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Environment of deposition of the Jurassic-Cretaceous continental deposit in Central Pahang (Peninsular Malaysia) by sedimentary facies analysis

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Abstract: Spatial lithofacies and lithofacies association serves as one of the reliable methods in assessing the depositional process of sediments and interpreting its depositional environment. The method of facies analysis is adapted in this study where four newly exposed stratigraphic sections along the Jerantut-Maran road in Jerantut, Central Pahang of Peninsular Malaysia were studied. Previous studies showed that the environment of deposition of these continental deposits is broadly of braided-meandering river. Sedimentological data from the newly exposed stratigraphic sections had given a better understanding on the sedimentation processes involved in these deposits where interpretation on the environment of deposition is construed up to its sub-environment. The main lithofacies recognized include conglomerate, sandstone, and fine-grained facies. The facies associations identified include (i) massive to laminated silt/mudstone, (ii) massive sandstone, (iii) thin to thick ripple to parallel laminated sandstone, (iv) conglomeratic sandstone, (v) graded channelized sandstone, (vi) coarsening upwards medium bedded sandstone and (vii) heterolithic sandstone. The different facies associations are grouped to four (4) facies assemblages showing characteristics of certain environment: (1) floodplain, (2) channel bar complex, (3) point bar and (4) crevasse splay. Floodplain facies assemblage is marked by fine-grained facies, mainly siltstone/mudstone and fine-grained sands with lower flow regime structures. Channel bar complex is identified by high energy deposits of coarse-to-medium grained sandstones often with scoured bottom and lenticular geometry. Point bar is recognized by the lateral accretion surfaces often consisting of normal graded sandstone with sharp top and bottom contact, sometimes capped with thin mudstones. Crevasse splay facies assemblage is characterized by heterolithic sandstone, dominated by flaser-wavy bedding and coarsening upwards medium bedded sandstone that is overlain by fine-grained facies of the floodplain assemblage. The overall facies based on an outcrop scale suggests general features of fluvial facies with fluctuations in flow energy. The environment of deposition is thus interpreted to be of braided river with floodplains and isolated point bar.

Keywords: Continental, facies analysis, fluvial, Mesozoic, sedimentology, Tembeling Group

INTRODUCTION

Oil and gas exploration activities on continental sediments has risen considerably these days, particularly in China, where a great amount of its hydrocarbons explored are hosted in continental sediments in both conventional and unconventional systems. Comprehension of continental depositional systems are thus in great need for better grasp on its influence in hydrocarbon exploration which could be easily attained by facies analysis on onshore outcrops.

Continental sedimentary rocks of Mesozoic age are widely distributed in Central Pahang of Peninsular Malaysia where the Tembeling Group resides. The exposure this group, particularly the Mangking Sandstone and Termus Shale along Jerantut – Maran road where a gently-dipping fluvial strata is observed, provides a good opportunity for outcrop studies to be conducted. This road cuts along the Central Belt where the Tembeling Group (Mangking Sandstone and Termus Shale) was regionally mapped to reside. The less deformed, poorly fossiliferous with presence of diagnostic red beds and palaeosols are distinctive characteristics of these beds that can be correlated to those of the Upper Mesozoic continental strata of the Mangking Sandstone and Termus Shale. Thus, the age of these deposits has been implied generally as “Jurassic – Cretaceous”.

Sedimentary logging was performed on the rock exposures with the aim to analyse the sedimentary facies and process of deposition involved. A conceptual depositional model for the Mangking Sandstone and Termus Shale of this area is proposed based on this new data and field observations.

THE TEMBELING GROUP

Located in the central basin of Peninsular Malaysia, the Tembeling Group is a part of an extensive Mesozoic deposits with similar characteristics to those of a molasse (Koopmans, 1968; Khoo, 1983; Madon *et al*., 2010) (Figure 1 and 2). The Tembeling basin was identified as a pull-apart depression developed due to dextral slip motion between overlapping wrench fault strands (Tjia, 1996) stretching from Gunung Tahan to Bukit Ibam (Madon *et al.*, 2010), along the eastern margin of the Central Belt. The sediments of this group is not as fossiliferous and deformed as the adjacent Semantan formation with its argillaceous sediments being predominantly red in color (Koopmans, 1968; Khoo, 1983; Abdullah *et al*., 2009; Madon *et al*., 2010).

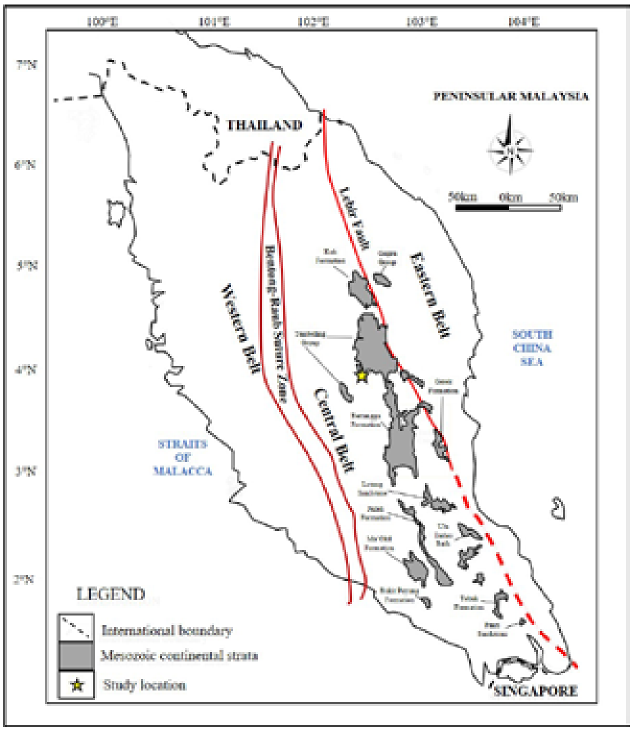

Figure 1: Mesozoic continental strata distribution along the Central Belt of Peninsular Malaysia. Modified after Ismail *et al.* (2007).

