *collosa* Reytlinger
x	*Howchinia bradyina* (Howchin)		x	*Palaeotextularia grahamensis* Cushman and W
	Howchinia longa (Braznikhova)		x	*Dekerellina* sp.
x	*Mediocris* sp.		x	*Climacammina textulariforme* Moller
	Monotaxinoides sp.		x	*Climacammina antiqua* Brady
	Neoarchaediscus incertus (Grozdilova)	x		*Tetraxis minima* Lee and Chen
	Neoarchaediscus sp.	x	x	*Earlandia* cf. *perparva* Cummings
	Palaeonubecularia sp.	x	x	*Tournayella* cf. *cepeki* Vasicek and Ruzicka
	Palaeotextularia of the group *P. consobrina* Lipina	x	x	*Forschia* sp.
x	*Palaeotextularia* of the group *P. longiseptata* Lipina	x	x	*Archaediscus ulmeri* Mikhaylov
x	*Parathurammina* sp.		x	*Permodiscus vetustus* Dutkevich
	Planospirodiscus minimus (Grozdilova and Lebedeva)	x		*Brunsia* cf. *pulchara* Mikhaylov
	Planospirodiscus sp.		x	*Glomospiroides* sp.
	Pseudoendothyra sp.		x	*Monotaxinoides transitorius* Brazhinikova and V
	Radiosphaerina sp.		x	*Seminovella elegantula* Rauser-Chernousova
x	*Sacamminopsis* sp.		x	*Yanischewskina* cf. *typica* Mikhaylov
	Stacheia sp.		x	*Endothyranopsis* cf. *pseudoglobulus* Reytlinger
x	*Stacheoides* sp.		x	*Endothyranella* cf. *armstrongi* Cushman and W
	Tetraxis of the group *T. angusta* Ehrenberg		x	*Quasiendothyra* cf. *aljutovica* Reytlinger
	Tetraxis of the group *T. conica* Ehrenberg		x	
	Tuberitina sp.		x	
	Trepeilopsis sp.		x	
	Valvulinella sp.		x	
	Vicinesphaera sp.		x	
	Yanichewkina sp.	x	x	

	Bt. C.	Bt. S.
		x
noussova	x	x
ova	x	x
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		x
		x
		x
		x
		x
	x	x

FORAMINIFERA

Ozawa (1975)	Bt. P.	Bt. C.	Bt. S.	Bt. T.
Mediocris mediocris (Vissarionova)		x		
Eostaffella mosquensis Vissarionova		x		
Eostaffella toriyamai Ozawa		x		
Millerella rossica Rozovskaya		x		
Pseudoendothyra sp.		x		
Howchinia gibba (von Moller)		x		
Archaediscus krestovnikovi Rauzer-Chernoussova		x		
Archaediscus cf. *maximus* Grozdilova and Lebedeva		x		
Bradyina cf. *rotura* (Eichwald)		x		
Palaeotextularia sp.		x		
Cribrospira cf. *panderi* Moller		x		
Quasiendothyra sp.		x		
Endothyra spp.		x		
Tournayella sp.		x		
Monotaxinoides sp.		x		
Teraxis cf. *conica* Ehrenberg		x		
Climacammina sp.		x		
Deckerella sp.		x		
Tubertina sp.		x		
Glomospira sp.		x		
This paper				
Turrispiroides sp.	x			
Tuberitina cf. *collosa* Reytlinger	x	x	x	x
Palaeotextularia grahamensis Cushman and Waters	x	x	x	x
Dekerellina sp.				x
Climacammina textulariforme Moller	x	x	x	x
Climacammina antiqua Brady	x	x	x	x
Tetraxis minima Lee and Chen				x
Earlandia cf. *perparva* Cummings	x	x	x	x
Tournayella cf. *cepeki* Vasicek and Ruzicka	x	x	x	x
Forschia sp.			x	x
Archaediscus ulmeri Mikhaylov				x
Permodiscus vetustus Dutkevich		x	x	x
Brunsia cf. *pulchara* Mikhaylov				x
Glomospiroides sp.			x	x
Monotaxinoides transitorius Brazhinikova and Varteseva	x	x	x	x
Seminovella elegantula Rauser-Chernousova			x	x
Yanischewskina cf. *typica* Mikhaylov		x	x	x
Endothyranopsis cf. *pseudoglobulus* Reytlinger	x	x	x	x
Endothyranella cf. *armstrongi* Cushman and Waters			x	x
Quasiendothyra cf. *aljutovica* Reytlinger	x	x	x	x

3. *Crinoidal facies*

This facies consists of coarse grained, pale grey, crinoidal limestones which grade laterally into biomicrite and biosparite facies. It is believed to have formed in a higher energy regime marginal to the biomicrite and biosparite facies. The fauna consists dominantly of crinoids.

