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Stratigraphy of the Jentik Formation, the transitional sequence from the Setul Limestone to the Kubang Pasu Formation at Guar Sanai, Kampung Guar Jentik, Beseri, Perlis — a preliminary study

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Abstract: The transitional sequence from the Setul Limestone to the Kubang Pasu Formation is well exposed at Guar Sanai, Kampung Guar Jentik, Beseri District, northwest Perlis, Malaysia. The rocks of the study area are divided into three major units: Upper Setul Limestone, Jentik Formation, and Kubang Pasu Formation.

The Upper Setul Limestone exposed in Guar Sanai contains *Scyphocrinites*, which gives it a late Silurian age.

The name Jentik Formation is proposed for the roughly 300 m thick sequence between the Setul Limestone and Kubang Pasu Formation. The Jentik Formation can be further divided into six informal units: (a) Unit 1; (b) Unit 2; (c) Unit 3; (d) Unit 4; (e) Unit 5; (f) Unit 6. Unit 1 consists mainly of black shales containing a Dacryoconarid-*Monograptus-Plagiolaria* faunal assemblage, which gives an early Devonian age. Unit 2 consists of light coloured, unfossiliferous sandstones and shales. Unit 3 is mainly thick red mudstone, interbedded with sandstone, sometimes showing graded bedding. A brachiopod-*Diacoryphe-Posidonomya* faunal assemblage gives it a late Devonian age. Unit 4 consists of well bedded, dark limestone, containing straight coned nautiloid fossils. Unit 5 is composed mainly of black mudstone interbedded with cherts, with slump structures. The base of the unit contains a brachiopod–gastropod fossil assemblage. Unit 6 consists mainly of thick beds of brownish red mudstone, interbedded with sandstone. The red mudstones contain a *Macrobole*–crinoid fossil assemblage, which is earliest Carboniferous in age. The Kubang Pasu Formation is suspected to be unconformably overlying the Jentik Formation.

The epicontinental sea that covered present day northwest Peninsular Malaysia during the Palaeozoic was probably density stratified. Transition from shelf carbonate, to black shale and redbed deposition could be due to shifting of the boundary between the oxygen minimum layer and the deeper oxic layer of the sea, triggered by sea level changes.

INTRODUCTION

Stratigraphic work in Perlis has always been spotty, due to the lack of large continuous exposures. Most outcrops are exposed by quarrying activities, and stratigraphic studies of these sites show a Palaeozoic succession similar to that of Pulau Langkawi (Jones, 1981). The transition from the Setul Limestone to the Singa Formation, the equivalent of the Kubang Pasu Formation on the mainland, is exposed in the northwest of Pulau Langgun, Langkawi, Kedah.

An earth quarry which exposes the transitional sequence between the Setul Limestone and the Kubang Pasu Formation was found at Guar Sanai, Kampung Guar Jentik, Beseri, Perlis. The Siluro-Devonian stratigraphy of Perlis is further refined here based on studies of this exposure by the authors.

Background on stratigraphic nomenclature

Extensive geologic mapping of northwest Peninsular Malaysia was done by the Geological Survey Department during the late 1950s and early 1960s. Jones (1966, 1981) published the first comprehensive stratigraphic study for the Palaeozoic rocks of Langkawi, mainland Kedah and Perlis (see Fig. 1 for summary of the history of the stratigraphic nomenclature), in which he divided the sedimentary rocks into four main lithostratigraphic units:

a. Machinchang Formation (oldest)
b. Setul Limestone
c. Singa/Kubang Pasu Formation
d. Chuping Limestone (youngest)

This classification was made before the discovery of Devonian rocks between the Setul Limestone and Singa/Kubang Pasu Formation. This clastic sequence has since then been surrounded by controversy. Based on Jones' original classification, this sequence is divided into two units, the black dacryoconarid shales of the Upper Detrital Member of the Upper Setul Limestone, and the red pebbly

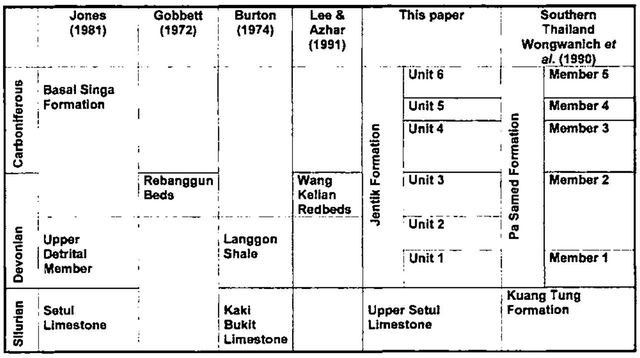

Figure 1. History of stratigraphic nomenclature for Perlis and Kedah, and possible correlations with southern Thailand.

mudstones of the basal Singa Pasu Formation. This division was based on the idea of an unconformity between the Setul Limestone and Singa/Kubang Pasu Formation, which was never actually observed, but inferred based on angular strike relations of the strata, and the presence of conglomeratic red mudstones and sandstones overlying the Upper Detrital Member in Langgun.

