# Sedimentology of Jurassic-Cretaceous Non-Marine Sandstones from the Bertangga formation, Maran, Pahang.

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***Abstract* —** The Bertangga formation is an informally named Jurassic-Cretaceous non-marine formation located at Pahang, introduced for a predominantly arenaceous sequence interbedded with argillaceous rocks. The rock formation has not been not well-investigated, although generally correlated to the Mangking Sandstone and interpreted as alluvial fan and fluvial deposits. In this study, detailed sedimentological and petrographic analysis were conducted to analyse the facies distribution and depositional system of the rock succession. The integration of outcrop descriptions, sedimentary logs, grain size analysis and petrographic analysis led to the detailed facies analysis of the fluvial deposits in Bertangga formation. Five facies associations identified in the study area are channel facies association, point bar facies association, floodplain facies association, crevasse splay facies association and shallow lacustrine facies association. Channel deposits are stacked bodies of fining upward sequences with prevalent erosional base and trough cross bedding. Point bar sands are massive sandstone bodies with parallel lamination and lateral accretion surfaces. Crevasse splay deposits form sheets of fine-to-medium-grained sandstone beds interbedded with floodplain mud. Floodplain sediments are generally massive fine-grained sediments of sand, silt or mud, and may be found present with crevasse splay and coal deposits. Shallow lacustrine deposits are represented by coarsening upward lacustrine mouth bar and wave-influence lacustrine coastline of interbedded sandstone and mudstone. Analysis of the facies distribution allows reconstruction of the fluvial system, and a meandering fluvio-lacustrine system is proposed. The distribution of these facies association also shows increasingly distal and fine-grained trend from west to east of the study area, which suggest possible eastward paleofluvial direction. Presence of smectite in eastern part of the study area may indicate the weathering of volcanic rocks from nearby sources. **Keywords—Bertangga formation, sedimentology, facies analysis, non-marine, meandering system, depositional environment.**

## I. INTRODUCTION

The Bertangga formation is an informally named Jurassic-Cretaceous non-marine formation located at Pahang, Peninsular Malaysia. According to Khoo [10], it was introduced in an unpublished work for a predominantly arenaceous sequence interbedded with argillaceous rocks. The type area is near Bukit Bertangga, the peak of N-S trending strike ridge. Generally, Jurassic-Cretaceous rock formations in Peninsular Malaysia are referred as continental red beds, due to its red-coloured characteristics. Bertangga formation and other Jurassic-Cretaceous formations such as Tembeling Group and Gagau group have been interpreted as molasse deposits due to the consequence of Triassic orogeny activities and are typically represented by alluvial and fluvial sediments.

However, not much is known about the Bertangga formation as the thickness and unit have not been detailly evaluated. The lithology and sedimentology of the Bertangga formation were correlated generally to the Tembeling Group and the Mangking Sandstone [10], [13], [20], [22]. Tjia [21] suggested that the Bertangga basin was developed from pull-apart graben between two wrench faults. Previously the Bertangga formation was part of Tembeling Formation illustrated by Koopsman [11] in his map of distribution of Tembeling Formation. Khoo [9] later upgraded the Tembeling Formation to Tembeling Group and Bertangga formation was separated from the Tembeling Group in the map of Mesozoic rocks [10].

The study area in this paper covers the distribution of Bertangga formation along the Pahang River. This area was considered as Tembeling Formation before Tembeling Group was formally upgraded. Detailed sedimentological and petrographic analysis were conducted with emphasis on the sandstones. Field observations, sedimentary logs, grain size analysis, XRD analysis and thin section analysis were conducted to study the facies distribution and depositional environment of Bertangga formation.

## II. PROBLEM STATEMENT

Previous sedimentological studies have correlated the Bertangga formation with the Mangking Sandstone of equivalent age. They were generally interpreted as alluvial fan, fluvial and floodplain dominated environment. However, these studies conducted are still insufficient to be representative. Further analytical approach on sedimentology and petrography is required to evaluate the facies and depositional environment of the Bertangga formation.

## III. OBJECTIVES

This research is aimed to study the Jurassic-Cretaceous non-marine sandstones from the Bertangga formation through sedimentological and petrographic investigations, and to interpret the facies distribution and depositional environment of Bertangga formation.