4. *Biosparite facies*

Biosparites and minor biosparudites with a fauna consisting mainly of brachiopods, bryozoa and foraminifera constitute this facies which is taken to represent a "reef core" type environment.

5. *Carbonaceous limestone facies*

Massive, unbedded very dark grey to black carbonaceous limestones with foraminifera, echinoderms, bryozoa, molluscs and trilobites form this facies. It is believed to represent the 'off reef, slightly deeper water environment.

The distribution of the five facies in the limestone hills is given in Fig. 3. The fact that these facies can be seen to cut across the general bedding of the limestone (dipping steeply to the southeast) shows that they are distinct penecontemporaneous facies. They are also typical of the facies recorded in Palaeozoic reefs elsewhere (eg. Miller and Grayson, 1972). Penecontemporaneous boulder beds are seen in the western face of Bukit Sagu which are interpreted as reef debris.

The fauna of the Panching Limestone is very reminiscent of the Lower Carboniferous reef faunas of Britain and of other Palaeozoic reefs. In particular, *Reticularia imbricata*, occurring commonly in the Panching Limestone, is a very common reef dweller elsewhere. The heterocoral *Hexaphyllia* is again most commonly found in reefal environments elsewhere and occurs commonly in the Panching Limestone. The general faunal assemblage of the Panching Limestone would appear to represent a reefal pre-climax community (Fig. 4). With more detailed work it should be possible to establish reef communities related to the five microfacies outlined above.

SAGOR FORMATION

Description

This unit consists of a sequence of conglomerates, sandstone, shale, mudstone, radiolarian mudstone and rare limestone lenses. The lower part consists of interbedded sandstone and shale with a single horizon of brownish conglomerate which occurs normally as thin beds but occasionally in beds up to 3 metres in thickness. The conglomerates, which contain clasts of sandstone, chert and quartz of 15–20 cm, are confined to the northern part of the area and pass laterally, southwards into sandstones and shales. In the sediments overlying the conglomerates, Fitch (1951) recorded impersistent limestone lenses. The sandstones of this formation are generally 1–3 m thick and are interbedded with thin shale or mudstone beds up to 1 m thick. Radiolarian chert occurs in the lower part of the Sagor Formation and is exposed 2 km north of Bukit Pak Sagor. Graded bedding is seen in some of the sandstones. The name Sagor Formation is derived from Bukit Pak Sagor and the type locality for the