The Tembeling Group was first identified as the Tembeling Formation by Koopmans (1968), further divided by Khoo (1977) into four formations, namely the Kerum Formation, Mangking Sandstone, Lanis Conglomerate and Termus Shale (Figure 3). The formations of this group are at large are made up of volcanics, conglomerates, quartzose sandstone and shale, respectively.

The age of this group established to be of Late Triassic to Early Cretaceous, identified through findings of palynomorphs and plant fossils in the beds of Mangking Sandstone and Termus Shale (Koopmans, 1968; Harbury *et al.,* 1990; Jirin & Morley, 1994; Ariffin *et al*., 2005; Peng & Suyin, 2007) and recently by findings of fish fossils in the beds of the Termus Shale (Teng *et al*., 2019).

OUTCROPS ALONG THE JERANTUT – MARAN ROAD

Rock exposures of the Jurassic-Cretaceous strata along the Jerantut-Maran road, 8 kilometers east from the Jerantut town were studied in terms of its sedimentology and stratigraphy (Figure 4). Sedimentary logging was done based on lithological composition, geometry, sedimentary and biogenic structures of four (4) vertical field sections (designated as JB1, JB2, JB4 and JB5) totalling up to 80.6 meters (Figure 5). Facies assemblages and its correlatable depositional features of the exposures were also studied to give better understanding on the processes and fluvial sedimentations of the study area.

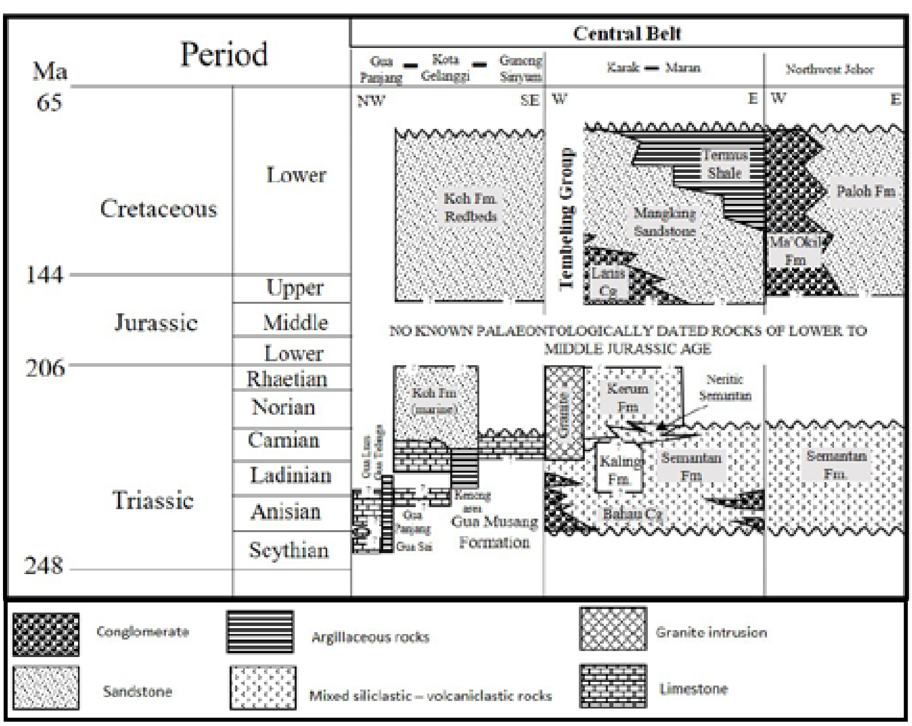

Figure 2: Mesozoic stratigraphic column of the Central Belt of Peninsular Malaysia. Modified after Abdullah *et al.* (2009).

AGE	ROCK UNIT	THICKNESS (M)	DESCRIPTION
Upper Jurassic	Termus Shale	>1500	Red, ferruginous mudstone and shale, minor beds of quartzose and lithic sandstone
Lower Cretaceous	Mangking Sandstone	2000	Protoquartzite and orthoquartzite interbedded with argillaceous rocks. Sandstone with cross-bedding
	Lanis Conglomerate	1300	Polymict-conglomerate, pebbly sandstone, sandstone, shale and mudstone
??	Kerum Formation	>2000	Volcanic + sedimentary rock consisting of quartzite, tuffaceous and lithic sandstone lava and pyroclastics

Figure 3: The Tembeling Group is made up of four formations; the Kerum Formation, Lanis Conglomerate, Mangking Sandstone and the Termus Shale (Metcalfe, 2010).