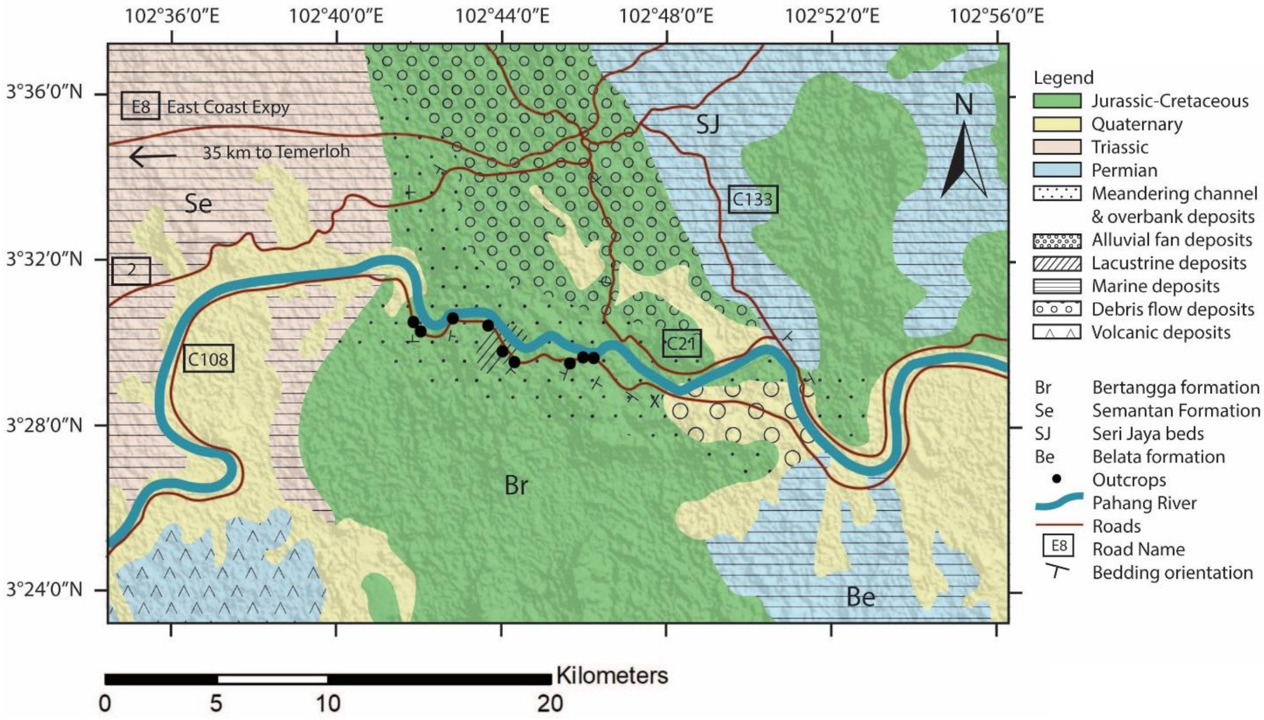


Figure 1. Geological Map of study area. Modified from Geological Map of Peninsular Malaysia [7].

## IV. LITERATURE REVIEW

### A. Geological Setting

In Peninsular Malaysia, non-marine deposits are found in post-Triassic stratigraphy. These Jurassic-Cretaceous rocks are dominantly distributed in the Central Belt of Peninsular Malaysia. The eastern limit of Central Belt Jurassic-Cretaceous deposits is marked by the granitoids of the Eastern Belt, or the prominent lineament Lebir Fault [17]. Large exposed formations are from the Tembeling Group, Koh Formation, Bertangga formation and Ma'Okil Formation.

In late Triassic-early Cretaceous time, a major tectonic deformation of Peninsular Malaysia occurred due to orogenesis and accompanied by intrusion of Titiwangsa granitoid bodies. According to Tjia [21], certain strike-slip fault developed in pre-late Jurassic developed pull apart basins where continental Jurassic-Cretaceous sediments were mainly deposited. The sediments were later deformed into drag folds during Middle Eocene due to wrench faulting along several pull apart boundaries. Tembeling Group, Koh Formation, Bertangga formation, Gerek Sandstone and Ma'Okil Formation are highly deformed by these wrench faults, with other slightly tilted formations such as the Gagau Group, Tebak Formation and Ulu-Endau Beds.

These red beds are non-marine clastic sedimentary rocks which are interpreted to be deposited in alluvial fan, fluvial channels and floodplains environment. The lower units of Jurassic-Cretaceous rocks are dominated by coarse sediments such as conglomerate, pebbly sandstone and sandstone, whereas the upper units are dominated by mudstone [17]. Clasts of older Triassic rocks were eroded and deposited within the lower conglomerates and sandstones. The presence of continental plant remains, cross-bedded sandstone and red ferric oxide are evidences of fluvial dominated depositional setting.