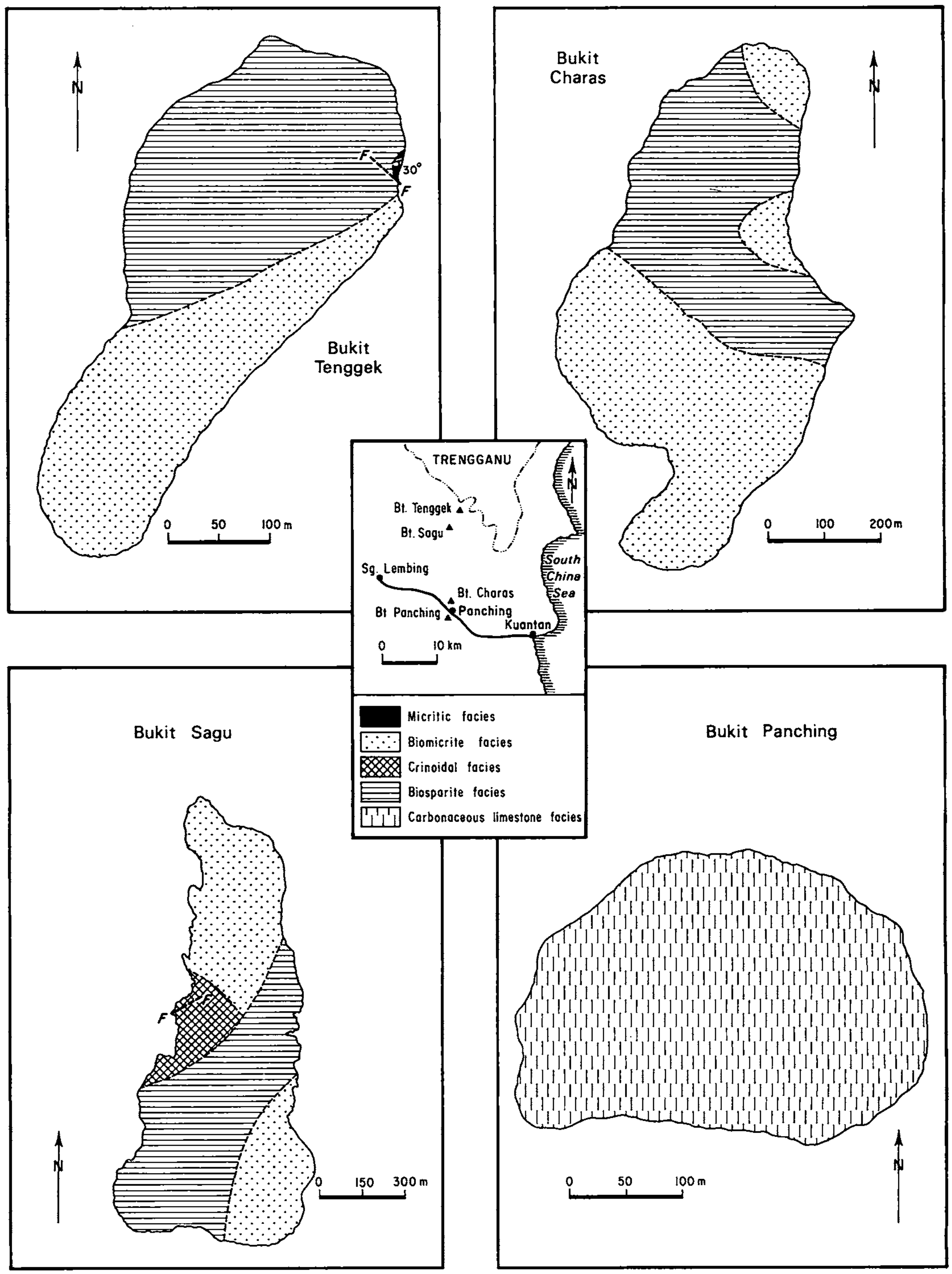

Fig. 3. Microfacies distribution in the four limestone hills of the Panching Limestone.