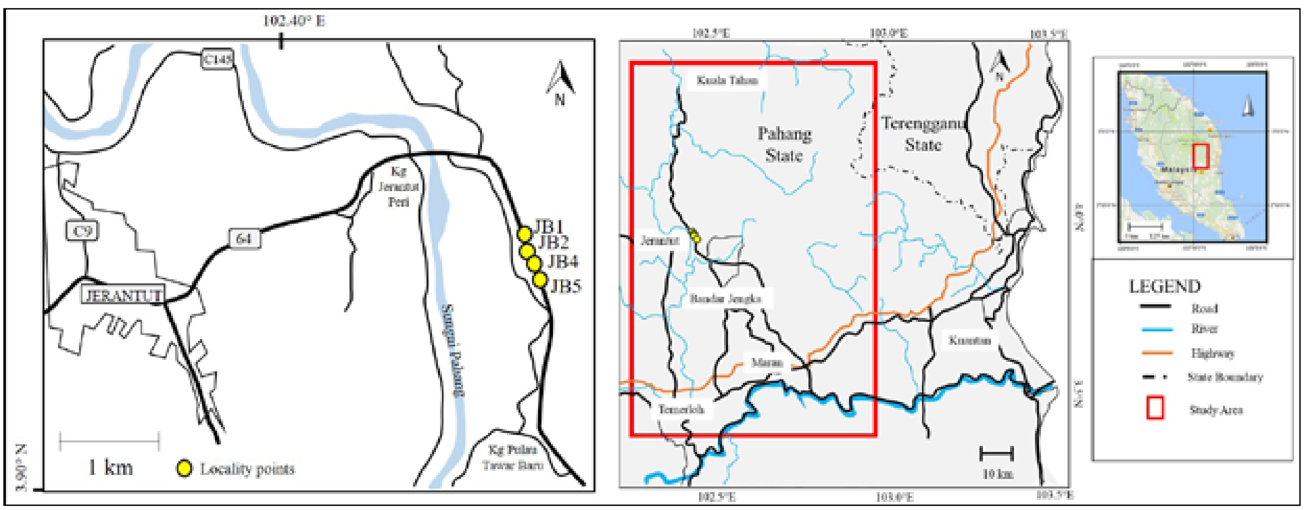

Figure 4: (A) Locality points of the research area along the Jerantut – Benta road, 8 km east of Jerantut town. (B) Location of the research area in Jerantut, Central Pahang of Peninsular Malaysia.

Sedimentary description

Sedimentary strata of the continental deposits in the study area shows sandy, occasionally conglomeratic and fine-grained deposits, with mostly unidirectional sedimentary structures like other previous studies in the Tekai Valley area (Koopmans, 1968; Harbury *et al.*, 1990; Jantan *et al.*, 1991). The succession is made up of sandstone-mudstone beds with conglomeratic lags, some occurring sparsely in which along with its sedimentary structures and textures, are mainly indicative deposits of unidirectional gravelly braided river fluvial sandstones, overbank deposits and point bar deposits. The dominant lithological component is the graded channelized sandstone which formed 23% of the full section followed by fine-grained sediments at 22%. The conglomerates take up 8.5% of the overall lithology.

Sedimentary facies

Ten (10) lithofacies are categorized by lithological composition, geometry, sedimentary structures and fossil content of the sediment body largely based on Miall (2006) with some modifications. These lithofacies are then divided into facies associations and subsequently grouped into seven (7) facies assemblages or depositional features which corresponds to certain depositional environment.

The ten (10) lithofacies are broadly categorised as conglomerate, sandy and fine-grained and coal facies (refer Table 1). Each lithofacies is distinguished with a combination code of lithology and key features by capital letters and lower-case letters respectively (Table 1). One (1) conglomerate facies, six (6) sandy facies and three (3) fine-grained facies were identified.

Facies associations

Ten (10) lithofacies are grouped accordingly into seven (7) facies associations; FA1, FA2, FA3, FA4, FA5, FA6 and FA7. These associations are grouped largely based on the energy of the deposits where FA1 and FA3 are of slow energy deposits with different flow regimes