Volcanic rocks and/or volcaniclastic sediments are present in most of the Jurassic-Cretaceous rocks, including the Tembeling Group, Gagau Group, Koh Fm, Ma'Okil Fm and Panti Sandstone. Common volcanic and volcaniclastic rocks are andesitic lavas, tuff and tuffaceous sandstone. Coal lenses are also found present in some of the rock formation [17].

Among the formations, Tembeling Group has the thickest section of rock succession and is commonly used as a basis for comparison and correlation with other Jurassic-Cretaceous deposits.

### B. Bertangga formation

Few sedimentological studies have been carried out to study the rocks in Bertangga formation. Previously, Smiley [20] correlated the lithology of Maran area to the middle portion of the type section of Tembeling Formation described by Koopsman [1968], as light-coloured sandstone and shale, with pebbly characteristic at the lower portion. Maran florules were also correlated biostratigraphically to the Panti Sandstone and Lotong Sandstone [20].

Mazlan et al. [13] studied an exposed outcrop along the Karak-Kuantan Highway and interpreted it as a fluvial channel and floodplain dominated depositional environment. Four major sand bodies were observed, three of which represent fining upward channel facies. The fourth sand body consists of at least four tabular or sheet-like sandstones interpreted as crevasse-splay sheet sand deposits. The features observed are cross bedding, erosive-based channel forms, lateral accretion surfaces, pebble lag deposits, and fining upwards sandstone intercalated with red and green mudstone. The crevasse splays thin sand bodies inferred the occurrence of high-sinuosity channels with extensive floodplain.

Another sedimentological study by Zainey et al. [22] described the rock succession along the road from Kampung Pejing to Kampung Lotong and suggested a close resemblance with the Mangking Sandstone in the Tembeling Group, where four sedimentary facies were identified: sandstone with conglomerate lenses facies, siltstone with minor sandstone facies, thickly bedded sandstone facies and the interbedded sandstone with siltstone facies. They were interpreted as deposits from alluvial fan environment.

## V. METHODOLOGY

Nine outcrops that belong to the Bertangga formation were investigated during this study along the road C108 beside the Pahang river near to Maran, Pahang. The study area is bounded by latitudes 3°29'31"N to 3°30'36"N and longitudes102°41'51"E 102°45'43"E, a stretch of 15 kilometers from west to east. The fieldwork conducted include detailed description of the lithology, primary sedimentary structures, and thickness of the rock succession. Representative samples from different facies were collected for laboratory analysis including grain size analysis, XRD analysis and petrography analysis. Nine grain size analysis were conducted, and three thin sections were investigated for the sandstone units to study the grain size distribution, composition and maturity of the samples. The method used for grain size analysis is the sieve and pipette method described by Krumbein and Pettijohn [12]. The pipette method was used determine the grain size of silt and clay particles smaller than 1/16 mm and followed by the wet sieving to separate the sand size particles larger than 1/16 mm. The clay fractions were separated from six sandstone and shale samples to study the mineralogy of the clays using X-ray diffraction (XRD) technique. These investigations were used to study the texture and mineralogy of each facies unit.

## VI. RESULTS

### A. *Grain Size Distribution*

Grain size analysis was performed for 9 sandstone samples from the study area using sieving and sedimentation method (sieve and pipette method). Samples 1-1, 1-2, 1-3 and 2-1 (figure 2) are characterized by distinct binomial distribution with two dominant grain size, indicating high degree of mixing and poor sorting. Sample 1-1, 1-3 and 2-1 show dominant mode at <2Φ (medium sand or coarser) and sample 1-2 shows dominant mode at >8Φ (clay size particle). Samples 7-1 and 8-3 (figure 3) are also characteristically bimodal, showing dominant mode at 3Φ-4Φ (very fine sand), and secondary dominance at >8Φ (clay size particle), indicating the mixing of fine sand and clay. Samples 3-3, 3-4 and M12-1 (figure 4) are slightly bimodal. All three samples showing dominant mode at <2Φ (medium sand or coarser). Sample 3-4 and M12-1 show secondary dominance at >8Φ (clay size particle), and 6Φ - 7Φ (silt size particle) for sample 3-3.

