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Stratigraphy and sedimentology of the chert unit of the Semanggol Formation

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Abstract: Excavation of rocks in the Semanggol Formation exposed more rock succession, making it feasible to study in detail the stratigraphical distribution of the rocks, their age and relationship among the units in the formation. Five Permian and four Triassic radiolarian biozones were recognized. Discovery of Permo-Triassic radiolarian faunas indicates the chert unit is partly equivalent in age to the rhythmite and conglomerate units. The chert unit is divided into eight sedimentary facies, which were deposited in an open-deep marine environment under the influence of different transport mechanisms. It is evident that there were widespread volcanogenic sediments prior to the deposition of the chert in the Semanggol Formation.

Abstrak: Pengorekan batuan di Formasi Semanggol telah mendedahkan lebih banyak jujukan batuan yang membolehkan kajian terperinci sebaran stratigrafi, usia, dan hubungan unit-unit dalam formasi ini. Lima biozon Perm dan empat biozon Trias radiolaria telah dikenal pasti. Penemuan radiolaria Perm dan Trias menunjukkan unit rijang ini sebahagiannya setara dengan unit berirama dan konglomerat. Unit rijang boleh dibahagikan kepada lapan fasies endapan yang diendapkan dalam sekitaran samudera laut dalam di bawah pengaruh mekanisme pengankutan yang berbeza. Bukti juga menunjukkan kewujudan endapan volkanogen yang meluas sebelum berlakunya pengendapan rijang Formasi Semanggol.

INTRODUCTION

The Semanggol Formation was introduced by Alexander (1959) for the sedimentary rocks exposed in the Semanggol range in north Perak. The term was adopted by Burton (1970, 1973, 1988), Courtier (1974), Abdul Rahim Samsudin *et al*. (1991) and Teoh (1992). The Semanggol Formation is widely exposed in north Perak, south Kedah and north Kedah. The formation was probably deposited in the same basin, which was later separated into three areas by wrench faults (Burton, 1973; Ibrahim Abdullah *et al*., 1989). Burton (1973) divided the formation into three informal members namely the chert member, the rhythmite member and the conglomerate member, which were later called units by Teoh (1992). The three units were interpreted to be in lateral and interfingering contact, representing lateral facies variation rather than in sequential superposition as have previously been reported (Ahmad Jantan *et al.*, 1989). The conglomerate unit was deposited in a proximal submarine fan, the rhythmite unit was deposited in distal submarine fan, and the chert unit was deposited in a basin environment (Ahmad Jantan *et al.,* 1989). The formation is folded and faulted. The age of the Semanggol Formation was previously assigned as Triassic based on the occurrence Bivalvia (Burton, 1973) and was later changed to Early Permian to Triassic (Basir Jasin, 1996, 1997).

The chert unit was considered as the oldest unit (Burton, 1973). The radiolarian bearing chert unit has been studied by many paleontologists (Sashida *et al*., 1992, 1993, 1995; Basir Jasin, 1994, 1996, 1997; Metcalfe and Spiller 1994, Spiller and Metcalfe 1995a, 1995b, Spiller, 2002, and Basir Jasin *et al*., 2005a, 2005b). Discovery of Early Permian to Middle Triassic radiolarians suggests that the chert unit is not the oldest unit. It is partly interfingering with the rhythmite and the conglomerate units (Basir Jasin, 1997). Burton (1973) described the chert unit as consisting of alternations of black, carbonaceous mudstone with chert, siltstone, and greywacke.

A new outcrop was exposed at an excavation site near Kuala Ketil, south Kedah. This outcrop shows a complete rock sequence of the chert unit. Detailed description of the chert unit is now possible.