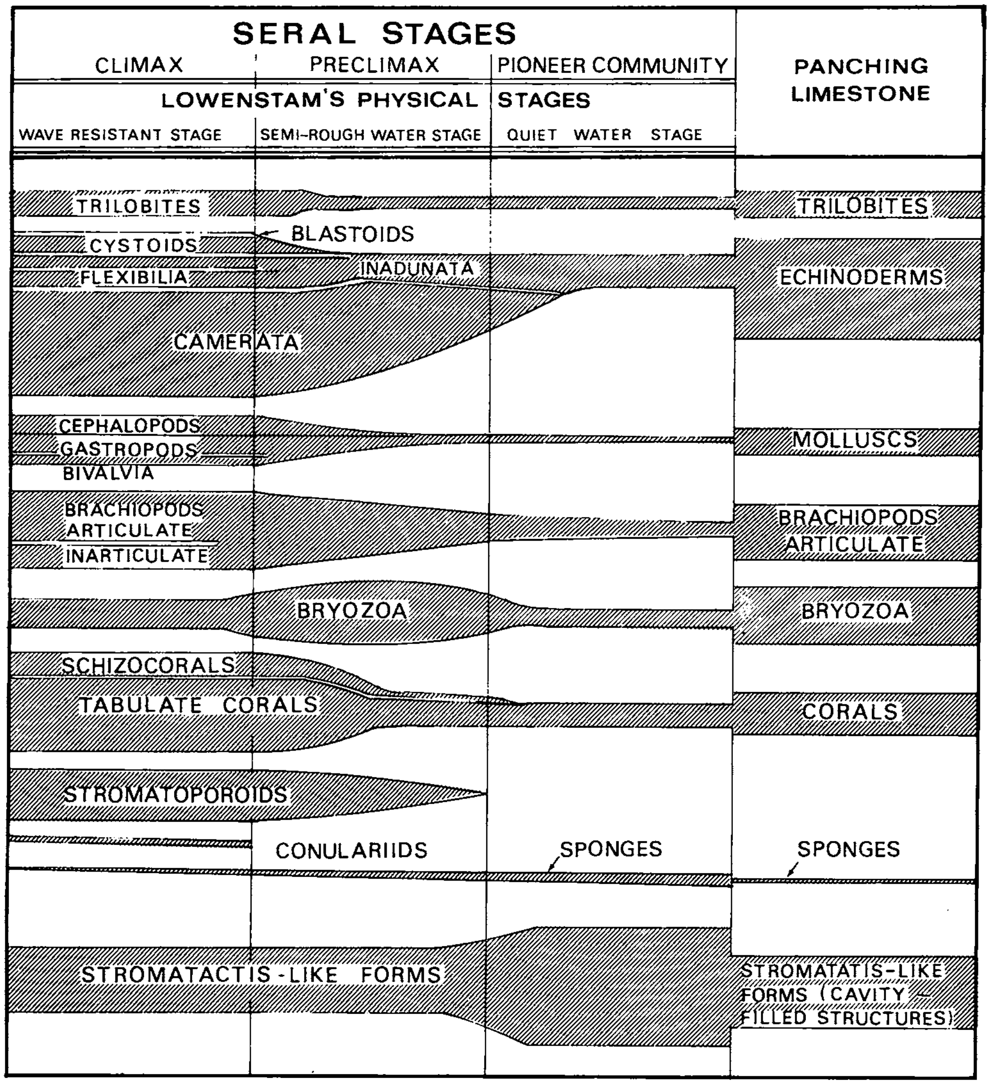

Fig. 4. Relationship between the macrofaunas of the Panching Limestone and those of Palaeozoic reefs. Greater relative abundance is indicated by thicker symbols.

formation is designated to be in stream sections 5 km north of Bukit Pak Sagor between Grid refs 268804 and 295808. A composite vertical stratigraphic section through the formation, based mainly on exposures at the type locality is given in Fig. 5.

Palaeontology and Age

Radiolaria and unidentifiable plant fragments are the only fossils recorded from this formation and these, as yet, do not provide any indication of age. An attempt to extract palynomorphs from shales of the formation proved negative. The formation lies conformably on the Panching Limestone of early Namurian age and is therefore most likely to be of late Carboniferous age.

Depositional Environment

The presence of radiolaria in mudstones of this formation indicate deposition in a marine environment. The sandstones of the formation do not exhibit any ripple marks or cross-bedding indicative of very shallow marine environments but they do show graded bedding. The thinly bedded conglomerates in the lower part of the sequence indicate a near shore environment and the Sagor Formation would appear to have been deposited in a slightly deeper shelf area. The presence of radiolarian mudstones, has in the past been taken to indicate a relatively deep marine environment. However, it is now known that radiolarites do occur interbedded with shallow marine sediments (e.g. Semanggol Formation, Kedah) and do not necessarily indicate deep water.

CORRELATION (WEST MALAYSIA)

Carboniferous sediments are widely distributed in West Malaysia but in general they are poorly dated because of the lack of fossils or their poor preservation due to metamorphism. The Dinantian-Silesian boundary is recognised in the upper part of the Charu Formation of Pahang (Metcalfe 1980a, 1980b and this paper) and in Perak within the Kanthan Limestone. A correlation is thus possible (Fig. 6). It has been suggested by Suntharalingham (1968) and by Gobbett and Hutchison (1973) that the boundary between the Kuan On beds and the Kim Loong No. 3 beds in the south Kinta Valley, Perak may also represent the Dinantian-Silesian boundary. Limestones at Batu Gajah in the same area contain foraminifera of probable Stephanian age (Jones *et al.*, 1966). Namurian and Westphalian fossils are not known from the south Kinta Valley.

In Perlis and Kedah, the Kubang Pasu Formation is believed to range in age from Carboniferous to Lower Permian. Westphalian foraminifera are recorded from the formation in Perlis (Scrivenor, 1926). The Singa Formation, outcropping in Langkawi with its characteristic pebbly mudstones is also inferred by bracketing to be of Carboniferous age (Gobbett and Hutchison, 1973) but no palaeontological confirmation of age has been made so far. A number of limestone and shale horizons in north Pahang, Trengganu and Kelantan have yielded fossils which indicate a Carboniferous age. The more confidently dated ones are included in Fig. 6. Tournaisian fossils have not been previously reported from the Malay Peninsula, although in south Thailand late Tournaisian (Tn3c) conodonts are recorded from cherts at Ko Yo, Songkla (Igo, 1973). However, one of us (I.M.) has recovered a late Tournaisian (Tn3c)