The grain size parameters (mode, mean, median, standard deviation and skewness) are calculated using Folk & Ward's [4] formula. From these parameters, it is identified that all the sand samples are generally poorly sorted and strongly fine-skewed. According to McLaren & Bowles [14], fine-skewed sands are usually river sands, due to much clay and silt not removed by the currents and trapped between larger grains. Sediments usually become more coarsely-skewed along its transportation path. The justification of river sands is also supported by the grain size bivariate plot of skewness vs. standard deviation as demonstrated by Friedman [5]. The bivariate plot shows that the samples fall in the field of "mainly river sands", where standard deviation of grain size is generally larger than 0.8 (figure 5).

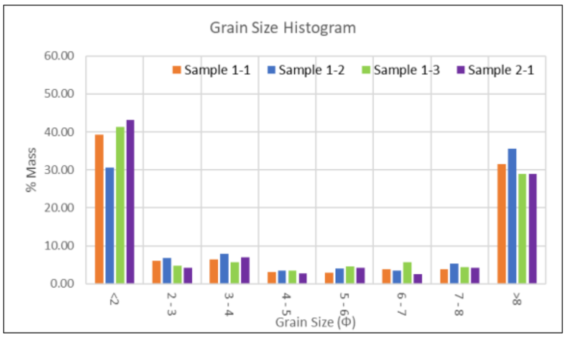


Figure 2. Assemblage 1: grain size vs percentage plots (histogram). Poorly sorted, fine-skewed, distinct binomial distribution. 50% sand and 1:1 sand to mud ratio.

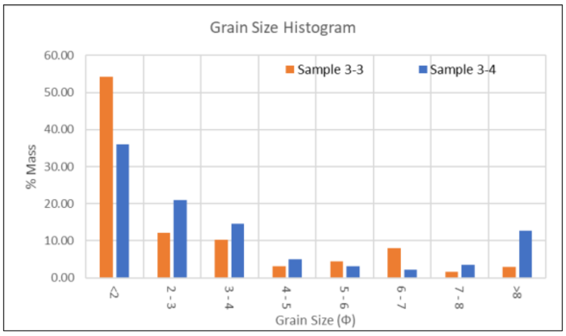


Figure 3. Assemblage 2: Grain size vs percentage plots (histogram). Poor to moderately well sorted, fine-skewed, slightly binomial distribution, with >75% sand.

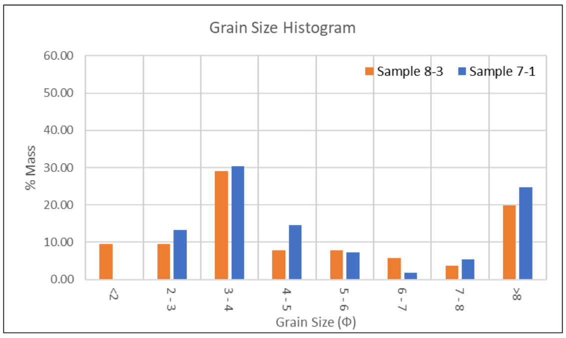


Figure 4. Assemblage 3: Grain size vs percentage plots (histogram). Poorly sorted, fine-skewed, with distinct binomial distribution, showing mixture of sand and clay. Dominantly Sand made up <50% and are mainly very fine-grain (3Φ –4Φ).

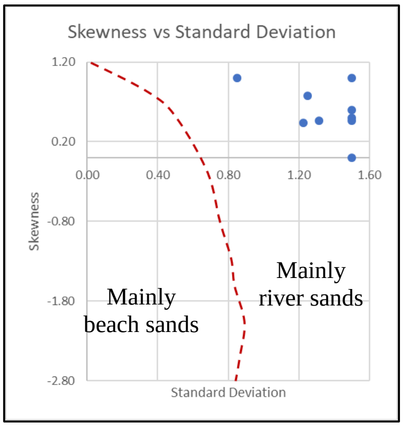


Figure 5. Grain size bivariate plot of skewness vs standard deviation as demonstrated by Friedman [5]. All samples fall in the field of "mainly river sands".

Using the grain size distribution data, the textural nomenclature of the sandstones is justified according to Folk's [3] sandstone classification. According to the percentage and ratio of sand, silt and clay, sample 1-1 and 2-1 is classified as clayey sand (cS), sample 1-2 as sandy clay (sC), sample 1-3, 3-4 and M12-1 as muddy sand (mS), sample 7-1 and 8-3 as sandy mud (sM), and sample 3-3 as silty sand (zS). Most of the samples are sand dominated with varying ratio of silt and clay (figure 6).