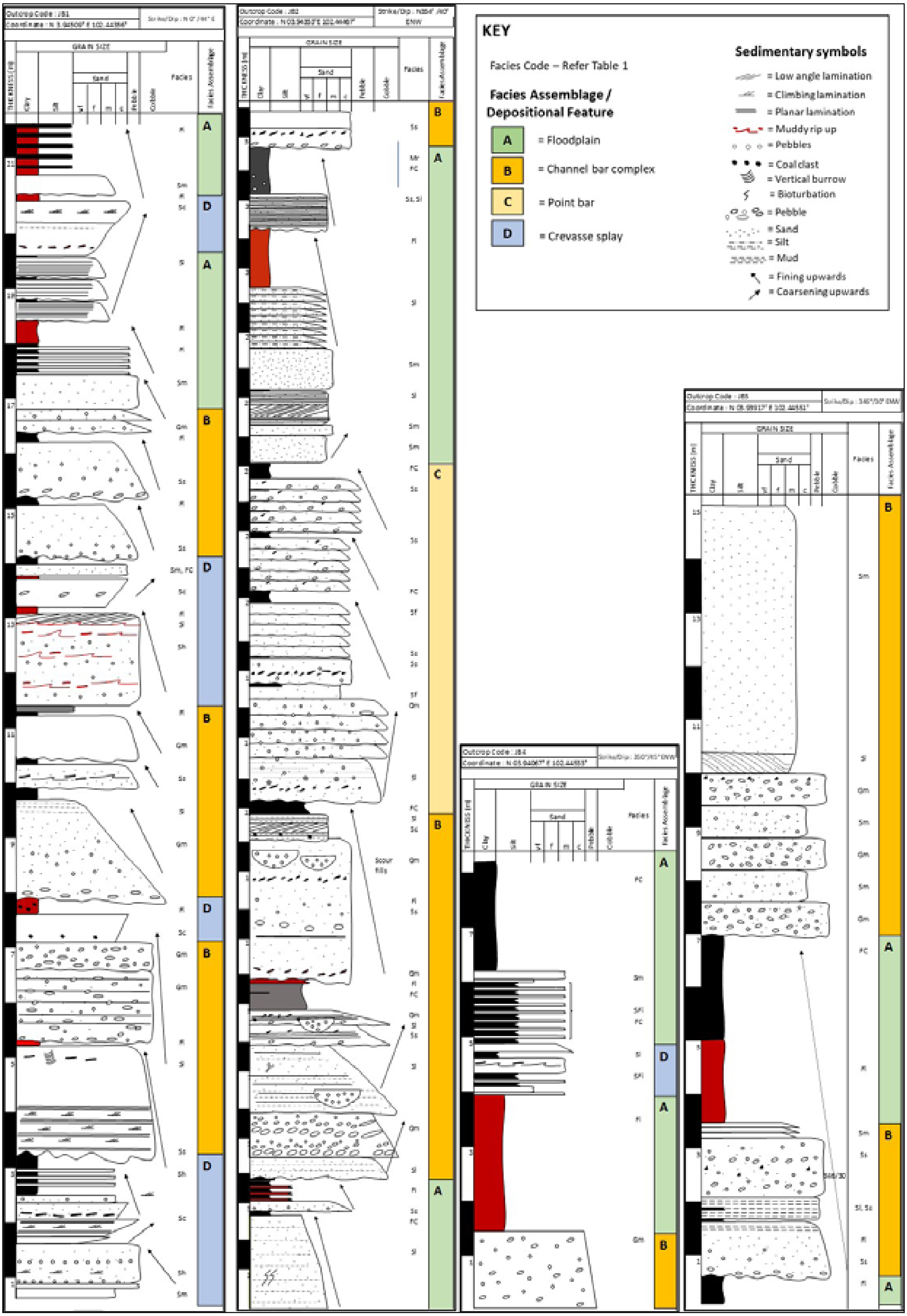

Figure 5: Sedimentary logs of the localities JB1, JB2, JB4 and JB5.

Table 1: Summary of lithofacies of the study area.

Code	Lithofacies	Contact	Grain Size	Color	Sorting	Bedding	Sedimentary structures	Other features
Gm	Thin to thick bedded conglomerate	Scoured or sharp top & bottom	Gravel -coarse grained	Mostly light brown	Very poor	Thin to thick bedded <1.2m	Massive-crudely bedded	Imbricated, angular - sub-rounded grains (0.5-3 cm), occasional rip up clasts, mud clasts
Ss	Upward fining package of sandstone	Erosive with conglomeratic lag bases	Very coarse to medium, occasionally silty	Varicolored	Poor to well	Channelized or lenticular	Cross stratified, imbricated structures	Coal clasts, mud drapes, angular clasts (0.1-1 cm)
Sm	Sheet of massive sandstone	Sharp top & bottom	Coarse-fine		Poor to well	Lenticular or undefined	Structureless	
Sc	Coarsening-upwards sandstone		Coarse to fine grained, occasionally silty				Parallel laminated (or indistinct) or imbricated structures	Occasional scattered clast (0.2 cm) & coal clast, carbonized organic matter
SFi	Interbedded sandstone and mudstone/ siltstone	Irregular sharp top and bottom contact	Medium - clay	Light grey, black		Thin layered (<0.03 m thick)		
Sl	Laminated sandstone	Sharp to irregular	Very fine-silty			Lenticular	Planar to ripple cross-lamination	Rare vertical burrow, mud drapes, carbonized organic matter & mud chips
Sh	Heterolithic sandstone	Sharp to irregular	Pebbly - clay	Light tan, red		Wavy - flaser bedded	Starved ripple lamination,	Mud drapes and mud chips
Fi	Interbedded mudstone and siltstone	Sharp to irregular	Clay to silt	Red, Black	N/A	N/A		
Fl	Siltstone/ mudstone	Sharp to irregular	Clay-silt	Red, black	N/A	N/A	Massive – laminated	Rare coal clast
FC	Carbonaceous/ coaly mudstone/ siltstone	Irregular	Clay-silt	Black to dark grey	N/A	Thin to thick bedded (0.2 -2 m)		Rootlets,coal/ mud layer

[G- gravel, S – sandstone, F – Fines (silt-clay), C – Coal, m – massive, l – laminated, s – scoured, i – interbedded, b – bioturbated, h – heterolithic, c – coarsening upward]

while FA4, FA5, FA6 and FA7 are of high energy deposits sometimes with waning flows. The classification of FA2 is somewhat arbitrary as the energy of deposition cannot be determined. Changes from FA4 and FA5 to lower energy deposits of FA3, FA2 and FA1 indicates a decrease in energy and vice-versa.

a. FA1 - Massive to laminated silt/mudstone (Sm, SFi, Fi, Fl, FC)

Lithology: This facies association consists of mostly fine-grained lithofacies; Sm, SFi, Fi, Fl, FC where it is medium bedded (0.6-1 meters) often with ripple cross-lamination. It is sometimes carbonaceous with no inner structure (structureless). FA1 shows no grading with mud/silt often amalgamated with sand. It is usually red, brown, white, or black in colour with irregular sharp bottom contact and erosive top contact. Some contain soft sediment deformation structures at the bottom of the bed. Lenticular body of sandstone are amalgamated with FA1 at Locality JB4 (Figure 6A).

Interpretation: This facies association are low energy deposits. The presence of grey beds and preservation of organic matter represents water-logged conditions and reducing water most likely a vegetated swamp origin for deposition. Red colours implies good drainage and an oxidizing early diagenetic regime (Collinson, 1986). Presence of sand indicates fluctuations in the energy of deposition.

b. FA2 - Massive sandstone (Sm)

Lithology: This facies association is made up of the massive sandstone lithofacies (Sm) where it is thin to thickly bedded (0.2 - 5 m) mostly lenticular in geometry with coarse-to-fine grained sand. The sorting is variable with irregular bottom and sharp top. It sometimes shows fining upward sequence with coal seams and is often overlain by FA1 (massive to laminated silt/mudstone) indicating a decreasing flow of energy.

