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Sedimentology of the Semantan Formation (Middle - Upper Triassic) along the Karak-Kuantan Highway, central Pahang

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Abstract: Outcrops of the Semantan Formation (Middle to Upper Triassic) along the Karak-Kuantan Highway at km 114.7, km 115, km 140 and km 149.3 were studied. Some beds were found to contain bivalves [*Entolium subdemisum* Muenster, *Neoschizodus* sp., *Costatoria pahangensis*(Kobayashi and Tamura) and *Costatoria chegarpahangensis* (Kobayashi and Tamura)] and gastropod (?*Nerita* sp.), which support the Middle to Upper Triassic age for the Semantan Formation. Sedimentary facies and facies associations were examined to gain a better understanding of deep-marine sedimentation processes in relation to submarine fan models. The main facies recognized in the field include conglomerate, pebbly sandstone, thick-bedded sandstone, interbedded sandstone-shale, contorted sandstone-shale, and shale-dominated heterolithics. The facies associations include fining- and coarsening-upward fan-lobe parasequences, slump deposits, and outer fan/basin plain shales. The sediments therefore represent a range of subenvironments from slope to outer fan. Both debris flow and turbidity current deposits are recognized as the main depositional processes in Semantan Formation. Features, such as disorganized clasts in conglomerate, "floating" mudclasts, and scour-and-fill structures indicates debris flow processes whereas normal graded bedding (fining upward) and thin waning-flow sandy layers in shale indicates turbidity current processes.

INTRODUCTION

Hydrocarbon exploration activities in deepwater have increased significantly in recent years and understanding the deepwater depositional system is now very important in oil exploration. Studying onshore outcrops of deep-marine sedimentary rocks gives a better understanding of deepwater depositional systems. In Peninsular Malaysia, deep-marine formations are common in the Permian to Triassic successions. Triassic formations, such as the Semantan and Semanggol formations, have been interpreted as deep-marine sediments based on sedimentological and palaeontological studies (e.g. Metcalfe *et al*., 1982; Metcalfe and Azhar Hussin, 1994). This paper focuses on the lithological and sedimentary features of deep-marine rocks in the Semantan Formation, which are exposed along the Karak-Kuantan highway. Some of the outcrops were described earlier by Madon (2006) as indicative of mass-transport processes in the deep-marine environment. In this study, a more detailed sedimentological logging was carried out on the rocks exposed along the Karak-Kuantan Highway at kilometres (km) 114.7, 115, 140 and 149.3 (Figure 1). The objective is to further identify the different sedimentary facies, depositional processes, palaeoenvironments, and formation age. A tentative depositional model for the Semantan Formation is proposed based on this new data and field observations.

REGIONAL SETTING

Peninsular Malaysia is divided into three main geological domains, namely the Western, Central and Eastern belts (Figure 2). These domains differ in several aspects, including lithology, age, tectonics, structure and palaeogeography. The Lebir fault and Bentong Suture

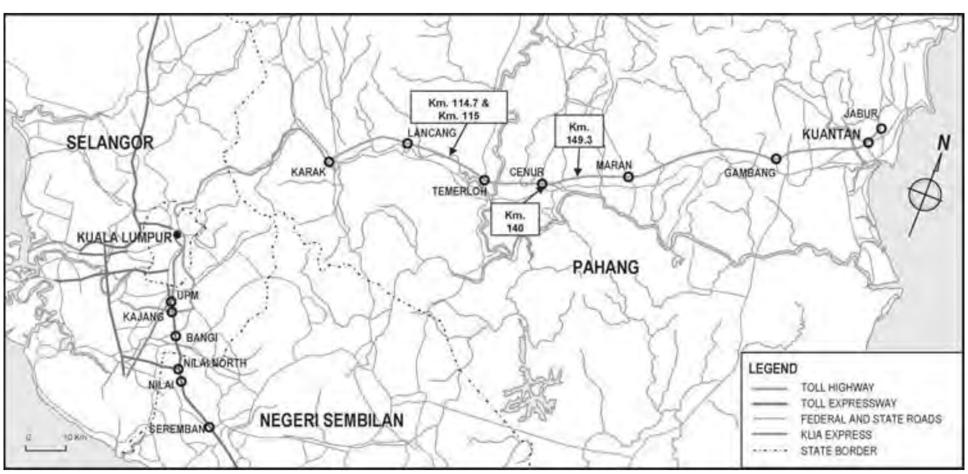

Figure 1: Location of outcrop localities in the Karak-Kuantan Highway.

define, respectively, the eastern and western margin of the Central Belt, which covers the entire state of Kelantan, the western and central parts of Pahang, the eastern part of Negeri Sembilan, and the western part of Johor. Lithostratigraphically, it is represented by the Kepis, Lop, Bera, Kaling, Paloh, Ma'Okil, Gemas, Semantan, Tembeling and Koh Formations, and the Gua Musang Group and the Bertangga Sandstone, which range in age from Permian to Cretaceous.