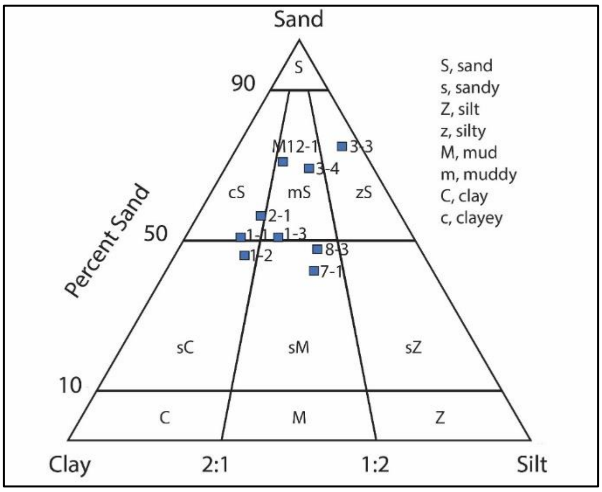


Figure 6. Sand-silt-clay ternary diagram showing different ratios of grain size, based on Folk's [3] sandstone classification. Sample 1-1 and 2-1 is classified as clayey sand (cS), sample 1-2 as sandy clay (sC), sample 1-3, 3-4 and M12-1 as muddy sand (mS), sample 7-1 and 8-3 as sandy mud (sM), and sample 3-3 as silty sand (zS).

### B. Petrography

Most sandstones in the study area is friable and clayey, therefore not suitable for producing thin sections. Three sandstone samples which are more consolidated and having less clay content are made into thin sections. Under the polarizing microscope, the Bertangga sandstones are composed of monocrystalline, subangular, fine to coarse-grained monocrystalline quartz, with little clay matrix. The grains are tightly fitted, porosity of the sandstones may be less than 5%. Feldspar grains are strongly weathered and altered into sericite. Lithic fragments and accessory minerals are present as fragments of other sedimentary rocks, muscovite, and iron oxide.

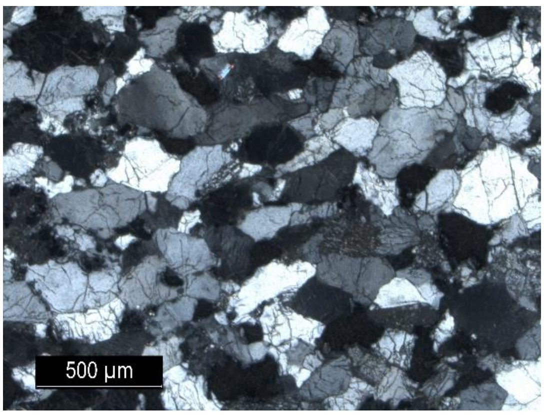


Figure 7. Photomicrograph of laminated sandstone (sample 3-1). Subangular, moderately well sorted, dominantly medium-grained monocrystalline quartz with very little matrix. Crossed-polarized light.

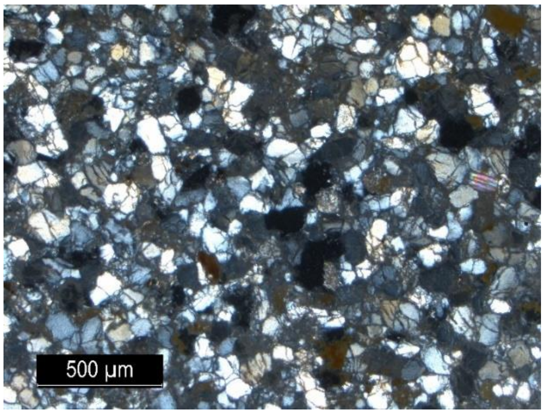


Figure 8. Photomicrograph of sandstone (sample 6-4). Subangular, moderately well sorted, fine-grained monocrystalline quartz with little clayey matrix. Crossed-polarized light.

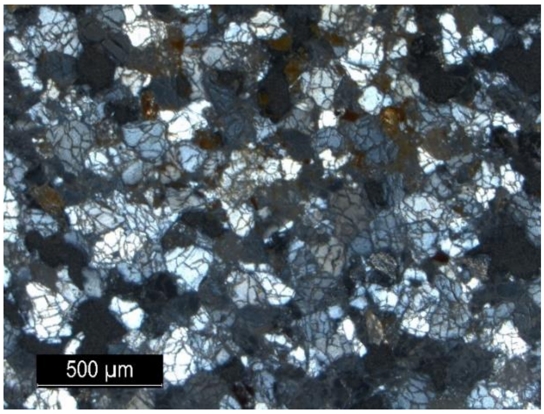


Figure 9. Photomicrograph of sandstone (sample 7-3). Subangular, moderately well sorted, fine-to-medium grained monocrystalline quarts. Crossed-polarized light.