Interpretation: This type of deposit shows moderate fluvial energy bedform formed as a result of gradual accumulation of sediment beneath steady or near steady flow or fluidization of sand bodies under subaqueous condition. Thickly bedded massive sandstone indicates non-cohesive debris flow while thinly bedded are most likely to be of sediment gravity flows. A characteristic occurrence of this facies association is in small channels resulting from bank collapse. Massive texture may also be produced by post-depositional modification, for example by dewatering and bioturbation (Miall, 2006).

c. FA3 - Thin to thick ripple to parallel laminated sandstone (Sl, Fl)

Lithology: The thin to thick ripple to parallel laminated sandstone is made up of lower flow regime deposits of laminated sandstone (Sl) and massive to laminated red mudstone (Fl). This deposit has a lenticular geometry, thin to thickly bedded with thickness ranging from 0.4 to 2.1 meters, and rest on flat to slightly scoured erosion surfaces. It is often capped by ripple laminated sandstone and mudstone/palaeosol. The grain ranges from very fine-to-medium grained, well sorted with planar to ripple cross-lamination (Figure 6B). Vertical burrow (?) is recorded at Locality JB1 and JB2 with presence of mud chips and coal clasts. It is

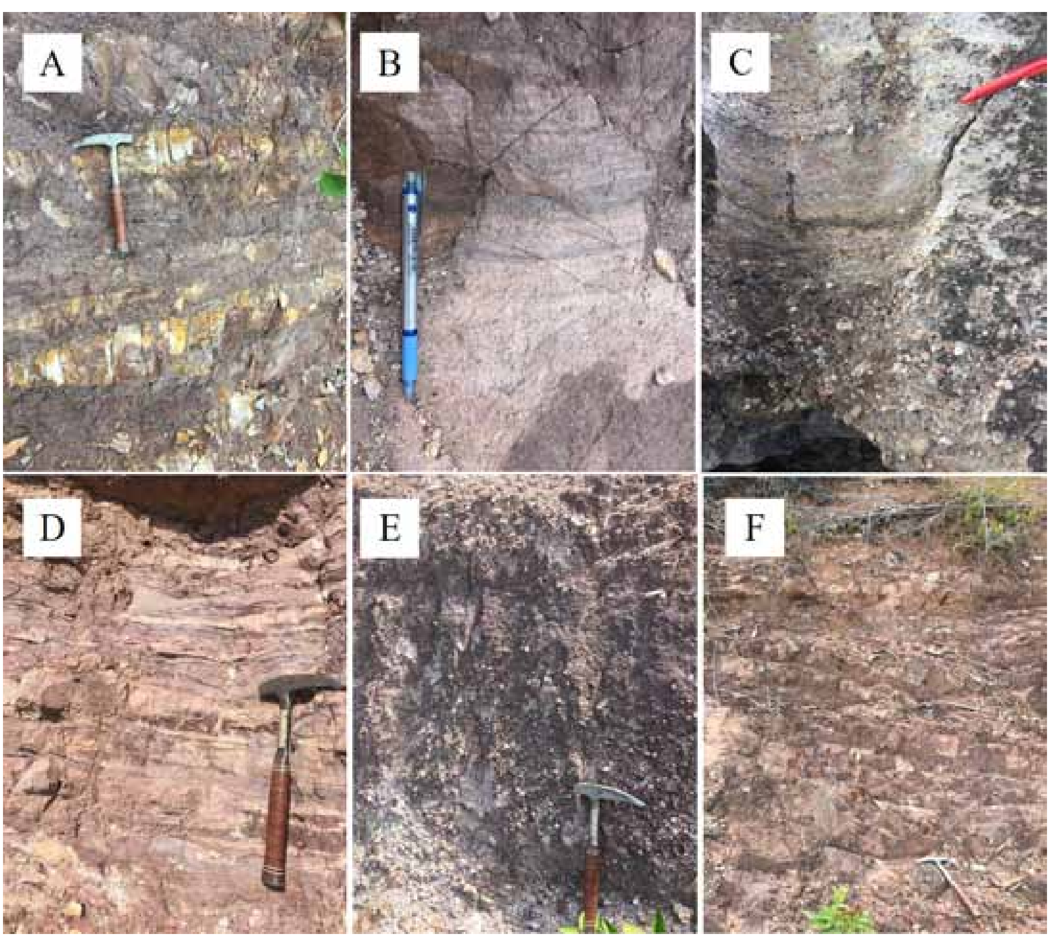

Figure 6: (A) Interbedded floodplain mudstones with lenticular shaped massive sandstone facies at locality JB4 (B) Parallel laminated sandstone of FA3 in locality JB2 (C) Graded channelized sandstone of FA5 with scoured bottom and imbricated sub-rounded clasts (D) Heterolithics sands of FA7 in locality JB1 (E) Conglomeratic sandstone of FA4 in locality JB2. (F) Lateral accretion surfaces of facies assemblage C observed in locality JB2.

amalgamated (stacked) at top of the sequence at Locality JB1 and often associated with an isolated conglomeratic lens at JB2. One bed in JB2 is micaceous at the top of the bed.

Palaeontology: Contains trace fossils in the form of burrows (?) and carbonized fossils (Figure 7). A single burrow oriented vertically with slight inclination to the bedding is found at JB1 (Figure 7A). This single burrow is about 6cm in length, shale-filled with concaving up internal structure. There is no obvious connection with an overlying shale bed exists probably removed by erosion matching the concealed bed junction preservation bioturbation structure classification of Simpson (1957). In JB2, copious amounts of vertical burrows (?) deforms the primary sedimentary structure of the sandstone (Figure 7B). The vertical burrows of are of passive infill burrows, apparent from the same lithology within the burrow from overlying strata, where the burrows were created by bottom dwelling faunas and infilled by overlying deposit after abandonment. Precise age determination is not possible as these traces of fossils are not indicative of any species. The carbonized fossil could indicate a later age of the Jurassic – Cretaceous age range (Othman, personal communication, 2019).

Interpretation: The laminated sandstone is a result of downstream subaqueous migration of 2D ripples during unidirectional stream flows. Fine grained deposition over than 2 meters are likely to be products of ephemeral streams. This deposit is interpreted to as the product of flash floods depositing sand under upper flow-regime plane bed settings (Miall, 1977a). Capping of this type of deposit by ripple laminated sandstone and mudstone indicates waning flow conditions at the end of flood event. These beds probably represent the margins of individual flood sheets. According to Manz (1978) in Collinson (1986), for beds that contain mica, the flow conditions may have been gentle as platy particles inhibit ripple formation.