GEOLOGICAL SETTING

The Semanggol Formation is located at three separate fault-displaced areas in Padang Terap (north Kedah), Kulim-Baling (south Kedah) and Gunung Semanggol (north Perak). In the Padang Terap area the Semanggol Formation consists of three units *i.e.* the conglomerate, the rhythmite and the chert units. The formation conformably overlies the Kubang Pasu Formation. In the Kulim-Baling area the formation is represented by two units; the chert and the rhythmite units. The rocks in this area comprise the Ordovician-Early Devonian Mahang Formation and the Permo-Triassic Semanggol Formation. The Carboniferous rocks are not exposed. Courtier (1974) proposed the Tawar Formation as a probable Carboniferous lithostratigraphic unit but no Carboniferous fossils were discovered. Burton (1988) considered that the Tawar chert was a part of the Semanggol Formation. The existence of Carboniferous rocks in the area is yet to be discovered

because the Paleozoic and early Mesozoic rocks in the area were continuously deposited in a deep marine environment and there is no trace of any unconformity or tectonic uplifting during this time. In Gunung Semanggol area only two units were exposed *i.e*. the conglomerate and the rhythmite units. The formation was uplifted by the Late Triassic granite intrusion.

The chert unit is well exposed only in the Padang Terap and Kulim-Baling areas (Figure 1). The chert unit in the Padang Terap area forms prominent north-south strike ridges located in the vicinity of the Pokok Sena area. The chert sequence is well exposed at Bukit Larek and Kampung Lanjut Malau. The Bukit Larek section exhibits six facies (in ascending order)

1. Black laminated mudstone
2. Interbedded sandstone and mudstone
3. Siliceous shale and mudstone
4. Interbedded siliceous shale and chert
5. Tuffaceous mudstone
6. Interbedded chert and siliceous shale.

Only Early Permian radiolarians were recovered from the siliceous shale facies at Bukit Larek section (Basir Jasin, 1997). No radiolarians were retrieved from the interbedded chert and siliceous shale facies.

The Semanggol chert in the Kulim-Baling area is faulted and strongly folded and it was very difficult to measure the actual thickness of the chert. Burton (1988) reported that the thickness of the chert in the Kulim-Baling area was approximately 700 m based on the outcrop where the rocks were not folded. Burton (1988) described a 1.12 m typical chert sequence at Lubuk Anak Batu Estate comprising mainly thinly bedded chert intercalating with siliceous shale of varying thicknesses.

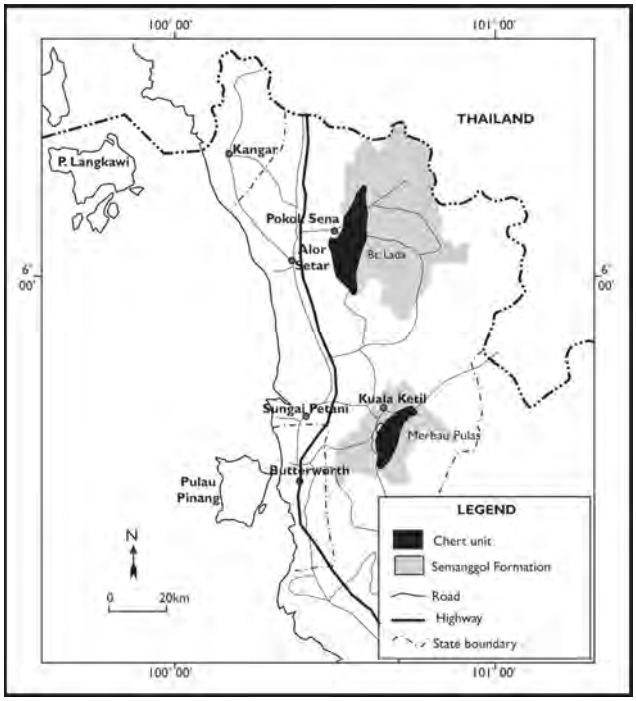

Figure 1: Map showing geographic distribution of the chert unit in the Semanggol Formation.