Gobbett (1972) erected the name Rebanggun Beds for the red conglomeratic mudstones of the basal Singa Formation in Pulau Langgun, due to its distinct lithology. This unit is also known as the Langgun Red Beds in the literature and an extension of the redbeds in Perlis have been named the Wang Kelian Redbeds (Lee & Azhar, 1991).

The existence of an unconformity between the Upper Detrital Member and the Rebanggun Beds was questioned by Ahmad Jantan (1973) and Yancey (1975). The conformable contact between the two units led Yancey (1975) to combine both units into one Unnamed Devonian unit.

The sedimentary strata of northwest Peninsular Malaysia actually extends into neighbouring southern Thailand. Detailed stratigraphic work on the Palaeozoic strata of southern Thailand indicates that the stratigraphy is more complex (Wongwanich *et al.*, 1990). Yancey's Unnamed unit is here known as the Pa Samed Formation.

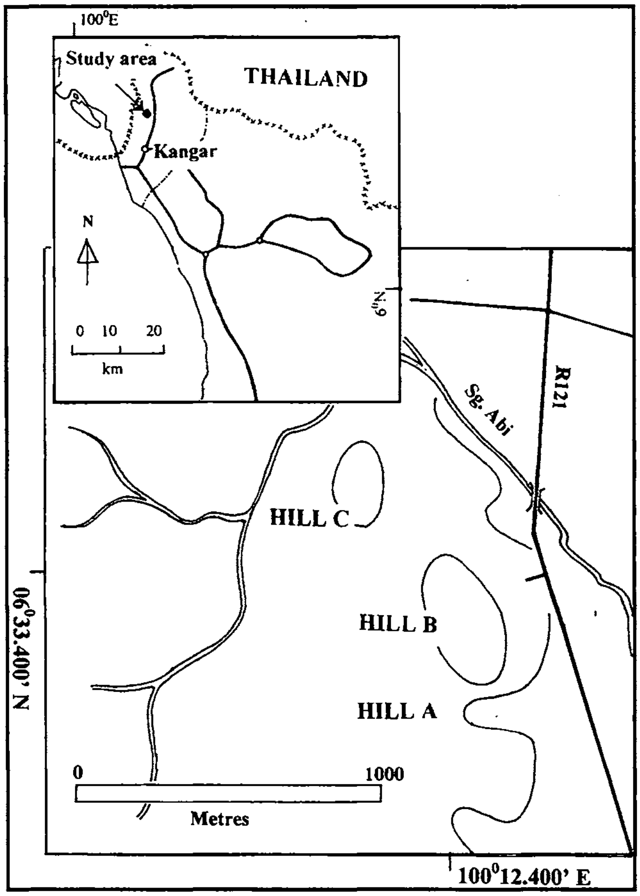

Figure 2. Map showing location of the study area.

Problems

At present, the stratigraphic nomenclature is very confusing. Different classification schemes have been used by different workers, definition of proposed units were based on limited data, and even the nature of the contact between certain units is still debatable. These problems arise because of several factors. The main factor is geographical. Exposures of mid-Palaeozoic sedimentary rocks in northwestern Peninsular Malaysia are spotty, and limited mostly to open quarries, and their distribution is discontinuous, due to the thick vegetative cover. The same sedimentary rocks also crossover into southern Thailand. This has led to different classification schemes being used for the same stratigraphic succession in Thailand. Another factor is geological. The strata in northwest Peninsular Malaysia shows intense folding, which makes detailed stratigraphic mapping and logging difficult. The critical contacts between the Upper Detrital Member and the overlapping redbeds are badly sheared or not exposed.

The lack of geographical place names in the small area where the stratigraphic section is exposed precludes the application of formal nomenclature to the smaller stratigraphic units proposed in this paper. This will hopefully be rectified as the units are mapped over a wider area in the future.

PRESENT STUDY

Location

The study area is a hilly ridge known locally as Guar Sanai, Kampung Guar Jentik, Beseri District, Perlis (Fig. 2). This lies between 6°33.129'N and 100°12.524'E. The ridge is separated into three small hills, here referred to as Hill A, B and C from south to north (Fig. 3). The study area is just south west of the Timah-Tasoh Dam. At the west of the ridge is the steep Setul Boundary Range.