Presence of isolated conglomeratic lens could be interpreted to be hollow fill similarly found in ephemeral streams (Olsen, 1989) formed by erosional action of spiral vortices during a sheet flooding effect. This element is mostly associated with braided streams though the true physical process pertaining to scour hollows are still poorly understood.

d. FA4 - Conglomeratic sandstone (Gm)

Lithology: The conglomeratic sandstone is thin-to-medium bedded (0.3 – 1.4 meters), with structureless to crude bedding with poorly sorted coarse-grained conglomeratic sandstone and clasts ranging from 0.3 – 3 cm. The clasts are rounded, sometimes imbricated with angular grained matrix. The base is erosional with conglomeratic lag with irregular sharp top. Clast-supported conglomeratic with rip-up clasts were recorded at JB2 and JB5 (Figure 6E).

Figure 7: (A) Vertical burrow (black arrow) with mud chips in parallel laminated sandstone of FA3 overlain by paleosol and sandstone with conglomeratic lag in locality JB1 (B) Numerous vertical burrow that alters the primary sedimentary structure of the in parallel laminated sandstone of FA3 in locality JB2 (C) & (D) Unidentified carbonized fossil.

Interpretation: This deposit is a product of bedload deposition from stream flows. Imbrication suggest deposition on near-horizontal pavements (top of braid bar or lags on channel floors). Stratification by contrasting grain size and texture may record changing water stage over flood cycles. It is interpreted to be of high energy fluvial channel lag deposit resulting mainly from debris flow with subordinate traction process.

e. FA5 - Graded channelized sandstone (Gm, Ss, Sr, Sm, Fl)

Lithology: The graded channelized sandstone is medium to thickly bedded with thickness ranging from 0.4-to-4 meters. The grain size ranges from coarse-to-pebbly (0.1 – 1 cm) with variable sorting. This deposit records a lenticular geometry with erosive base often with conglomeratic lag (0.5 – 3 cm) and irregular sharp top capped with mudstone (Figure 6C). Floating clasts are angular (0.3 – 1cm) to sub-rounded (1cm). It sometimes grades to black and grey laminated mudstone with some beds containing coal clasts, mud chips and drapes with amalgamation (stacked) at Locality JB1. One occurrence at JB1 are associated with FA2 (massive sandstone) and FA1 (massive to laminated silt/mudstone) which can be associated with abandoned channel. Association with isolated conglomeratic scour fill is recorded at JB2.

Interpretation: The main sandy facies show a characteristic of fining upwards succession which starts from a conglomeratic lag fining into cross laminated sands and floodplain muds. Ripple lamination within the sequence are also of abundance and when considered only the velocity as a controlling variable, this could suggest a deposition with a rather low current velocity. This element is a product of bed-load sedimentation with flow regime change form upper to lower flow regime. Presence of mud drapes suggests an intervening period of low water while occurrence of coal suggests a swampy and vegetated sub-environment.

f. FA6 - Coarsening upwards medium bedded sandstone (Sc, Sm, Fl, FC)

Lithology: This facies association is made up of coarsening upwards medium bedded (0.3-1 m) sandstone with grain sizes ranging from coarse to medium with a sharp irregular top and bottom contact. Imbricated clasts, coal clasts and mud chips are sometimes present. Carbonaceous laminations and red mudstone are sometimes observed at the top and lower part of this facies.

Interpretation: Interbedding of this facies with FA1 is interpreted to be deposits of crevasse splay occurred by breaching of levee and other backswamp deposits by river avulsion (Miall, 2006).

g. FA7 - Heterolithic sandstone (Sm, Sh, Sl, Fl)

Lithology: The heterolithic sandstone are thick (1.6 meters) flaser to wavy bedded with poorly sorted sandstone and mudstone alterations (Figure 6D). The sandstones are light tan to red while the mudstone are red to black in colour. Some sandstone and mudstone are lenticular while some shows more horizontally continuous mud layers. Rip-up clasts and pebbly basal load structure were also observed. It often grades into ripple cross-laminated sandstone.

Interpretation: Deposition during alternating intervals of water turbulence and slack water: sand deposition forms ripples during times of rapid flow and mud is deposited atop the ripples during times of slack water (Reineck & Wunderlich, 1968). The close association of this deposit with FA4 (conglomeratic sandstone) and FA6 (coarsening upwards medium bedded sandstone) suggests an overbank deposition formed by low to mixed energy stream flow.

FACIES ASSEMBLAGES / DEPOSITIONAL FEATURE

Five (5) facies assemblages/ depositional feature are interpreted based on groupings of the facies association: (i) floodplain, (ii) channel bar complex, (iii) point bar and (iv) crevasse splay. The classification is mostly based on Miall (2006), and Galloway & Hobday (1996).

Floodplain

Assemblage of FA1, FA2 and FA3 indicates floodplain environment which is of thick beds in localities JB2 and JB4. Floodplain facies assemblage is marked by fine-grained facies, mostly siltstone/mudstone and fine-grained sands with lower flow regime structures. The arrangement of the facies associations varies. Different order of these association is merely an indication of the change in energy which is most likely localized. Rare presence of FA5 within this assemblage indicates a presence of an ephemeral stream in the floodplain while presence of FA6 in the beginning of the facies assemblage indicates channel avulsion that can be related to channel abandonment (A1).

Channel bar complex

Channel bar complex is identified by high energy deposits of coarse-to-medium grained sandstones often with scoured bottom and lenticular in geometry. It is made up of mostly FA4 with occurrences of FA2, FA3 and FA5 and capped with FA1. Assemblage of these facies is mostly in increasing order of energy. These high energy deposits are interpreted to be a result of surging flow or sudden rise in energy like a debris flow. Thick beds of the channel bar complex represent currents of high energy and a rather moderate topography. Thick sequences (>1meters) of this deposit could be associated to a braided river.