Most of the previous studies (Burton, 1973, 1988; Courtier, 1974; Teoh, 1992) considered the chert unit to consist of mainly interbedded chert and siliceous shale. Extensive earth excavation at Padang Terap and Kulim-Baling areas exposed many outcrops with a complete stratigraphic section of the chert unit especially at Bukit Larek and Kampung Lanjut Malau (Padang Terap) and at Bukit Kukus near Kuala Ketil (Kulim-Baling). The section at Bukit Kukus is chosen to represent the chert unit because it provides a more complete rock sequence with a good radiolarian biostratigraphic control.

DESCRIPTION OF THE OUTCROP

An extensive outcrop was exposed at an excavation site at a hill known to the locals as Bukit Kukus, approximately 4.5 km east of the Kuala Ketil town (Figure 2). The section is cut in a north-south direction. Many reverse and thrust faults displaced the rock sequence but it can still be identified and measured. The section has two terraces. The base of the section is less disturbed and exhibits a good rock succession, which was measured. The rocks on the first and the second terraces are structurally complicated. The rocks strike generally east-west and dip southwards. Seven lithofacies were identified (Figure 3) in ascending order:-

1. Laminated black mudstone
2. Interbedded sandstone and mudstone
3. Interbedded tuffaceous sandstone and tuff with a paraconglomerate bed.
4. Interbedded tuffaceous sandstone, siliceous shale and chert
5. Bedded chert
6. Tuffaceous mudstone
7. Interbedded chert and siliceous mudstone

The rock sequence is similar to the section exposed at Bukit Larek, Padang Terap district north Kedah.

STRATIGRAPHY OF THE CHERT UNIT

The chert unit is the most studied sequence of the Semanggol Formation. Many radiolarian paleontologists conducted researches on the radiolarian bearing chert layers. This resulted in several radiolarian biozones being identified (Sashida *et al,*. 1992, 1993, 1995; Basir Jasin, 1994, 1996, 1997; Spiller and Metcalfe, 1995a, 1995b, Spiller, 2002, and Basir Jasin *et al.,* 2005a, 2005b). Basir Jasin *et al.* (2005a, 2005b) made a detailed study of the radiolarians from the Bukit Kukus section in Kuala Ketil and identified nine radiolarian zones (Figure 4).

Three assemblege zones were identified from the thin black chert in the upper part of the interbedded tuffaceous sandstone, siliceous shale, and chert facies. The radiolarian zones are the *Pseudoalbaillella scalprata rhombothoracata* Zone, Sakmarian (late Early Permian), the *Follicucullus monacanthus* Zone, Wordian, (Middle Permian) and *Follicucullus porrectus* Zone, Capitanian-Wuchapingian,

(late Middle Permian to early Late Permian). The *Neoalbaillella ornithoformis* Zone is found in the bedded chert facies and the Late Permian *Neoalbaillella optima* zone was discovered in the lower part of the interbedded chert and siliceous mudstone facies (Basir Jasin *et al.,* 2005a). No radiolarians were retrieved from the mudstone facies.

The lower and the upper parts of the interbedded chert and siliceous mudstone facies are displaced by a thrust fault. Four radiolarian zones were identified *i.e. Entactinosphaera chiakensis* Zone, *Triassocampe coronata* Zone, *Triassocampe deweveri* Zone and *Oertlispongus inaequispinosa* Zone. The radiolarian assemblages indicate an age ranging from late Spathian to early Ladinian, Triassic (Basir Jasin *et al.* 2005b). The occurrence of radiolarian chert reflects the high plankton productivity during the Late Permian and Triassic.

The rock sequence at the lower part of the section i.e. laminated black mudstone, interbedded sandstone and mudstone and interbedded tuffaceous sandstone, tuff, and conglomerate are lacking in fossils. The sequence is older and probably of very early Permian age. These rocks, with the exception of the laminated black mudstone, were deposited in a very short duration by turbidity currents. The volcanogenic sediments first appeared in the Semanggol basin during Early Permian and are very much older than those of the Semantan Formation. The source of the volcanogenic material is still obscure.