The Semantan Formation is one of the Paleo-Tethyan deposits which is reported as Middle to Upper Triassic in age. Convergence between of the Eastmal/Indosinia and Sibumasu blocks resulted in closure of the Paleo-Tethys ocean in Late Triassic times (Hutchison, 1989). The resultant Indosinian Orogeny produced the Main Range granitoids of Peninsular Malaysia, which range in age from Upper Triassic to Lower Jurassic. In generally, the Permian-Triassic formations were deposited in deep to shallow marine environments whereas the Jurassic-Cretaceous formations were deposited on terrestrial environments. The convergent margin setting of the Semantan Formation, with the predominantly deep-marine "flysch" sedimentation, suggest that the Semantan basin was a probably a foreland basin associated with eastwards subduction of West Malaya lithosphere beneath Eastmal. A summary of the stratigraphic column from Khoo (1983) shows the Semantan Formation as equivalent in age to the Gemas Formation and Ma'Okil (Figure 3).

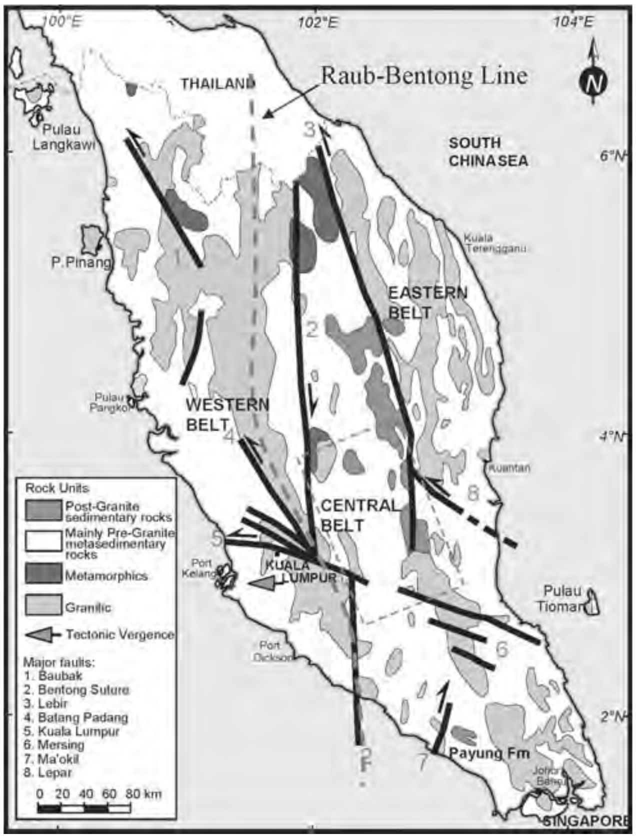

Figure 2: Simplified geological map of Peninsular Malaysia, showing the main rock groups and faults. The terrane east of the Raub-Bentong Line is termed EastMal (Hutchison, 1989). Studied area is in the dashed rectangle.

THE SEMANTAN FORMATION

The Semantan Formation was first named by Jaafar Ahmad in 1976. He mapped this formation in road cuts from Karak to Temerloh and assigned the age as middle to upper Triassic based on palaeontological evidences. He also included the Kerdau Formation in this formation. From exposures near Lanchang, Metcalfe *et al*. (1982) reported bivalves, ammonites, plant fragments and trace fossils of late Middle Triassic age. Shafeea Leman and Masatoshi (2001) found the ammonoid *Paraceratites* sp. in shale beds near Taman Setia Jasa, Temerloh. During this field study, fossils were also found in the Semantan Formation (shown in Figure 9). At the Chenor interchange, km 140, *Entolium subdemisum* Muenster, *Neoschizodus* sp., *Costatoria pahangensis* (Kobayashi and Tamura) and *Costatoria chegarpahangensis* (Kobayashi and Tamura) and gastropod (?*Nerita* sp.) were found in mudstone layers. Most of the *Entolium subdemisum* Muenster are 8 to 10 mm long and 10 to 12 mm wide. The *Neoschizodus* sp., *Costatoria pahangensis* (Kobayashi and Tamura) and *Costatoria chegarpahangensis* (Kobayashi and Tamura) are about 5 to 12 mm in diameter. The gastropod (?*Nerita* sp.) is approximately 5 to 7 mm. The assemblage indicates a Middle to Upper Triassic, as determined by previous workers. The fossils however, are indicative of shallow marine (shelf) environment. Therefore, the fossils were probably transported and resedimented in a deep marine environment.

Age		CENTRAL BELT			
		South Kelantan		Pahang	Johor
Cretaceous	Upper	Non Deposition			
	Lower	Gagau group		Koh Formation Tembeling Group	Ulu Endau Formation; Panti Sst Tebak Formation
Jurassic	Upper				
	Middle	Non Deposition		Non Deposition	Non Deposition
	Lower				
Triassic	Rhaetian			Kaling Formation (Lipis Group)	
	Norian				
	Carnian	Gunung Rabong Formation	Telong Formation		Gemas/Ma'Okil Formation
	Ladinian			Semantan Formation	
	Anisian	Gua Musang Formation	Non Deposition		
	Scythian		Aring Formation	Non Deposition	Non Deposition
				Palaeozoic	Upper Palaeozoic

Figure 3: Mesozoic stratigraphic column of Central Belt. After Khoo (1983).

Evidences from sedimentary structures indicate that the Semantan depositional environment was predominantly deep marine, possibly bathyal (slope). The widespread occurrence of volcanic and tuffaceous sediment in the Semantan (e.g. Azhar, 1992; Metcalfe and Chakraborty, 1994; Ong, 2001) indicates proximity to a volcanic arc, probably related to the closure of the Paleo-Tethys.