Point bar

Point bar facies assemblage is recognized by the lateral accretion surfaces often consisting of normal graded sandstone with sharp top and bottom contact, sometimes capped with thin mudstones (Figure 6F). A combination of FA3 and FA5 makes up this depositional feature. This feature is often linked with meander bends where it is a product of ongoing cutting of slope at the outer part of the river bend and subsequent deposition of sediments at the inner part of the bend.

Crevasse splay

The crevasse splay facies assemblage consists of heterolithic sandstone of FA7 with coarsening upwards medium bedded sandstone of FA6, overlain by channel bar complex assemblage or fine-grained facies of the floodplain assemblage. Occurrence of FA7 and FA6 in between high energy facies FA4 and FA5 and subsequent deposition of slow energy deposits of FA1, FA2 and FA3 (varying order) indicates channel avulsion or channel shifting while occurrence of FA7 and FA6 in between slow energy deposits of FA1 is related to flooding events. This facies assemblage can be found in locality JB1 and JB5.

DISCUSSION

Outcrop exposures along the Jerantut – Maran road records different ranges of flow regime deposits from low flow regime to upper flow regimes. Observation of high energy deposits in between low energy deposits indicates fluctuations in energy within a fluvial environment. The changes in energy shows an overall increase in its depositional energy.

The sedimentology definition in the study area well suggest a fluvial environment of deposition, identified by the presence of lateral accretion surfaces, rootlets, palaeosols and coals. Rare flaser to wavy bedding at Locality JB1 is interpreted here to be of fluvial influence due to its close association with crevasse deposits. Though flaser and wavy beddings are well documented in tidal influenced environment, studies have proven that these beddings also existed in fluvial environments (Martin, 2000).

Thick beds of the channel bar complex is interpreted as deposits of braided rivers apparent by the prominence of gravel sized grains with lenticular geometry of the deposits. Lateral accretion surfaces, often found on meander belts is were also documented in braided rivers (Miall, 1977b). The correlation between this point bar deposit and the channel bar complex is ambiguous, but due to its single occurrence within the whole facies sequence, this deposit is interpreted to occur as an isolated point bar within the braided river deposits though a more thorough analysis is needed to confirm this interpretation. According to Leopold & Wolman (1957), a given channel can change in short distance from a braid to a meander or vice versa where such changes could be attributed to variations in locally independent factors.

Lots of crevassing on floodplains occurs in the first locality. The energy slows down with the deposition of floodplain deposits and then rises with the deposition of bar complexes and continues to slow down to isolated point bar deposits and subsequently floodplain deposits. It rises again with thick deposition of bar complexes.

The crevasse splay overlies the floodplain deposits when in increase in the energy flow can flood the sand until it covers the floodplain periodically. Meanwhile, change from channel bar complex of the braided river to floodplain and vice versa occurs when the river stream flows through the floodplain during dry season and the floodplain covers the river during flooding season. Same changes occur with the point bar and floodplain.

In terms of the position of the depositional environment, the distal part of these sequences is the floodplain and the proximal part is set to be of the channel bar complex.

Thick sequences of floodplain deposits alongside bar complexes with minor lateral accretion deposit would suggest an environment that underwent high energy flows alongside low energy flows. Braided rivers, associated with the channel bar complex thus fits the interpretation of the depositional environment (Figure 8).

CONCLUSION

Facies analysis on the Jurassic – Cretaceous outcrops along Jerantut – Maran road indicates fluvial deposition with conditions of fluctuating energy. Ten lithofacies of conglomerate, sandstone, and fine-grained facies were interpreted with sandy facies and fine-grained facies dominating the lithological component from the full section both at 23% and 22% respectively.

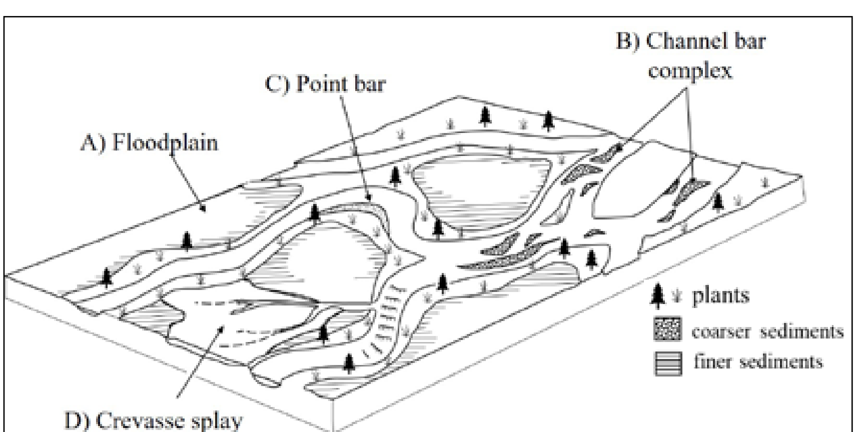

Figure 8: Artistical illustration on depositional environment of the study area, showing facies assemblage of A) floodplain, B) channel bar complex C) point bar and D) crevasse splay. Modified after Miall (2006)

Facies analysis of the study area shows a range of sub-depositional environment from floodplain, channel bar complex, point bar and crevasse splay. The floodplain is set to be the distal part of the study area while the channel bar complex is set to be the proximal part. Changes from proximal to distal part of these deposits is observed to be in high variability, with high- fluctuations of energy as one of the variables that controls the rate of sedimentation. The overall facies based on an outcrop scale suggests general features of fluvial facies. The environment of deposition is interpreted to be of braided river with floodplains and an isolated point bar.