SEDIMENTOLOGY

The chert unit of the Semanggol Formation can be divided into eight sedimentary facies (Figure 5).

Laminated black mudstone facies

The facies is equivalent to E2.2 laminated muds and clays of Pickering *et al.* (1989). The facies is characterised by thinly laminated black mudstone and gray siltstone with traces of bioturbations. The facies is approximately 43 m thick and exhibits parallel lamination. The black mudstone contains carbonaceous material ranging from 1.2–2.08%. The facies was deposited in a calm environment of a relatively deep marine basin. The presence of parallel laminations indicates that it was under the influence of weak currents, which transport the suspended silt and clay-sized particles to the basin. The presence of black carbonaceous material suggests that environment was anoxic.

Interbedded sandstone and mudstone facies

This facies represents C2.2 of the Pickering *et al.* (1989) classification. The facies exhibits interbedded dominant sandstone with very thin mudstone. The thickness of sandstone varies from 5cm to 30cm. The sandstone shows parallel laminations and occasional ripple marks. The sandstone has a sharp contact at the base and gradually grades to mudstone. The mudstone is usually very thin

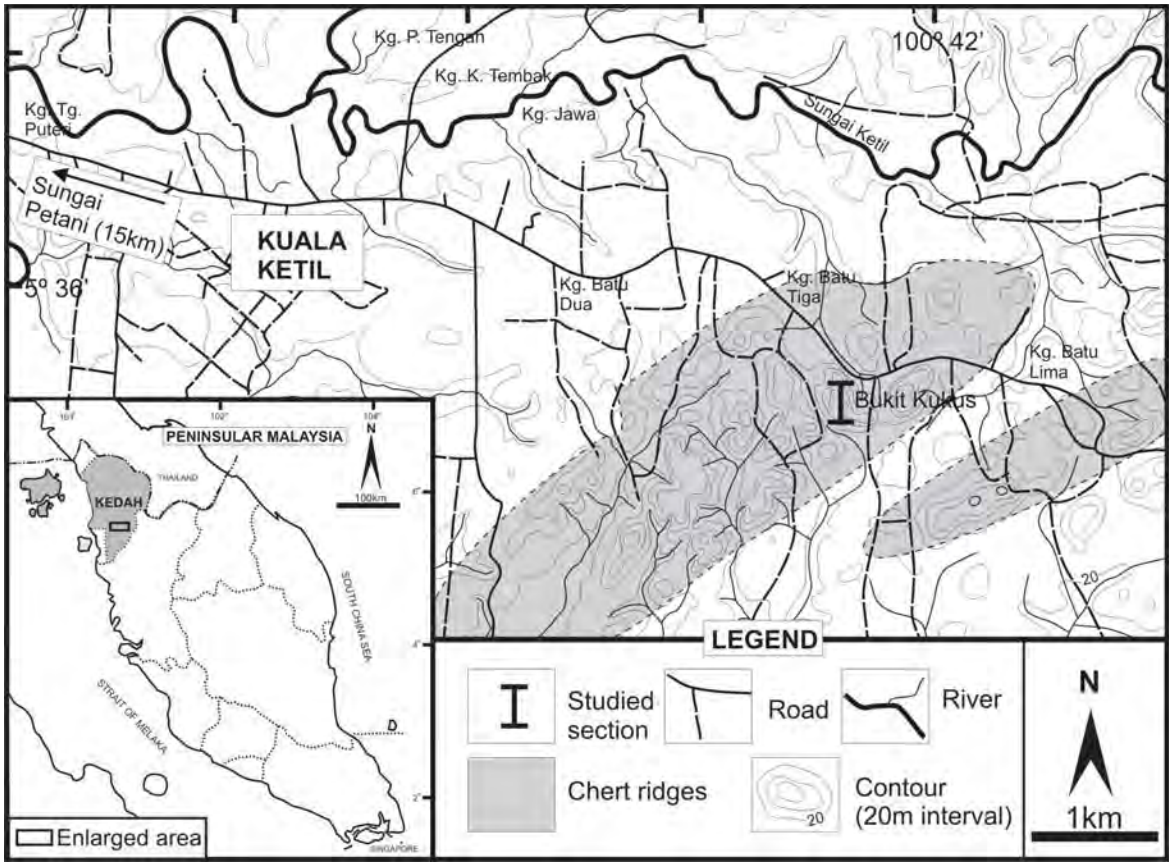

Figure 2: Map showing studied section in Kuala Ketil, south Kedah.

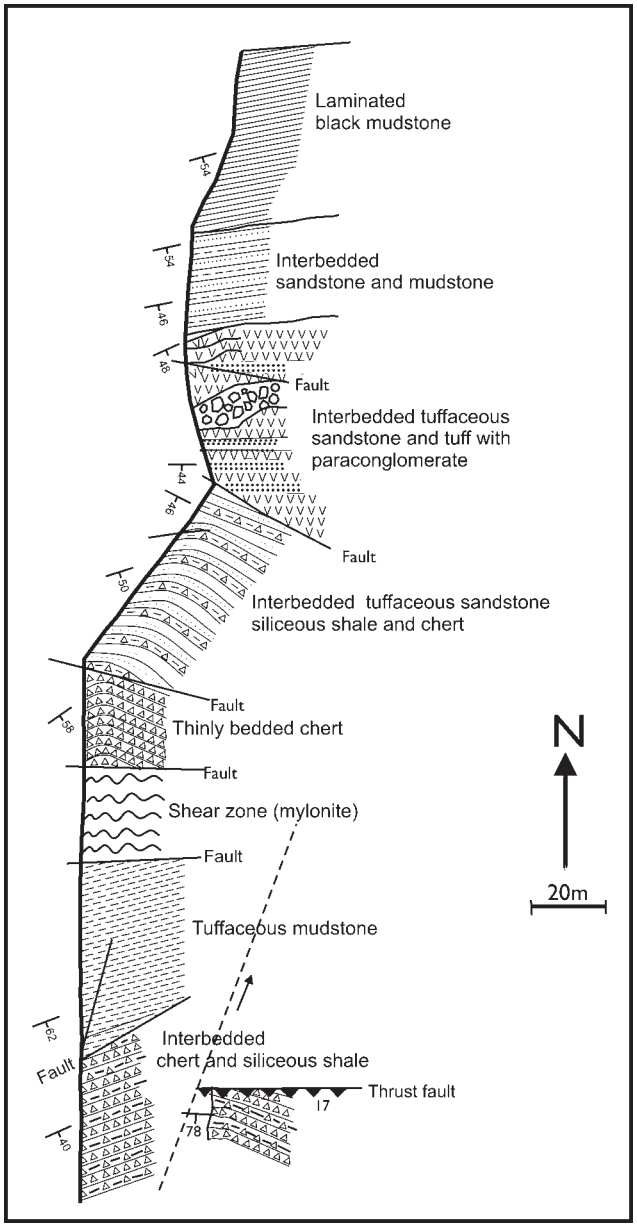

Figure 3: Lithofacies map of the studied section.