Kamal Roslan (1989) included part of the Jelai, Gemas, and part of Jurong Formation into the Semantan Formation based on lithological similarities and fossil evidences. The occurrence of oolitic limestones and fossil gastropods in the Semantan Formation near Mentakab Industrial Park led Kamal Roslan and Ibrahim Abdullah (1993) to interpret part of the Semantan Formation as shallow marine deposits. In general, however, the Semantan Formation comprises deep-marine turbidite sequences. Khoo (1998) reported arenaceous and argillaceous facies in the Semantan Formation near Bahau and Kuala Pilah, which he interpreted as representing a littoral environment, based on sedimentary structures and ichnofossils. The evidences noted by Kamal Roslan and Khoo, therefore, suggest that the Semantan Formation is not entirely deep-marine sediments.

Metcalfe and Chakraborty (1994) studied coarse to fine tuffs and grey mudstone sequence along the western portion of Mentakab-Temerloh bypass. He interpreted the overall fining upwards sequence as due to deepening of the basin and waning of volcanic activity or shift of the volcanic centre. Constant strike and dip directions in the Semantan Formation suggests no isoclinal folding and imbrication of the strata. The deformation style of Semantan Formation was studied by Tjia (1996) who documented evidences for tectonic overprinting on soft-sediment deformational structures, which has resulted in complex fold styles and structures.

FACIES DESCRIPTION

Six facies are recognized from the sedimentological logs measured at km 114.7, km 115, km 140 and km 149.3. The sedimentary logs are shown in Figs. 4, 5, 6 and 7. Some examples of the different facies are shown in the photographs in Figure 8. The facies are described below:

Conglomerate (F1)

Facies F1 is a matrix-supported conglomerate (Figure 8a) comprising subangular to angular mudstone, siltstone and sandstone clasts, measuring 5 to 50 cm, in mainly coarse-grained sand matrix. It is very common in the km 149.3 outcrop, which is moderately weathered (grade III). Most of the clasts are scattered randomly, but some show imbrication. Bed thickness varies from 20 cm to 2 m. The conglomerates are interbedded with thin shale and siltstone. The presence of conglomerates in the Semantan Formation has been reported by Metcalfe and Chakraborty (1983).

Pebbly sandstone (F2)

Facies F2 (Figure 8b) is composed of fine to coarse grained sandstone with subangular to angular pebbles. The beds are thick, ranging from 50 to 60 cm, and contain randomly scattered pebbles or mudclasts. Generally the upper contact is sharp but some beds shows gradational contacts. Some sandstones are poorly sorted, consisting of mudclasts and scour surfaces at the base. Mudclast diameter ranges from a few millimeters to 10 cm.

Thick-bedded sandstone (F3)

Thick bedded sandstone facies (F3) is common at km 114.7 and km 149.3 and is characterized by fine- to coarse-grained, light grey sandstone. The beds may be amalgamated from several beds or alternate with thin shale beds. Individual bed thickness range from 20 cm to 1.2 m and have sharp upper and basal contacts (Figure 8c).

Interbedded sandstone-shale (F4)

Facies F4 is common in km 114.7, 115 and km 140. It consists of thinly bedded (5-20 cm) sandstone, siltstone and shale. The sandstone is light grey, fine to coarse grained, and well sorted. At km 140, the lower sandstone is relatively thicker and coarser, generally grading upward with thinner beds of siltstone and shale (Figure 8c).

Contorted sandstone-shale (F5)

The contorted sandstone-shale facies (F5) is composed of deformed interbeds of dark grey to black shale and light grey, fine-grained, poorly sorted sandstone. Some of the sandstones contain mud clasts and drapes. Its thickness varies from few cm to 1 m, while the shale thickness varies from a few mm to a few cm. This facies are common at km 140 and km 149.3 (Figure 8d and 8e).

Shale-dominated heterolithics (F6)

Shale-dominated heterolithics facies is most common at km 115 and km 140. The shale is black to dark grey and ranges in thickness from few cm to 1 m (Figure 8f). It commonly interbeds with siltstone and mudstone, but rarely with sandstone. Generally, the sandstone beds are planar or wavy, has sharp contacts, and show parallel lamination. Some sandstone beds are lenticular. Some bivalves including *Entolium subdemisum* Muenster, *Neoschizodus* sp., *Costatoria pahangensis* (Kobayashi and Tamura) and *Costatoria chegarpahangensis* (Kobayashi and Tamura) and gastropod (?*Nerita* sp.) are fairly well preserved in the mudstone layers (Figure 9).

Facies Associations

From the sedimentological field logs, five facies associations are recognized. They are interpreted to represent the various parts of a hypothetical submarine fan (Figure 10). Facies association 1 (FA1) is a fining-