On a larger scale, these deposits show an overall retrograding sequence pattern. As the scale of the study is only on an outcrop scale, more studies on the surrounding area is needed to further conclude the more regional scale interpretation on the depositional environment.

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REFERENCES

Abdullah, N. T., Hutchison, C. & Tan, D., 2009. Mesozoic stratigraphy. In: Hutchison, C.S. and Tan, D.N.K. (Eds.), Geology of Peninsular Malaysia. University of Malaya, Geological Society of Malaysia, Kuala Lumpur. 479 p.

Ariffin, A. R., Wafa, S. S. W. S. K., Abdullah, S. & Said, U., 2005. Sedimentological and Palaeontological Study along the Kuala Tekai-Kuala Tahan stretch of Tembeling River, Jerantut Pahang. Bulletin of the Geological Society of Malaysia, 51, 77-82.

Collinson, J. D., 1986. Alluvial sediments. In: Reading, H.G. (Ed.), Sedimentary Environments and Facies. Blackwell Science, Oxford. 642 p.

Galloway, W. & Hobday, D., 1996. Terrigenous Clastic Depositional Systems: Applications to Fossil Fuel and Groundwater Resources. Springer-Verlag, Berlin Heidelberg. 489 p.

Harbury, N. A., Jones, M. E., Audley–Charles, M. G., Metcalfe, I. & Mohamed, K. R., 1990. Structural evolution of Mesozoic Peninsular Malaysia. Journal of the Geological Society, 147(1), 11-26.

Ismail, H., Madon, M. & Bakar, Z., 2007. Sedimentology of the Semantan Formation (Middle - Upper Triassic) along the Karak-Kuantan Highway, central Pahang. Bulletin of the Geological Society of Malaysia, 53, 27-34. doi:10.7186/bgsm53200706.

Jantan, A., Mohamad, K. R., Ali, C. A., Abdullah, I., Said, U. & Samsudin, A. R., 1991. Relationship and Depositional Setting of the Lanis Conglomerate, Mangkin Sandstone and Termus Shale of the Tembeling Group in Tekai Valley, Pahang [abstract]. Warta Geologi, 17(3), 158.

Jirin, S. & Morley, R., 1994. Lower Cretaceous Palynomorphs from the Termus and Mangking Formations (Tembeling Group), Peninsular Malaysia: Their Stratigraphic and Climatic Significance [abstract]. Warta Geologi, 20(3), 219.

Khoo, H. P., 1977. The Geology of the Sg. Tekai Area. Laporan Tahunan Kajibumi Malaysia (93 - 103).

Khoo, H. P., 1983. Mesozoic Stratigraphy in Peninsula Malaysia. Paper presented at the Workshop on Stratigraphic Correlation of Thailand and Malaysia, Haad Yai, Thailand. Sep. 8-10, 1983.

Koopmans, B., 1968. The Tembeling Formation-A Litho-Stratigraphic Description (West Malaysia). Bulletin of the Geological Society of Malaysia, 1, 23-43.

Leopold, L. B. & Wolman, M. G., 1957. River channel patterns: braided, meandering, and straight. Geological Survey Professional Paper 282-B. US Government Printing Office, Washington. 50 p.

Madon, M., Bakar, Z. A. A. & Ismail, H. H., 2010. Jurassic-Cretaceous fluvial channel and floodplain deposits along the Karak-Kuantan Highway, central Pahang (Peninsular Malaysia). Bulletin of the Geological Society of Malaysia, 56, 9-14. doi:10.7186/bgsm2010002.

Martin, A., 2000. Flaser and wavy bedding in ephemeral streams: a modern and an ancient example. Sedimentary Geology, 136(1-2), 1-5.

Metcalfe, I., 2010. Geology of Peninsular Malaysia. In: C.S. Hutchison and D.N.K. Tan, (Eds.), University of Malaya/ Geological Society of Malaysia, Kuala Lumpur. xvi+479 p.

Miall, A. D., 1977a. Lithofacies types and vertical profile models in braided river deposits: a summary. In: Miall, A.D. (Ed.), Fluvial Sedimentology, Memoir 5, Canadian Society of Petroleum Geologists, Calgary, 597-604.

Miall, A. D., 1977b. A review of the braided-river depositional environment. Earth-Science Reviews, 13(1), 1-62.

Miall, A. D., 2006. The Geology of Fluvial Deposits (4th ed.). Springer-Verlag, Berlin, Germany. 582 p.

Olsen, H., 1989. Sandstone-body structures and ephemeral stream processes in the Dinosaur Canyon Member, Moenave Formation (Lower Jurassic), Utah, U.S.A. Sedimentary Geology, 61, 207-221. doi:10.1016/0037-0738(89)90058-4.

Othman, A. R., 2019. [Personal interview].

Peng, L. C. & Suyin, S. K., 2007. Sedimentology and Structural Geology of Jurassic-Cretaceous Mangking Sandstone at Simpang Jengka 8, Kota Gelanggi, Jerantut, Pahang (P4A-2). Paper presented at the National Geoscience Conference 2007, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia.

Reineck, H.-E. & Wunderlich, F. , 1968. Classification and Origin of Flaser and Lenticular Bedding. Sedimentology, 11(1-2), 99-104.

Simpson, S., 1957. On the trace fossil Chondrites. Quarterly Journal of the Geological Society of London, 112, 475-499.

Teng, Y. H., Sone, M., Hirayama, R., Yoshida, M., Komatsu, T., Khamha, S. & Cuny, G., 2019. First Cretaceous fish fauna from Malaysia. Journal of Vertebrate Paleontology, 39(1), e1573735.

Tjia, H. D., 1996. Tectonics of deformed and undeformed Jurassic-Cretaceous strata of Peninsular Malaysia. Bulletin of the Geological Society of Malaysia, 39, 131-156.

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