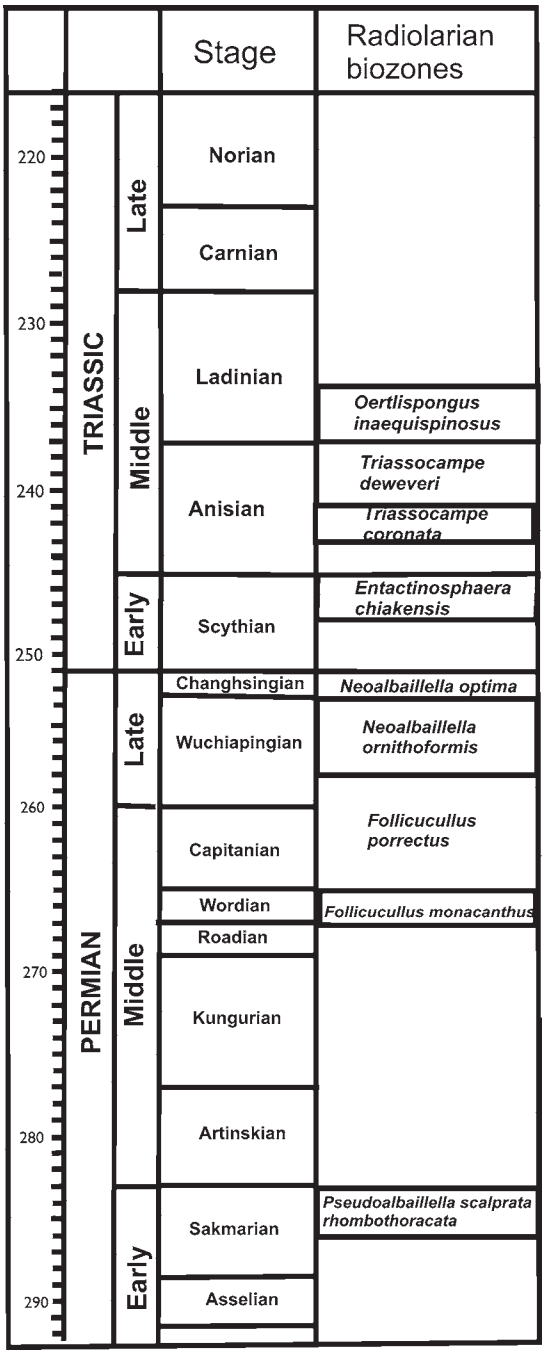

Figure 5: Sedimentary facies of the chert unit. R indicates the presence of radiolarian faunas.

and sometime forms parting between two sandstone beds. The sandstone is a greywacke. The thickness of the facies is approximately 28 m. The facies represents rhythmite sequences deposited by many episodes of intermediate turbidity currents (Pickering *et al.* 1989).

Interbedded tuffaceous sandstone and tuff facies

The facies comprises repetitive interbedded tuffaceous sandstone and tuff. The facies represents thinly bedded sand-mud couplets. The thickness of the tuffaceous sandstone ranges from 2 cm to 5 cm and grades to fine tuff. The tuff is 1-3 cm thick. The facies is equivalent to facies C2.3 (Pickering *et al.*, 1989). The facies is characterized by fine sand and mud deposited by weak turbidity currents. This facies indicates the early deposition of volcanic material in the Semanggol Formation by weak turbidity currents.

Paraconglomerate facies (Chaotic deposit facies F1.1 rubble of Pickering *et al.*, 1989)

A 5m thick channelised paraconglomerate bed separates the two interbedded tuffaceous sandstone and tuff facies. The paraconglomerate contains clasts ranging in size from 5 to 90 cm embedded in a fine tuffaceous matrix. The clasts are mainly of angular to lenticular-shaped tuffaceous sandstone fragments and some clasts