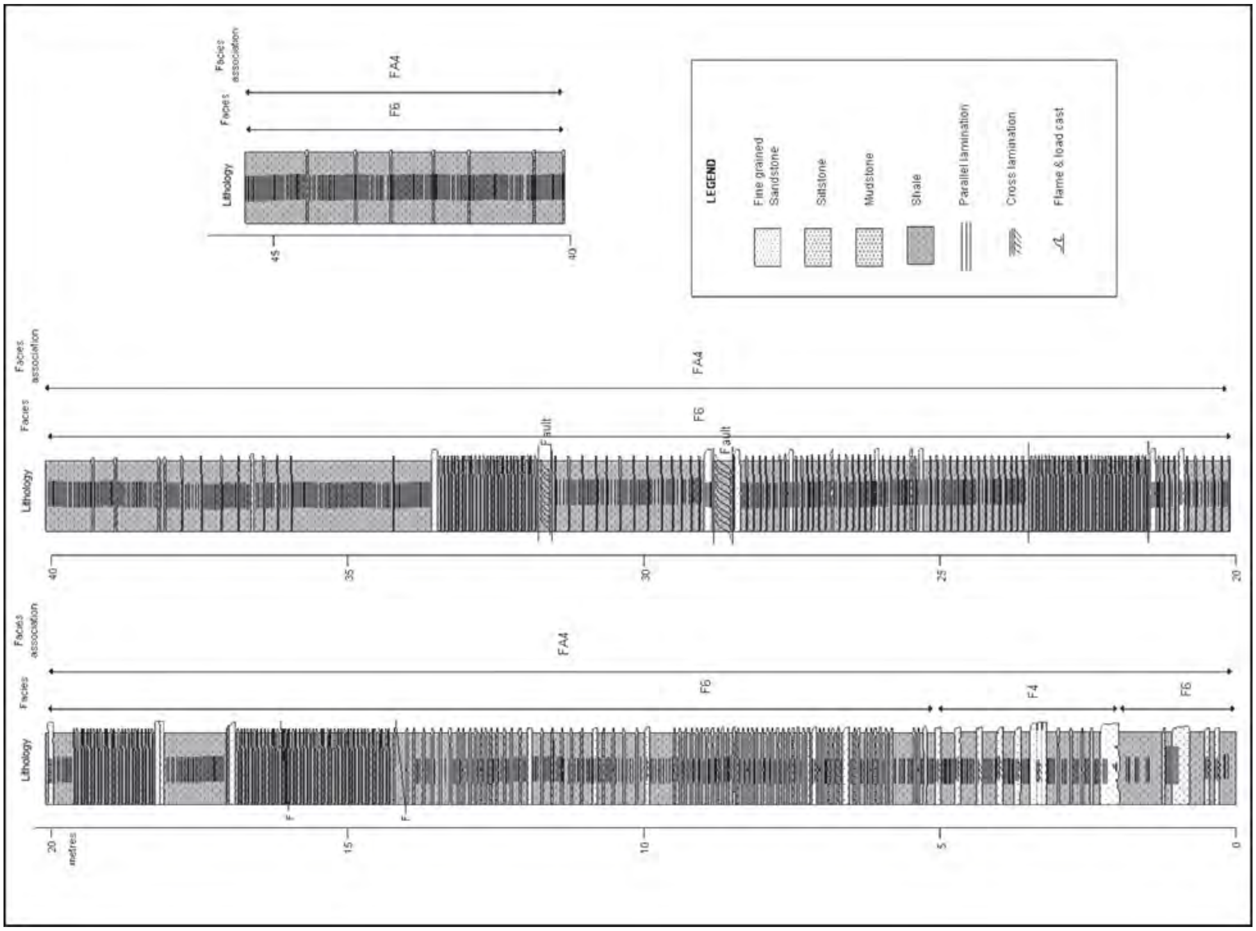

Figure 5: Sedimentological log at km 115 succession.