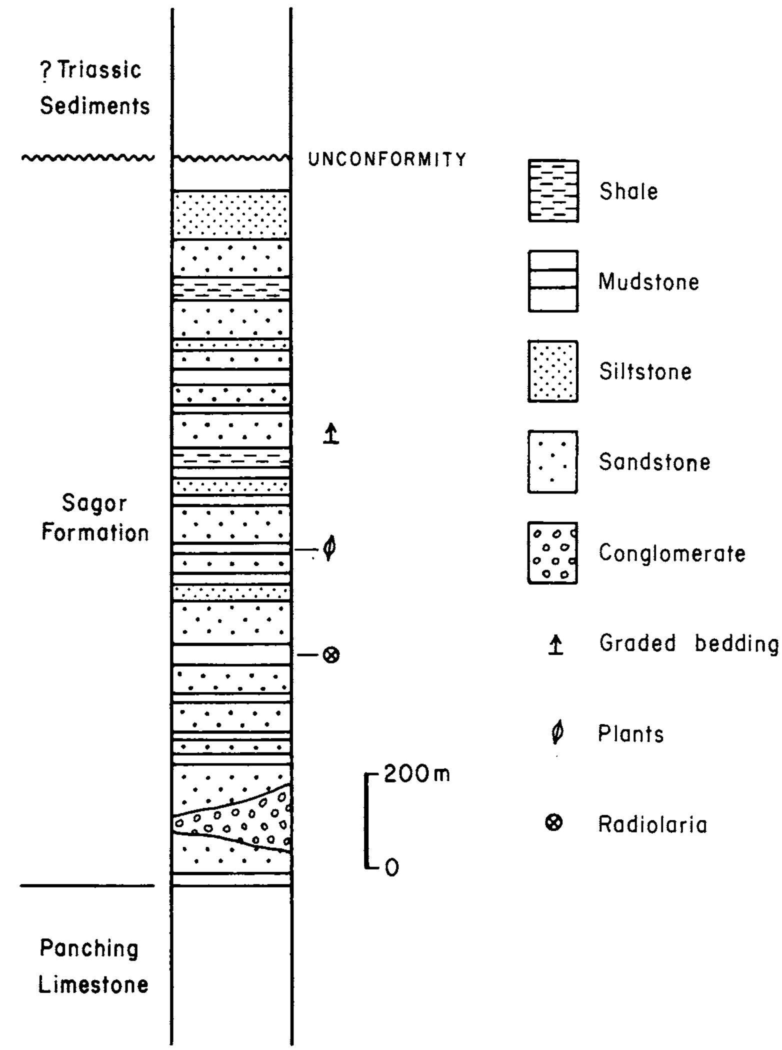

Fig. 5. Composite lithological section through the Sagor Formation of the type locality.