Stratigraphy

In general, the exposed rocks of the study area show a transitional sequence in which the lithology changes upwards from carbonate to clastic deposition. The thickness of the exposed sequence is about 300 m, and encompasses rocks of late Silurian to earliest Carboniferous age.

Orientation of the beds are roughly north northwest-south southeast, and dipping to the east (Fig. 3). The lower and middle part of the sequence dips at a steep angle. The bottommost exposure of the sequence consists of well bedded, dark coloured Upper Setul Limestone. This is overlain conformably by clastic beds of the newly proposed Jentik Formation. Overlying these units is the Kubang Pasu Formation.

Eight sections were logged from exposures on all three hills of the Guar Sanai area (Fig. 4), and are described below.

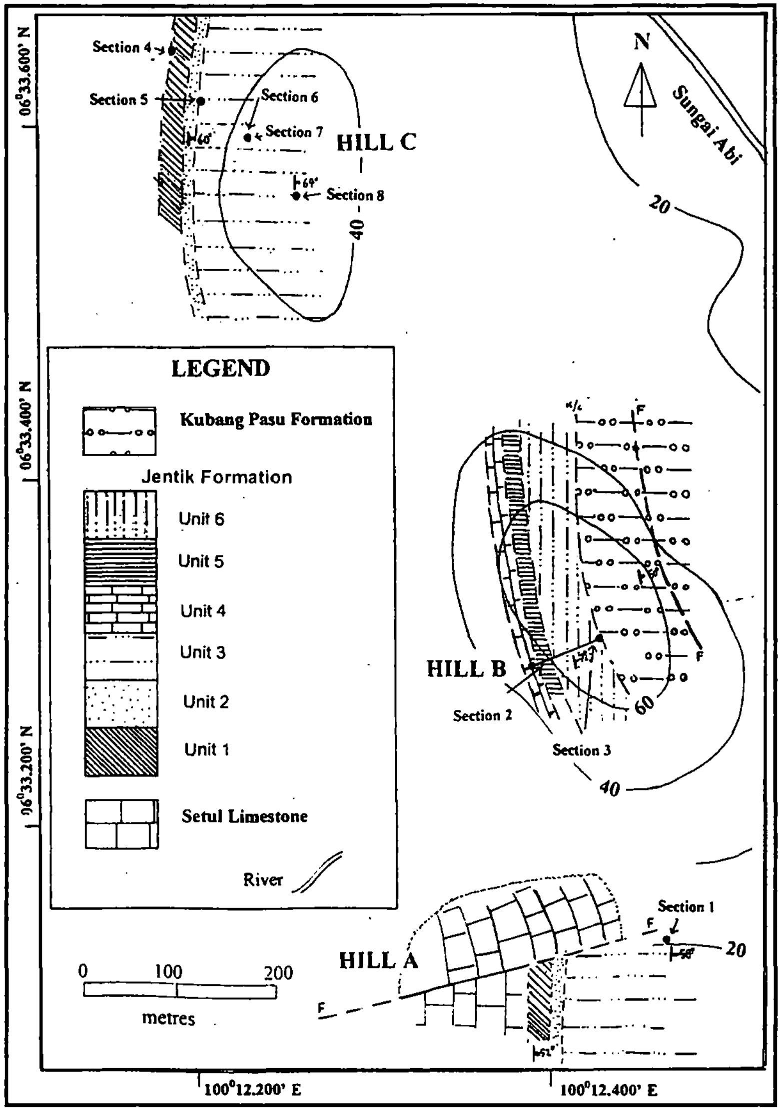

Figure 3. Outcrop geological map of Guar Sanai and logged section location.