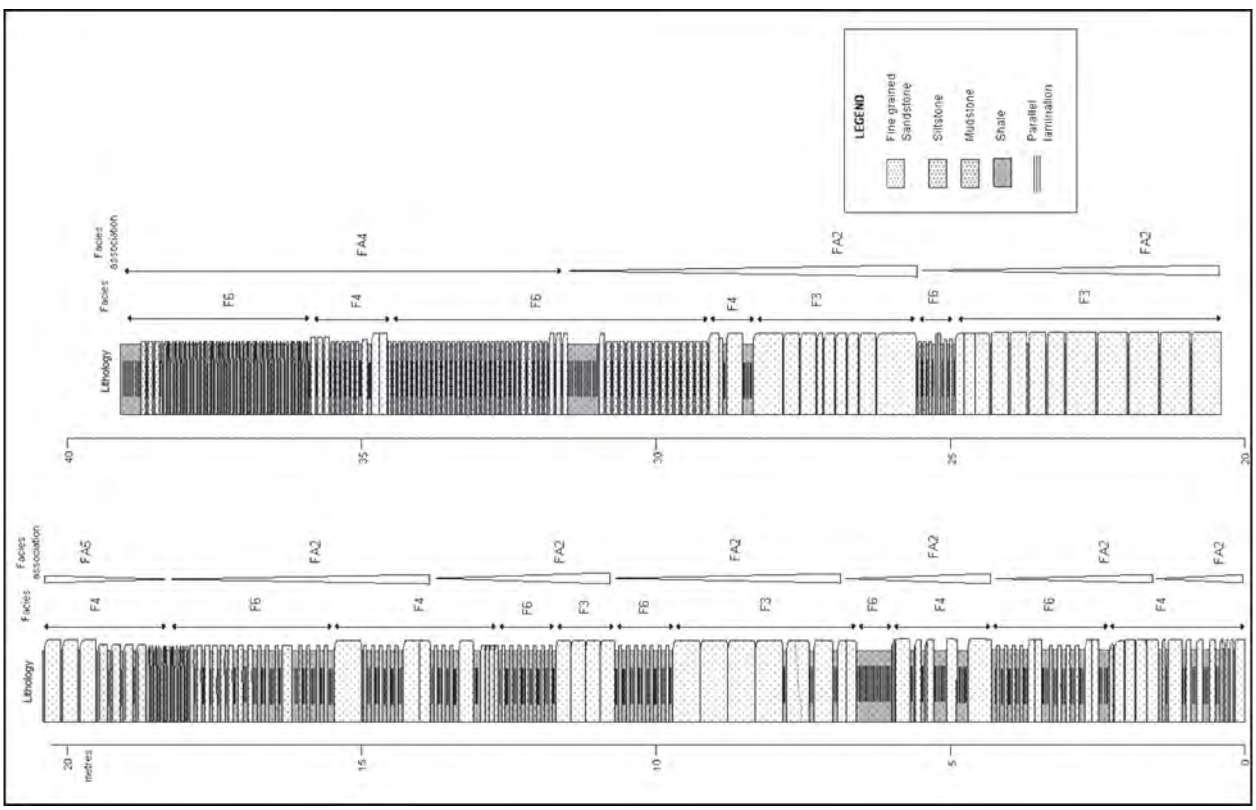

Figure 4: Sedimentological log at km 114.7 succession.

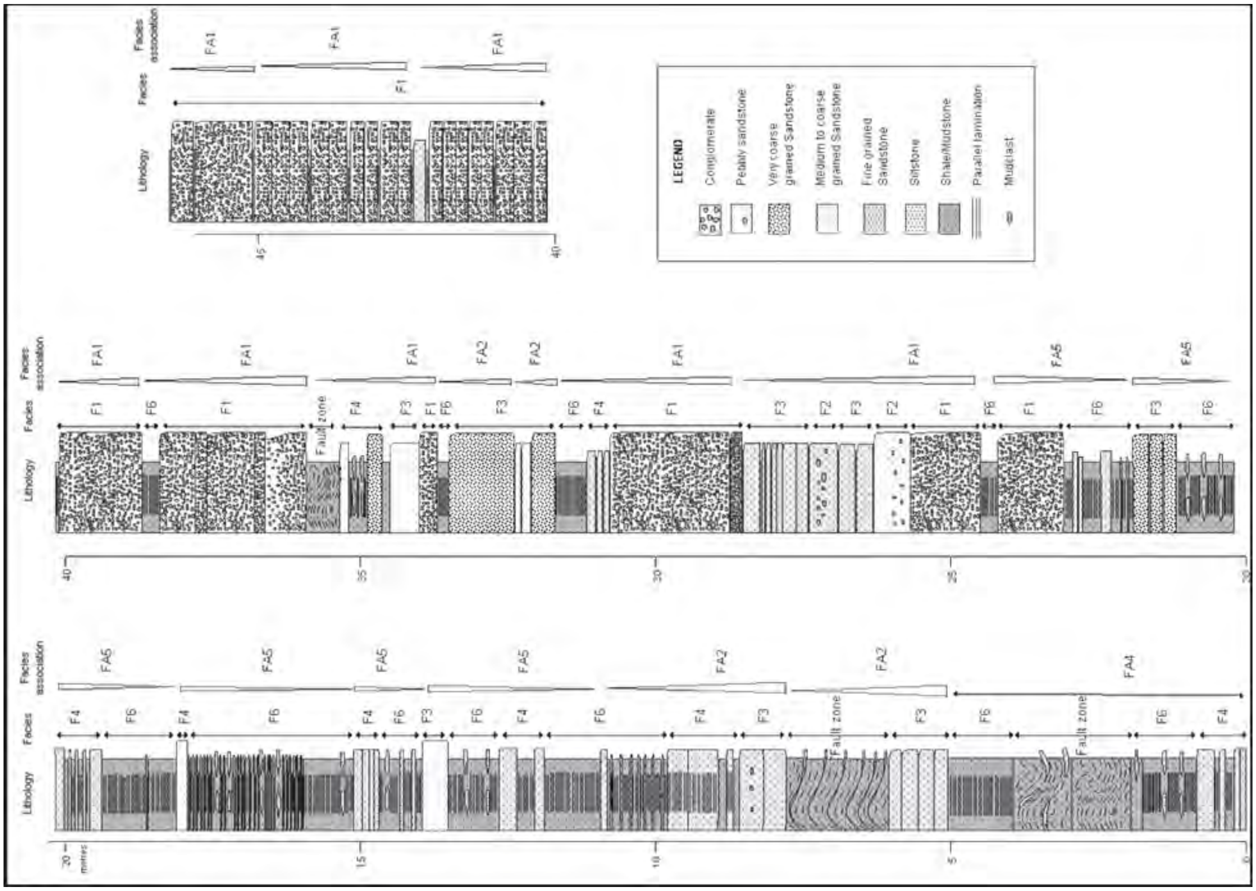

Figure 7: Sedimentological log at km 149.3 succession.