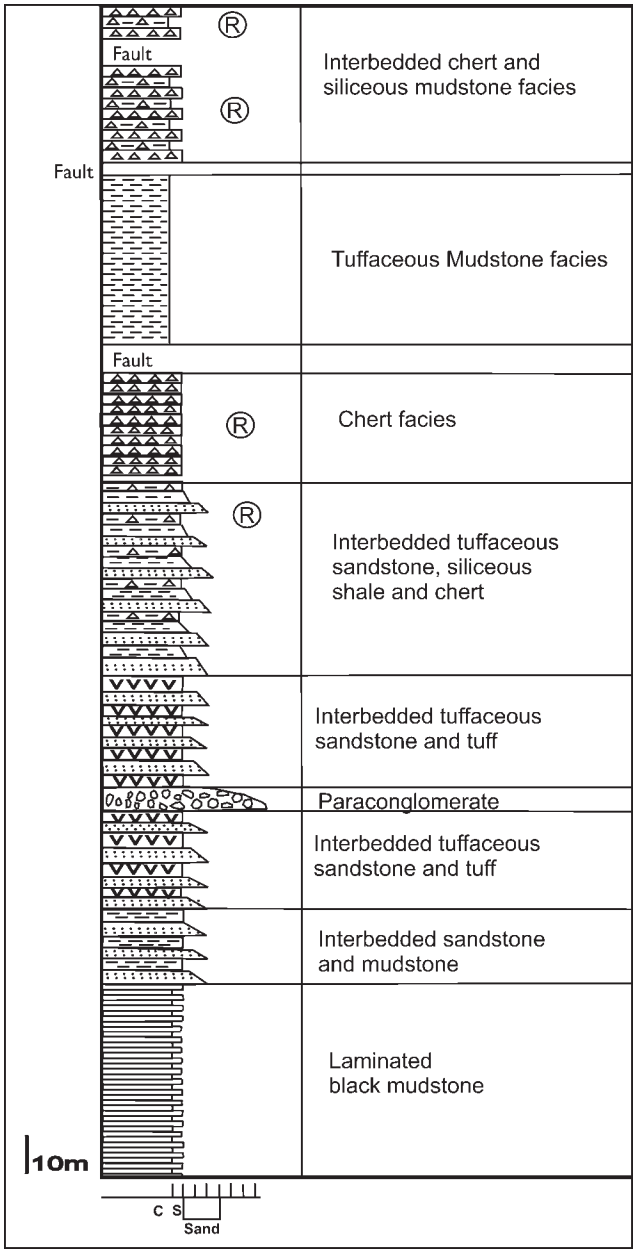

Figure 4: Radiolarian biozones of the chert unit exposed at Bukit Kukus, Kuala Ketil.

contain traces of crinoid stems and bryozoa (*Fenestrella* sp.). The clasts were derived from the shallow marine environment. The facies was deposited by debris flow, which was probably triggered by an earthquake or a volcanic eruption.

Interbedded tuffaceous sandstone, siliceous shale and chert facies

The most dominant rocks are tuffaceous sandstone interbedded with siliceous shale facies. The facies is equivalent to C2.3 of Pickering *et al.* (1989). Tuffaceous sandstone ranges in thickness from 2-5 cm. The thickness of the siliceous shale is from 2-3 cm. The total thickness of the facies is approximately 44 m. The facies exhibits the presence of weak turbidity currents, which transported and deposited the sand-sized tuffaceous material followed by deposition of siliceous mud. Chert occurs as thin dark layers in the siliceous shale at the top 10 m of the facies. The occurrence of radiolarian chert at the top of this facies indicates the slow deposition of pelagic material. The deposition of radiolarian chert suggests that productivity of radiolarians was moderate and the turbidity currents were less frequent and the deposition was relatively very slow.

Chert facies

The facies is approximately 27 m thick comprising mainly thinly bedded chert with minor siliceous shale. This facies is equivalent to G1.1 of Pickering *et al.* (1989). The chert is mostly gray in colour, hard and slightly to strongly folded. The thickness of an individual chert bed ranges from 2 to 4 cm. The chert is rich in radiolarians. It is considered as a radiolarian chert (radiolarite), which was deposited during a period of high plankton productivity associated with the supply of nutrient and silica by upwelling currents (De Wever and Baudin, 1996). The occurrence of radiolarian chert and the absence of pelagic limestone facies indicate that deposition occurred in a deep-water environment below the calcite compensation depth. This pelagic sediment was deposited in an open ocean far away from the source of terrigenous material (Pickering *et al.*, 1989).