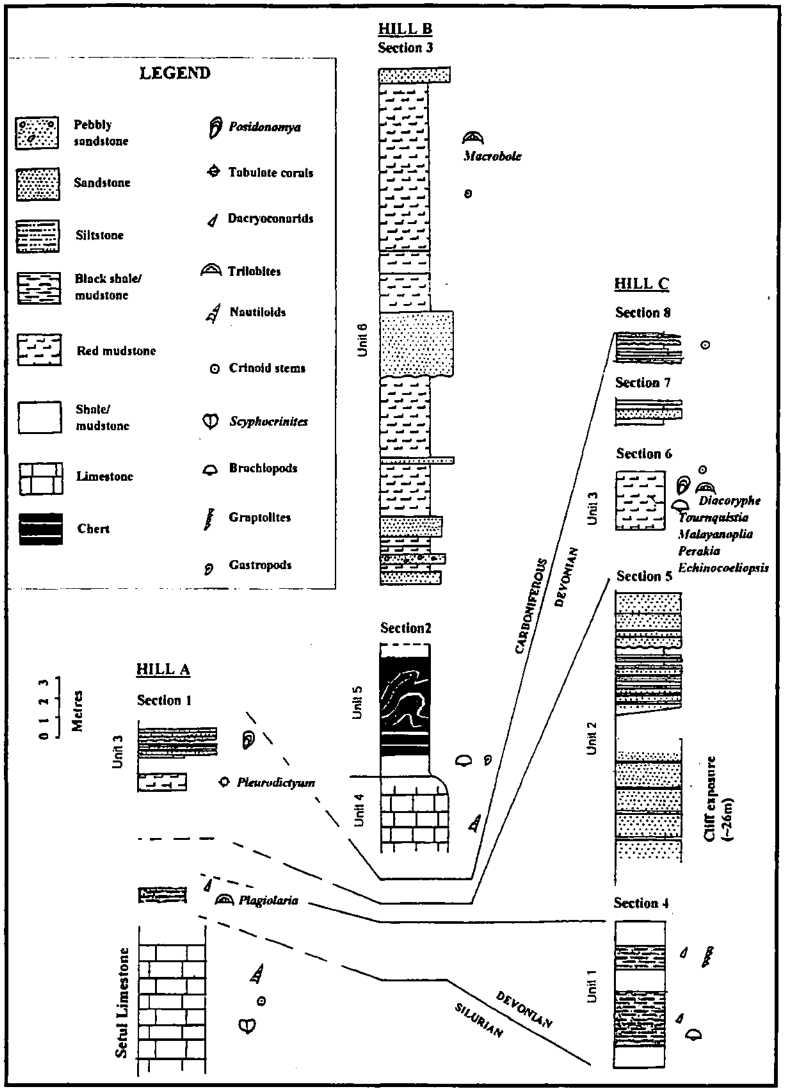

Figure 4. Logged sections of the Guar Sanai area, and possible correlation.

Hill A

This is the southernmost outcrop, with the southern face of the small hill exposed by quarrying activities. The hill is composed mainly of well bedded, dark coloured limestone. The limestone beds are 3–40 cm thick, and are rhythmically interbedded with millimeter thick, darker coloured marls. The colour of the exposed limestone is reddish white, due to weathering. Fresh samples are dark grey in colour. Thin clastic horizons also occur in some parts of the limestone, which show bioturbation. Some isolated blocks of limestone contain small incomplete polygonal structures identified as syneresis cracks but Wongwanich, (*pers. comm*), thinks that these are actually a type of deepwater stromatolite). Some parts of the limestone are highly fossiliferous, containing crinoid ossicles and straight-cone nautiloids. Large fallen blocks of limestone found scattered around the hill contain fossil ossicles and loboliths of the strange crinoid *Scyphocrinites* (Lee, 2001).

Black shales are exposed in a ditch just south of Hill A. The shale beds are 2–5 cm thick, and black in colour, but weather to grey. These shales are highly fossiliferous, containing dacryoconarids, trilobites and brachiopods.

Section 1 (Fig. 4)

This section consists of clastic beds south of the limestone hill. The lower part of the section consists of a 1.3 m thick red mudstone bed containing fossil coral. One metre above this is a 1.55 m thick unit of weathered, light brown coloured mudstone interbedded with flatbottom, coarse grained, clean sandstones. These mudstones show crude laminations, and contain abundant *Posidonomya* fossils. The top of the section consists of three beds of coarse sandstone, with a combined thickness of 55 cm. The sandstone beds show erosive bottoms, similar to channel deposits. The sandstone is white in colour and very clean.

Hill B

The section at Hill B is well exposed, and shows a transitional sequence from carbonate to clastic deposition.

Section 2 (Fig. 4)

The bottommost part of the section consists of dark-coloured limestone (Fig. 5), weathering to white, which contains fossil crinoids and nautiloids. The limestone shows planar bedding measuring 10 to 30 cm in thickness.

The lithology changes quite abruptly (Fig. 5) from carbonates at the bottom, to clastics at the top. The transition zone consists of siltstone and light coloured mudstone. A thin (10 cm) light coloured mudstone bed just above the limestone contains a gastropod-brachiopod fossil assemblage.

Above this, a 5 m thick band of black mudstone and chert occurs. The beds are 2–5 cm thick. These do not contain fossils. The beds are folded intraformationally in some parts of the black rocks. These folds are restricted only to the black chert and mudstone, and do not occur in the limestone beds below or in the light coloured mudstones above. Based on this, and the disharmonic nature of the folds, they are interpreted as syndepositional structures, formed due to slumping. Small quartz veins are observed crosscutting the beds. The texture of the rock is hard and almost slaty. On top of the black rocks is a green coloured mudstone.