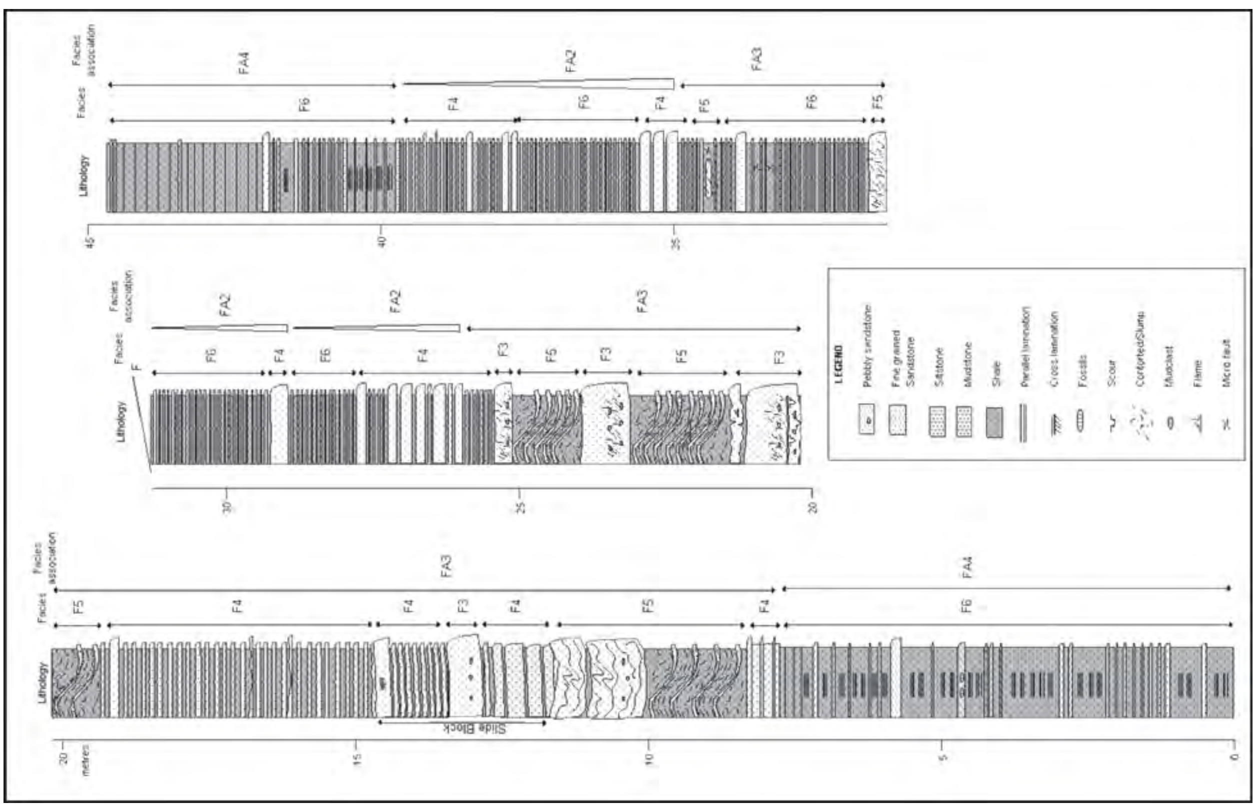

Figure 6: Sedimentological log at km 140 succession.