Tuffaceous mudstone facies

The facies exhibits finely laminated, highly weathered mudstone, with a total thickness of approximately 45 m. The facies is separated from the chert facies by a mylonite zone more than 30 m. The mudstone is gray in colour and composed of thinly laminated clay interbedded with silt. The facies was deposited in a similar environment to that of laminated mudstone facies except that this mudstone contains tuffaceous material which was transported in by wind and deposited in a quiet deep basin of an open marine environment.

Interbedded chert and siliceous mudstone facies

The facies is separated from the mudstone facies by a fault. The thickness of an individual chert bed ranges from 2-5 cm. Siliceous shale has thickness ranging from 1 to 3 cm. The chert is a biogenic chert containing numerous radiolarian skeletons. The facies is divided into two parts based on the occurrence of different assemblages of radiolarians and is separated by a thrust fault. The lower part is approximately 20 m and contains Late Permian radiolarians and the upper part is about 5 m and contains Triassic radiolarians. The chert sequence consists of pelagic faunas and hemipelagic mud, which was deposited in a basin that was lacking in supply of terrigenous material from the continent.

DEPOSITIONAL ENVIRONMENT

The chert unit of the Semanggol Formation was deposited deep open marine environment under different conditions. The lowermost part of the unit was deposited in a by very weak deep ocean currents. The presence of organic carbon suggests that the basin was anoxic. Subsequently, there was a change in the transporting agents. The environment was subjected to turbidity currents, which deposited the interbedded sandstone and mudstone facies. Sedimentation continued by the deposition of tuffaceous sandstone and tuff facies by weak turbidity currents. This was the first deposition of volcanogenic material in the chert unit. The chaotic paraconglomerate was deposited by debris flow, possibly triggered by a volcanic eruption or earthquake. The presence of bryozoa and crinoid in the blocks indicates a shallow marine origin of the debris flow.

Tuffaceous sandstone and siliceous shale facies suggests the presence of weak turbidity currents which deposited the sand-sized material, followed by deposition of hemiplagic mud from suspended load. Turbidity current generated facies diminished towards the top of the facies where radiolarian chert was more common. The chert facies was a pelagic facies which was deposited in an open ocean, lacking in supply of terrigenous material from the continent. The deposition of tuffaceous mudstone suggests a quiet deep-water environment. The tuffaceous mud was transported to the environment by wind and later settled out from suspension in the water column. Finally, the topmost facies *viz.* interbedded chert and siliceous mudstone was deposited in an open-ocean environment (Pickering *et al.,* 1989).

CONCLUSIONS

The chert unit of the Semanggol Formation is composed of more rock sequences other than chert. The chert unit presently comprises eight facies which were deposited in a basin of deep ocean environment under the influence of different regimes of transportation. The laminated mudstone facies at the bottom was deposited by weak ocean currents through suspended load, followed by deposition of turbidity currents and finally the environment was calm and deposition was mainly from pelagic material. There was wide spread deposition of volcanogenic sediments in the middle part of the chert unit prior to deposition of the pelagic chert. The volcanogenic sediments were deposited before Sakmarian, Early Permian. The occurrence of tuffaceous material was common in the lower part of the Semanggol Formation.

Radiolarians are very rich in the bedded chert. Five Permian radiolarian biozones were identified, i.e. the *Pseudoalbaillella scalprata rhombothoracata* Zone, *Follicucullus monacanthus* Zone, *Follicucullus porrectus* Zone, *Neoalbaillella ornithoformis* Zone and *Neoalbaillella optima* Zone. The oldest radiolarian assemblage is *Pseudoalbaillella scalprata rhombothoracata* Assemblage Zone, which indicates an age of Sakmarian, late Early Permian. Four Triassic radiolarian zones were identified *ie. Entactinosphaera chiakensis* Zone, *Triassocampe coronata* Zone, *Triassocampe deweveri* Zone and *Oertlispongus inaequispinosa* Zone. The chert unit of the Semanggol Formation is well dated by radiolarians. The occurrence of radiolarian chert indicates high plankton productivity during the Late Perm and Triassic.

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