Section 3 (Fig. 4)

The section consists mainly of brownish red mudstones, with interbedded medium and coarse grained sandstones. One sandstone bed is conglomeratic. Above this are three thick red mudstone beds containing fossils of trilobites and crinoids. At the top of the red mudstones is a dark coloured, medium grained muddy sandstone bed. The base is erosive. Overlying this bed are light brown coloured laminated mudstones and thick white sandstones. There is a significant difference in dip angle between the redbeds below and the light brown mudstones above. The base of the dark coloured muddy sandstone is possibly the contact.

Above the logged section of Hill B are dark coloured rocks. These are predominantly argillaceous, interbedded by thin-medium thick beds of muddy sandstone. Pebbles and cobbles are occasionally found in the dark mudstone. Two cobbles jutting out of the hill face measure about 15 cm in length.

Hill C (Fig. 6)

This is the northernmost hill of the Guar Sanai ridge, and has been greatly eroded due to earth quarrying activities.

Section 4 (7+ m)

The westernmost logged section consists of two units of thinly bedded black carbonaceous shale, divided by a 1.5 m thick light coloured mudstone bed. The shales are very soft. The black shale is highly fossiliferous with abundant dacryoconarids, monograptids, brachiopods and lamellibranchs. The shales show signs of slump deformation, with faulted and folded layers.

Section 5 (6+ m)

The section is located on a faulted block, and is predominantly arenaceous. It consists of thick, flatbottomed fine sandstone and thin beds of shale. The rocks are light green to white in colour. The sandstone beds become thinner lower in the section, and are interbedded with thin shale layers. Scouring is seen at the bottom of a 50 cm sandstone bed near the top.

Section 6 (3.9 m)

This is a single, thick red massive mudstone bed. The mudstone is highly fossiliferous, and most of the brachiopod fossils collected were from this single bed. The mudstone is soft, showing no laminations and no indications of bioturbation. Manganese nodules also occur. These nodules are usually ovoid in shape, and measure from 15–50 mm.

Section 7 (1.25 m)

The sandstone and mudstone here are thicker than in section 1. Most of the sandstones are well bedded, but one bed shows a scoured bottom, where it meets the sandstone.

Section 8 (2.2 m)

This is the easternmost section logged at Hill 3. It consists of thin beds of interbedded red fossiliferous mudstone, siltstone and fine sandstone. The middle of the section shows well bedded fine sandstone interbedded with mudstone and siltstone. The uppermost part of the section shows three fining upward cycles, from fine grained sandstone, followed by siltstone and mudstone, with each cycle about 30 cm thick. The sandstone at the topmost part shows scoured bottoms, where it cuts the mudstone. Fossil crinoid stems are found in the mudstone.

Palaeontology

Fossils occur in abundance in several localities in the study area. Fallen blocks of Hill A are found to be rich in crinoid ossicles and straight-cone nautiloid fossils. The occurrence of *Scyphocrinites* gives a late Silurian age to the limestone.

The black shales of Hill A contain abundant remains of the dacryoconarids *Nowakia* sp., *Styliolina fissurella*, and *Styliolina* sp., and the trilobite *Plagiolaria*. Similar fossils are found in the black shales of Section 4 at Hill C. The dacryoconarids here are associated with monograptids. The fossils indicate that the black shales are of early Devonian age.

The thick red mudstone beds of Hill B (Section 3) contain mostly crinoid ossicles and also trilobite fragments identified as *Macrobole kedahensis*. *Macrobole* gives an earliest Carboniferous (Tourniaisian) age. The limestone at the bottom of Section 2 contains unidentified straight cone nautiloids, and a thin, light coloured mudstone bed just above the top of the limestone contains unidentified gastropods and brachiopods.

The red mudstones of Hill C (Section 6) contain an abundant fossil assemblage. This includes crinoid ossicles, *Posidonomya*, brachiopods such as *Tournquistia burtonae*, *Malayanoplia* sp., *Perakia* sp., and *Echinocoeliopsis* sp., and the trilobite *Diacoryphe* sp. The fossils are late Devonian in age.

The isolated red mudstone on Hill A contains only the tabulate coral *Pleurodictyum*, which gives it a Devonian age. Light brown mudstones above it are rich with *Posidonomya* fossils.

DISCUSSION

Proposal

The exposed sedimentary rocks of Guar Sanai have given us a clearer view of the stratigraphic sequence between the Setul Limestone and Kubang Pasu Formation. It now seems that there are two red mudstone units of different ages, and also a new limestone unit, younger in age than the Setul Limestone.