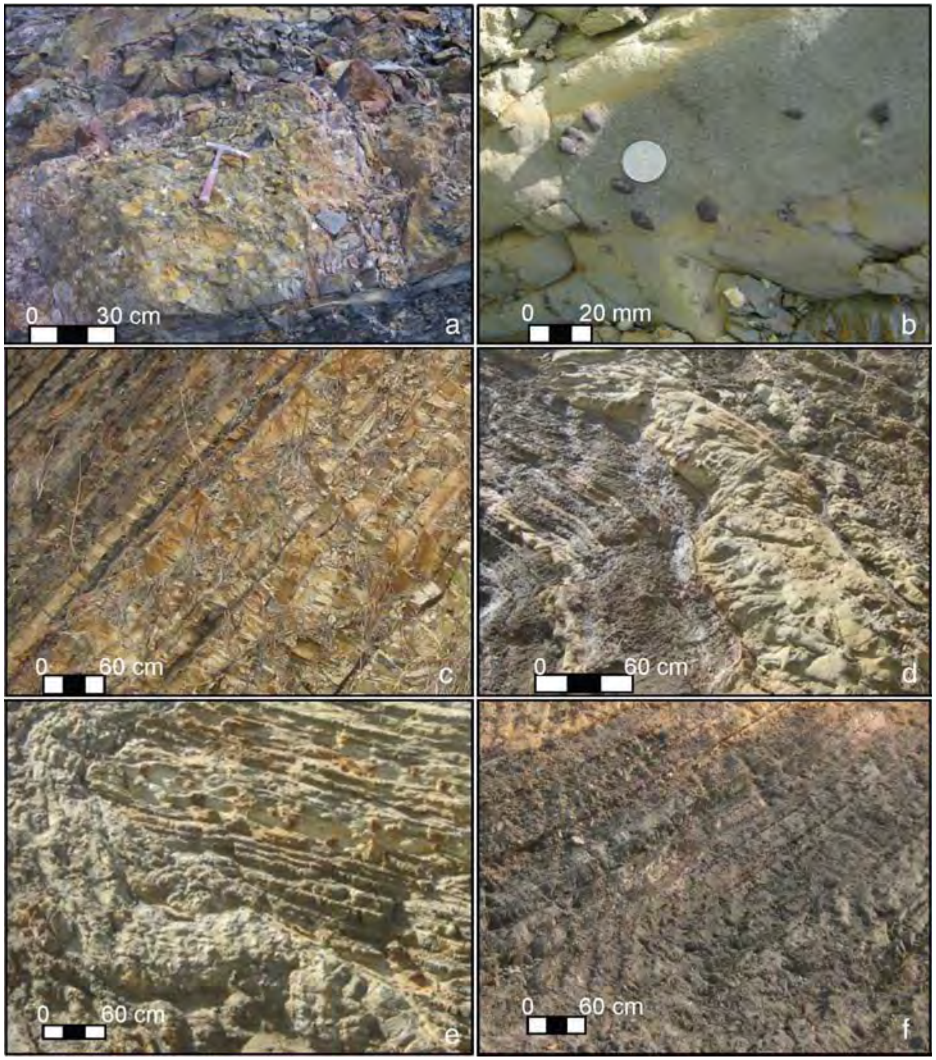

Figure 8: a- Conglomerate facies with sand matrix-supported at km 149.3. b- Pebbly sandstone facies contains subangular to angular clasts at km 140. c- Thick-bedded sandstone facies overlain by interbedded sandstone-shale facies at km 114.7. d- Contorted sandstone-shale facies at km 140. e- Contorted sandstone-shale facies associated with slide block of interbedded sandstone-shale facies at km 140. f- Shale-dominanted heterolithics facies at km 115.

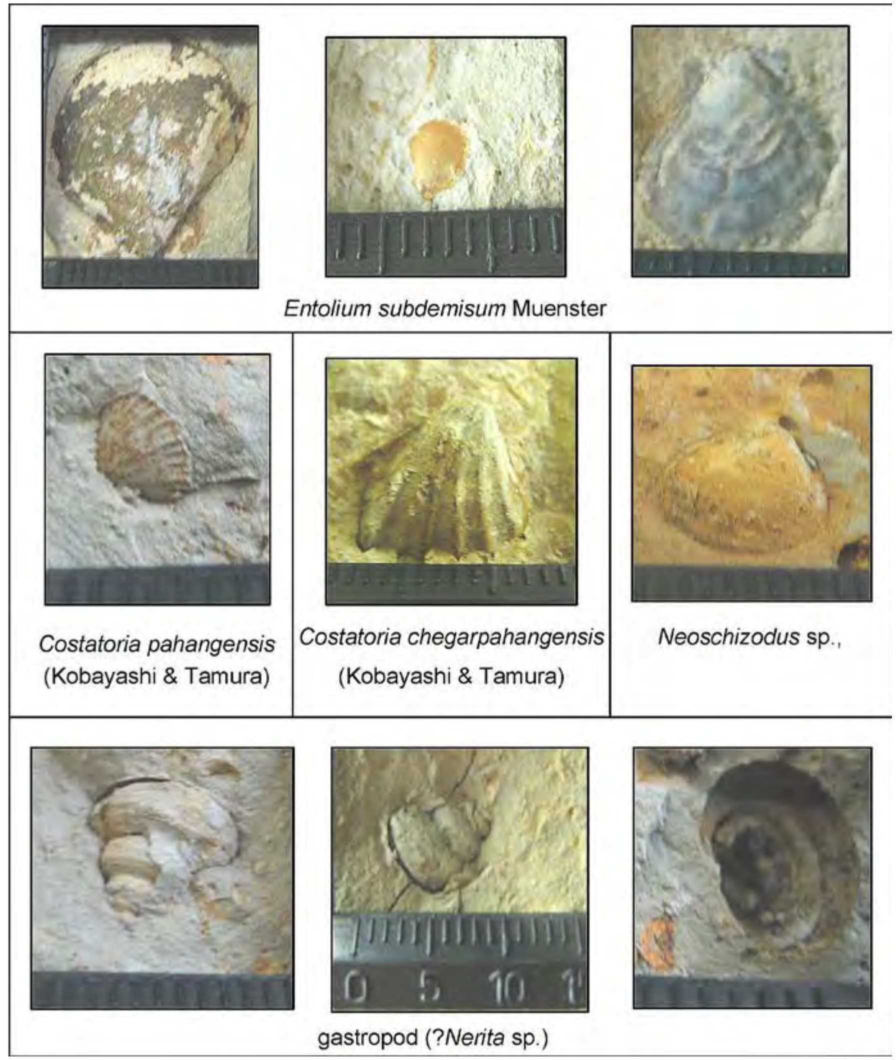

Figure 9: Fossils of Semantan Formation found in mudstone beds at km 140, Karak-Kuantan highway (scale in mm).

upward parasequence of conglomerate, overlain by sandstone and shale. It probably represents a channel fill in the upper part of the fan, or even on the slope, probably a canyon fill, based on its very coarse grain size. FA2 is a fining and thinning upward sandstone, siltstone/mudstone and shale parasequences which represents a channel-levee deposit; the sandy part is the channel fill, whereas the shaly part is the overbank or levee deposits. This channel facies association is deposited in the upper fan environment, where strong turbidity flows are confined to channels.

Where the energy of flow becomes weaker, turbidity currents are able to spread outwards into the basin, and deposit sheet-like sandbodies, which typifies the middle fan area. This is represented by FA5 which is characterized by coarsening-upward parasequence of shale to sandstone (Figure 10), produced by progradation of the fan lobe. FA5 is characterized by shale, overlain by interbedded mudstone/sandstone, and sometimes capped by conglomerate. This association is common at km 114.7 and km 149.3. FA4 is a shale-dominated facies association deposited in the distal parts of the submarine fan (outer fan to basin plain) where weak turbidity flows carry silt and fine sand into a predominantly hemipelagic mud depositional environment.