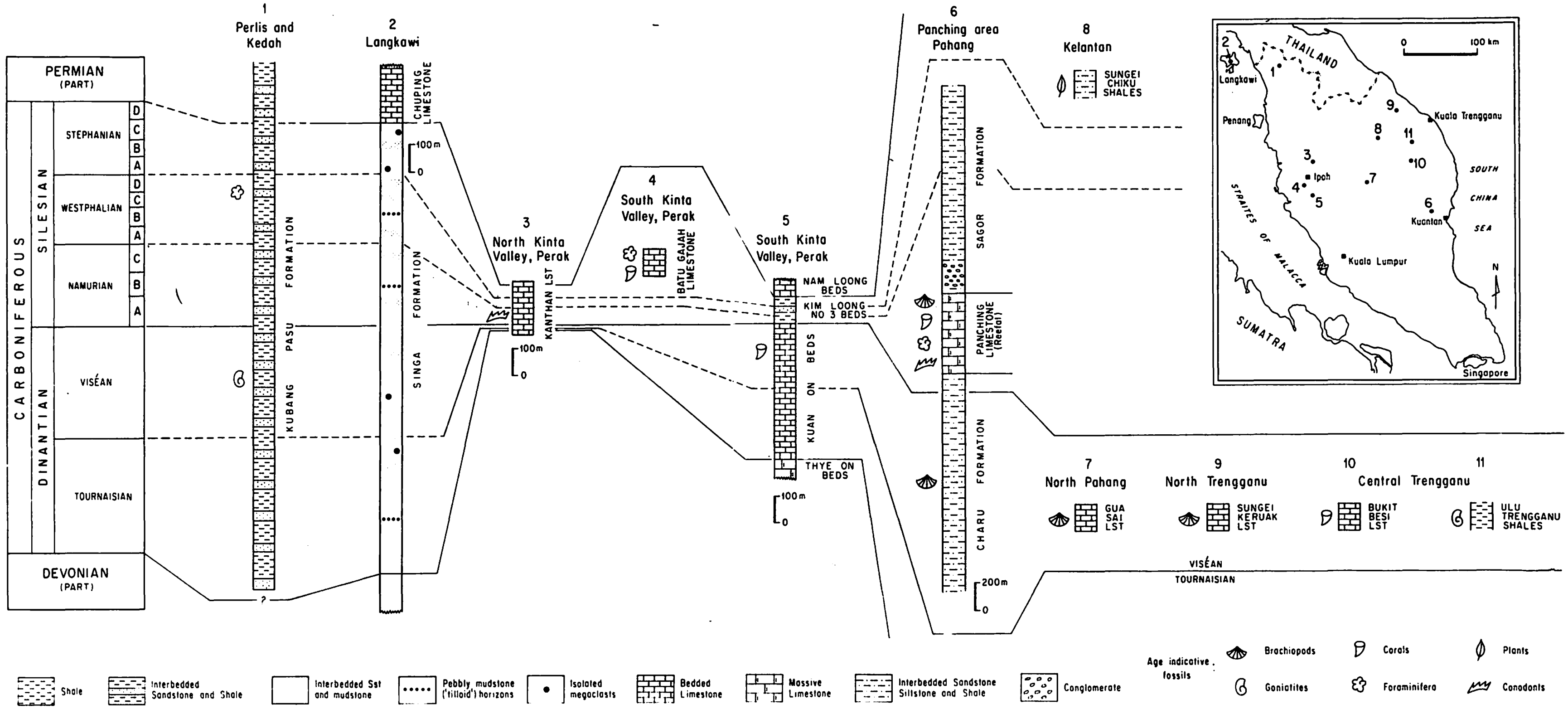

Fig. 6. Correlation of Carboniferous sections in West Malaysia. The Singa Formation section is taken from Stauffer and Mantajit (in press).

conodont fauna representative of the *Scaliognathus anchoralis* Zone at Gunung Kanthan, Perak thus, for the first time, proving Tournaisian sediments in Malaysia.

SYSTEMATIC PALAEONTOLOGY

All type and figured specimens are deposited in the Department of Geology, University of Malaya, Kuala Lumpur.

Genus *Hexaphyllia* Struckenberg 1904

Type species: *Hexaphyllia prismatica* Struckenberg 1904

Hexaphyllia concavia sp. nov.

Plate 3, Figs. 13, 15

?1959 *Hexaphyllia* sp. indet. Kato, p. 284, fig. 6.
?1973 *Hexaphyllia* sp. indet. Sada, p. 85.

Holotype: A476 from Bukit Charas, Namurian A (H_1), Panching Limestone.

Diagnosis: A *Hexaphyllia* with six septa and a star shaped hexagonal outline in cross-section. The coralite peripheries between the points where septa meet the coralite wall are distinctly concave.

Description: The coralites are long and prismatic with a diameter of 0.7–0.95 mm. In transverse section the coralite is hexagonal and star shaped. The 'points' of the star correspond to the positions where the six septa meet the coralite wall. The peripheries between these are distinctly concave. The cardinal and counter cardinal septa meet at the centre of the coralite with slight disalignment. The alar and counter lateral septa merge to form a Y shape, the bottom of the Y extending to the centre of the coralite and meeting the cardinal septa at about 90°. Each arm of the two Ys and the cardinal septa extend to the 'points' of the star.

Remarks: *Hexaphyllia concavia* sp. nov. differs from other species of *Hexaphyllia* in having six sharp ridges separated by concave coralite peripheries as seen in cross-section. The pronounced star shape of this species suggests it is an advanced form. *Hexaphyllia elegans* Yabe and Sugiyama from the Viséan has a sub-rounded cross-section and *Hexaphyllia prismatica* Struckenberg (Viséan-basal Namurian) has a hexagonal polygonal outline. There appears to be a progressive change within the genus during Viséan to Namurian times from a sub-rounded to polygonal to star shape in cross-section. Specimens regarded here as possibly synonymous with *H. concavia* sp. nov. have been reported from the Coffee Creek Formation of Oregon (Late Chesterian) and the Ichinotani Formation of Japan (early Late Carboniferous). The present occurrence of *Hexaphyllia* in limestones of H_1 age represents to date the highest stratigraphic record of the genus.

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