Based on field observations and palaeontological data, the rocks of the study area can be divided into three main units:

a) Upper Setul Limestone (oldest)
b) Jentik Formation
c) Kubang Pasu Formation

Upper Setul Limestone

Limestone beds found at Hill A are here identified as the upper part of the Setul Limestone based on the following criteria:

- The calcareous lithology, consisting of well bedded, dark coloured limestone.
- Stratigraphic position below rocks of Devonian age.
- The late Silurian age of the limestone, based on the occurrence of *Scyphocrinites*.

The lower boundary of the Upper Setul with the Lower Detrital Member of Jones (1981) cannot be located in the study area. The exact thickness of the limestone exposed cannot be ascertained, due to the faulted nature of the outcrop.

The limestone is very fossiliferous, with fossils of crinoids and nautiloids. The limestone is well, thin to medium bedded, and separated by centimetre thick marl layers. Nodular limestone can also be seen. Stylolites and syneresis cracks also occur. Some thin clastic horizons exist, showing bioturbation.

Jentik Formation

A new stratigraphic unit is proposed here for the mainly clastic transitional sequence between the Upper Setul Limestone and the Kubang Pasu Formation. This new formation includes the black dacryoconarid shales of Jones' basal Upper Detrital Member, and also the Langgun Red Beds. The Jentik Formation is named after Kampung Guar Jentik, the nearest named village in the topographic map to Guar Sanai where the present exposures are exposed.

The Jentik Formation is defined as the mainly clastic sequence conformably overlying the Upper Setul Limestone, and underlying the Kubang Pasu Formation. The sections in the study area are not continuous, with some parts deformed, but the thickness of the formation can be estimated to be about 300 m. The formation ranges from early Devonian-earliest Carboniferous (Tourniaisian) in age. The Jentik Formation can be separated into smaller informal units (the approach is adopted here due to the lack of place names in this small area for erecting formal members):

i) Unit 1 (oldest)
ii) Unit 2
iii) Unit 3
iv) Unit 4
v) Unit 5
vi) Unit 6 (youngest)

Unit 1 (8+ m)

This unit is exposed just south of Hill A, and on Hill C (Section 4). The lithology is mainly argillaceous, predominantly black carbonaceous shale, with some brown coloured beds. It contains a dacryoconarid-monograptid-*Plagiolaria* fossil assemblage, giving an early Devonian age. Some parts of the unit show slump folds and faults. This unit encompasses Jones' (1981) basal Upper Detrital Member.

Unit 2 (36+ m)

Unit 2 is exposed on Hill A just above Unit 1. Only one small section was logged (Section 5), but the member is estimated to be about 36 m thick, based on the cliff exposure on Hill C (Fig. 6). The lithology consists of light coloured argillo-arenites, predominantly arenaceous, with thick, flat bottomed, fine grained sandstone beds. Shales make up about 15% of the unit, and are thin bedded.

Unit 3 (150+ m)

Unit 3 is exposed on Hill C (Section 6, 7, 8). The lithology is predominantly argillaceous, consisting mainly of thick red mudstone, interbedded with thin to medium thick sandstones. The sandstones are fine to coarse grained quartzites, showing normal graded bedding with scoured bottoms, and interpreted as turbidites. The unit contains a brachiopod-*Diacoryphe-Posidonomya* fossil assemblage, which gives it a late Devonian age. The upper and lower boundaries of the unit with Units 2 and 4 are not exposed in the field, but the thickness of the unit is at least 150 m. Isolated red mudstone on Hill A contains the Devonian coral *Pleurodictyum*, suggesting that it is a part of Unit 3. Above the red mudstone are thick sandstone beds with scoured bottoms, interbedded with crudely laminated, light brown mudstone containing *Posidonomya*.

Unit 4 (9 m)

Well bedded limestone beds are exposed on Hill B (Section 2). These are dark coloured, weathering to white. The only fossils found are straight cone nautiloids, but the position of the limestone just below rocks of early Carboniferous age indicates that this unit is younger than the Upper Setul Limestone. Geological mapping of the area also shows that its stratigraphic position is probably above Unit 3. The lower boundary is not exposed, therefore its exact thickness cannot be determined. The upper boundary is clearly seen on Hill B, where the lithology changes somewhat abruptly from limestone to mudstone.

Unit 5 (10+ m)

This unit is exposed on Hill B, just above Unit 4. It is mainly argillaceous. At the bottommost part of the unit, just above the limestone, is a 10 cm bed of light coloured mudstone containing a brachiopod-gastropod fossil assemblage. The colour of the rocks gradually changes from white to black towards the top, where they are interbedded by cherts. These black mudstones are unfossiliferous, and show an almost slaty texture. Some parts of the black cherty mudstone are greatly folded. These structures are intraformational, and are interpreted as slump structures. Above the cherty black mudstone is a brown coloured mudstone.