Finally, a common facies association at km 140 is the slump facies association (FA3), which consists of slumped or contorted sandstone/mudstone interbeds indicating deposition on an unstable sloping surface, probably in the upper part of the submarine fan or near the base of slope.

DEPOSITIONAL ENVIRONMENT AND PROCESSES

The five facies associations identified in the Semantan Formation represent different parts of the deep-marine depositional environment. Generally, bed thickness is a useful criterion to distinguish between proximal and distal environments of the submarine fan (Figure 10). Thick beds and coarse-grained facies (e.g. conglomerate) are likely to be deposited in the proximal part of the fan or even on the slope or canyons. Thin bedded facies and mudstone facies are indicative of distal turbidite/debris flow deposits at the lower (outer), distal part of the fan.

Slumps structures indicate deposition on the continental slope. The conglomerate-sandstone-shale facies association (FA1) therefore represents deposition in a proximal part of the fan, possibly in the inner fan channel and levee complex near the canyon mouth. The shale-dominated facies with alternating thin siltstone and mudstone is interpreted as a distal deposit, possibly in the outer fan to basin plain environment. At km 149.3, the succession generally show coarsening upward, from interbedded shale, siltstone and sandstone facies association (FA4) to conglomerate and sandstone facies association (FA1), and may be interpreted as a progradational fan system. Lateral changes in the grain size and bed thickness, from the proximal to the distal parts of the fan, also results in fining and thinning patterns towards the basin.

Mass-transport deposits, such as slides, slumps, debris flows and associated turbidites, appear to be a common feature of the Semantan depositional system. In the km 140 succession, evidence of mass transport deposits is indicated by large sandstone/siltstone and shale blocks within an otherwise regularly bedded section. The slide blocks of undisturbed sedimentary rock seem to have been derived from failure on the continental slope, and moved along glide planes in a mechanism similar to sub-aerial landslides. Slump deposits are represented by contorted sandstone and shale (Facies F5) overlain by undeformed strata. There are some internal deformation within the slump blocks; these resulted from rotational movement of the slide blocks downslope. Evidence for debris flow processes as opposed to turbidity currents include the occurrence of “floating” mudclasts at the top of some beds, scour marks, flame structures, load cast (or moulds) and disorganized clast fabric in the conglomerate.

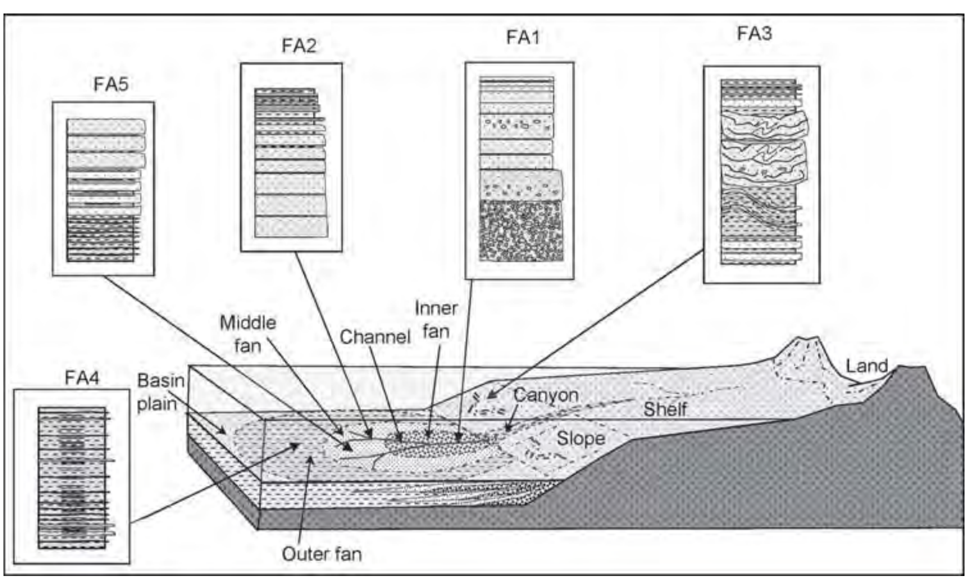

Figure 10: Depositional model of Semantan Formation showing facies association in deepwater environment.

The angular to subangular clasts (e.g. at km 140) are possibly shelf sediments reworked and transported down slope during a mass-transport event. Graded bedding and organized clast fabric in the conglomerate is interpreted as the deposits of turbidity current or weak debris flows. It appears that pebbly debris flow is more common than sandy debris flow. The inverse grading or irregular clast-fabric in the conglomerate indicate rapid freezing of the sandy debris flow. The "floating" mudclasts in contorted sandstone gravitationally-induced slumping may be closely linked with debris flow processes.

CONCLUSIONS

Outcrops of the Semantan Formation along the Karak-Temerloh highway offer an excellent opportunity to study deep-marine deposits. The main facies in the Semantan include conglomerate, sandstone, siltstone, and shale. These are interbedded to form several facies association that are interpreted as representing different parts of a submarine fan system, from proximal to distal, in relation to the sediment source area. The Semantan Formation is characterized by an assemblage of slumping, turbidity current and debris flow deposits. The discovery of bivalves fossils give support for the age of the Semantan Formation to be Middle to Upper Triassic. More sedimentological and structural studies are currently being undertaken on the Semantan Formation and other deep-marine rocks to further our understanding of the deep-marine environments.

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