Unit 6 (35+ m)

The lithology of Unit 6 thick is predominantly argillaceous, consisting of thick brownish red coloured mudstones, interbedded with medium thick sandstone, sometimes showing scoured bottoms and pebbles (Section 3). The red mudstone contains a trilobite-brachiopod fossil assemblage. The trilobite *Macrobole kedahensis*, gives an early Carboniferous (Tourniaisian) age. The contact between this unit with the Kubang Pasu Formation is suspected to be an unconformity, based on abrupt change in dip angle, and observation of an erosional contact on Hill B.

Kubang Pasu Formation

The predominantly argillaceous unit exposed above the Jentik Formation on Hill B is here identified as part of the Kubang Pasu Formation. The lithology consists of rapidly alternating deposits of argillo-arenites, with a predominance of grey and dark coloured mudstones. The sandstone beds are identified as greywackes. Pebbles and cobbles are occasionally found imbedded in the mudstones. Lithologically similar rocks in Pulau Langkawi were named Singa Formation (Jones, 1973). These are laterally equivalent to the Kubang Pasu Formation. Both of these units are lumped together here, under the name Kubang Pasu Formation, based on its wider usage and larger area, as suggested by Foo (1983).

Age of the Jentik Formation

The stratigraphic position of the Jentik Formation, which underlies *Scyphocrinites* bearing Upper Setul Limestone, indicates a post Silurian age for the unit. The black shales near the base of the Jentik Formation contain an early Devonian faunal assemblage, consisting of *Nowakia, Styliolina, Plagiolaria* and monograptids. The upper part of the Jentik Formation (Unit 6) contains fossils of the cyrtosymbolid trilobite *Macrobole kedahensis*, which gives an early Carboniferous (Tourniaisian) age. Therefore, the age range of the Jentik Formation is concluded to be from early Devonian to earliest Carboniferous (Tourniaisian).

Correlation

The outcrops of Guar Sanai have enabled us to resolve the transitional sequence between the Setul Limestone and Kubang Pasu Formation, and have also allowed us to correlate these rocks with those in southern Thailand. A sequence similar to the Jentik Formation has been reported by Wongwanich *et al.* (1990), in Satun Province, where the unit is called the Pa Samed Formation. Unit 1 can be biostratigraphically and lithostratigraphicaly correlated to Member 1 of the Pa Samed Formation, whose black shales also contain monograptids, *Nowakia*, *Styliolina* and *Plagiolaria*. Unit 2 is similar to Member 2 of Pa Samed Formation, which is also composed of white sandstones and shales. Red mudstone showing incomplete Bouma sequences, similar to the late Devonian Unit 3, are found near the top of Member 2. Unit 4 is probably the lateral equivalent of Member 3 of the Pa Samed Formation, based on its stratigraphic position and similar lithology. Member 3 is 55 m thick. Unit 6 may be represented in the Pa Samed Formation by Member 5, which consists of massively bedded sandstones interbedded with red mudstone. Crinoid fragments are found in both units.

Depositional Environment

The depositional environment for the Jentik Formation is interpreted here as a moderately deepwater marine slope environment. Unit 1 is wholly argillaceous in lithology, indicating a low energy environment. Slump folds suggest deposition on a slope. Black shales are also usually associated with anoxic water conditions, and the lack of benthic fossils supports this interpretation. Slump folds are also found in Unit 5, and the orientation of the fold axes here suggests eastward sloping. Unit 3 (Section 8) reveals a cyclical pattern of deposition of sandstone, siltstone, red mudstone, shale, followed by another cycle of the same deposition pattern. Fining upwards sands indicate deposition from suspension. Occurrences of angular pebbles, and scouring on mudstone show rapid deposition. Based on these features, these rocks are interpreted as turbidites. The red mudstone beds can be thick, and fossils are well preserved, indicating a low energy environment. The small size of the fauna and absence of bioturbation suggest an inhospitable environment. Unit 3 contains the trilobite *Diacoryphe*, which is a small animal with no eyes, suggesting that it lived in dark, relatively deep waters, either in the dysphotic or the aphotic zone, where eyes can be lost without giving a disadvantage to the animal. The combination of slumping, turbidites and thick mudstone are indicative of deepwater slope deposits.

The Palaeozoic redbeds of Perlis and Langkawi have always been used to imply an uplift episode at that time (Hutchison, 1983). This is because redbeds were usually interpreted as oxidised terrestrial sediments of continental origin. But this interpretation is not consistent with our model of a relatively deep marine depositional setting for the redbeds of Unit 3 and 6. Red colouration of deep marine sediments is not rare as thirty eight percent of the present day seafloor is covered by red clay (Fischer & Arthur, 1977). A density stratification model of a somewhat closed basin is proposed here to explain the existence of black shales and red mudstone. Stagnant seas, where water circulation is poor, usually show a division of the water column into three layers (see Fig. 7):

Shallow aerobic layer

Near the surface of the sea, oxic conditions prevail, as the water is supplied oxygen by photosynthesis.

Oxygen minimum layer

In intermediate depths, anoxic conditions prevail. This layer obtains its oxygen when it was near the surface. Due to lack of circulation, the oxygen content of the layer becomes depleted. This is because it is used up by the high biomass and metabolism rate of life in the intermediate layer. Black laminated shales are deposited in this oxygen minimum layer, as in the Jentik Formation.

Figure 5. Outcrop on Hill B (Section 2) showing steeply dipping limestone beds (Unit 4, Jentik Formation) and interbedded black cherts and mudstone on the right (Unit 5, Jentik Formation).

Figure 6. Western face of Hill C (Section 4). Note black dacryoconarid bearing shales at the base (Unit 1, Jentik Formation) and cliff exposure consisting predominantly of light coloured sandstones (Unit 2, Jentik Formation).

Oxic bottom layer

Oxic conditions occur again in deeper parts of the sea. The oxygen content here is less depleted than the oxygen minimum layer, because of the lower biomass at greater depths. Red and tan coloured clays are deposited. The red mudstones of the Rebanggun Beds are interpreted to have occurred in such an environment. The intense red coloration of the sediments may indicate a large increase in dissolved oxygen content of the deep waters, or what is called an underwater oxic event. Such stratification of sea water is due to differences in density, and is usually prominent in stagnant, epicontinental seas with no water circulation. The depth of the basin is in the range of hundreds of metres, and stratification was at a smaller scale than that suggested by Fischer and Arthur (1977).

CONCLUSION

A new stratigraphic unit is proposed here to encompass the transitional sequence between the Setul Limestone and Kubang Pasu Formation. This unit includes once separate units such as the Upper Detrital Member of the Setul Limestone and the Langgun Red Beds. Is seems that there

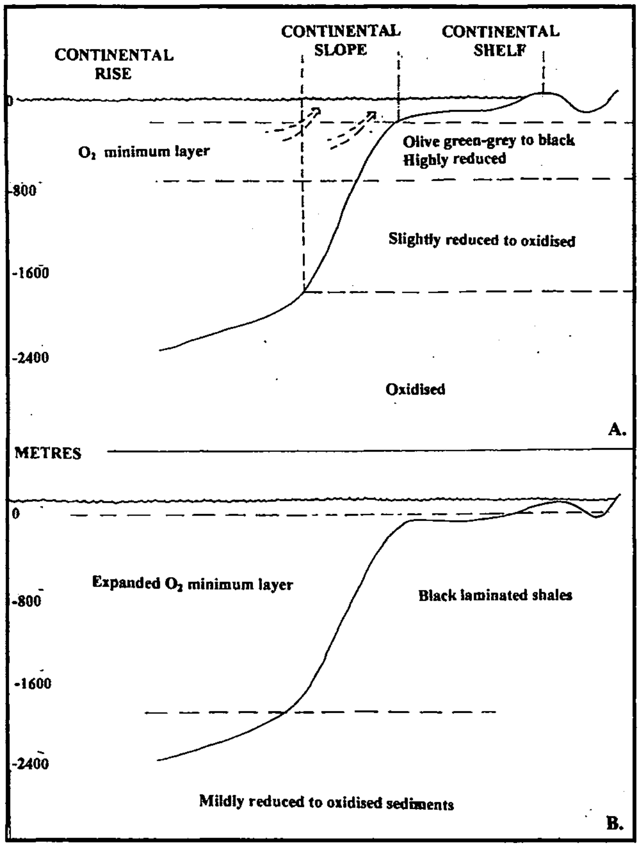

Figure 7. Density stratification model for an epicontinental sea (From Fischer & Arthur, 1977). (A) Present day density stratification, (B) Model of expanded oxygen minimum zone during transgression.

are actually two red mudstone units of different age, one late Devonian (Unit 3) and the other early Carboniferous (Unit 6). Preliminary results show that the stratigraphic sequence of the Jentik Formation is very similar to the Pa Samed Formation of southern Thailand, but only further detailed stratigraphic and palaeontological study will confirm this.

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