### C. Clay Mineralogy

The sandstones are composed of quartz and clay matrix. The XRD data for the clay fractions separated from the sandstones from different outcrops are dominated by illite, kaolininte and smectite. Kaolinite is present in all samples, and illite is present in most of the samples. Two outcrops at the east section of the study area contains smectite. Quartz is also present in all samples.

XRD analysis was conducted for 7 clay fractions separated from sample 1-1, 1-2, 2-1, 3-4, 7-1, -5 and X-2. Sample 1-1, 1-2, and 2-1 show similar XRD peaks, suggesting the presence of illite and kaolinite. Sample 3-4 shows very weak intensity of XRD peaks and the possible clay mineral presence is kaolinite. Sample 7-1, 7-5 and X-2 having XRD peaks which suggest the presence of smectite, illite and kaolinite.

The presence of kaolinite in all samples indicate origin of clay minerals from weathering of feldspars under acidic conditions, or weathering from other clay minerals. Identification of illite in samples 1-1, 1-2 (figure 10), 2-1, 7-1 (figure 11), 7-5 and X-2 indicates that these clay minerals are the product of weathering of primarily feldspars and muscovite under alkaline conditions. The smectite peak identified in sample 7-1, 7-5 and X-2 indicates the presence of weathered basic rocks. Smectite is a common product of alteration of mafic igneous rocks, such as weathering of volcanic ash. The presence of smectite may indicate the poorly drained environment, as water can easily leach the ions and results in alteration.

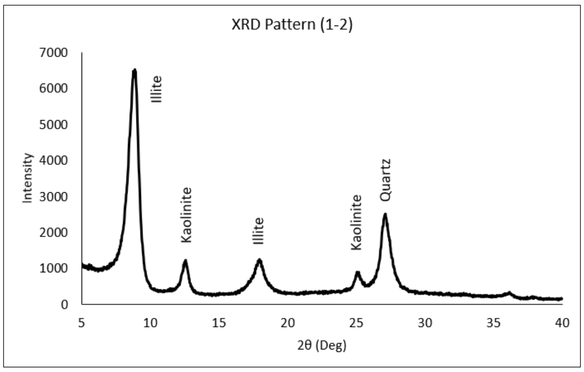


Figure 10. X-ray diffraction pattern of the clay fraction separated from the sandstone interval 1-2. Composition: illite, kaolinite and quartz.

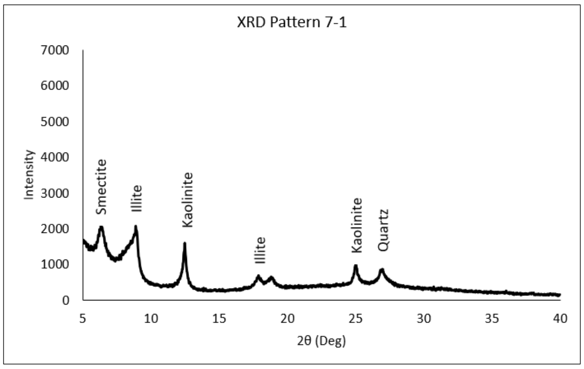


Figure 11. X-ray diffraction pattern of the clay fraction separated from the sandstone interval 1-2. Composition: illite, kaolinite, smectite and quartz.

## D. Facies Analysis

Based on sedimentary facies identified in sedimentary logs, five facies associations have been identified, namely channel facies association, point bar facies association, floodplain facies association, crevasse splay facies association, and shallow lacustrine facies association. The facies associations are classified with considerations for lithology, bed geometry, primary sedimentary structure, and grain size.

### 1) Channel Facies Association (CH)

The channel facies association is characterized by lens or sheet-like sandstone with concave-up erosional base. Sedimentary structure identified is trough-cross bedding. The rock succession generally shows periodic gradational fining up cycles from conglomerate to pebbly sandstone, sandstone and mudstone. The thickness of each cycle ranges from less than 1m to 6m. These multi-story fills are bounded by erosional surface. According to Miall [16], These stacking of fining upward successions and reflect vertical aggradation which may due to progressive abandonment as a result of avulsion. The upper section of the fining upward section filled by fine-grained mudstone is also a typical occurrence in high-sinuosity channels. The channel sands (sample 1-1, 1-2, 1-3, 2-1) are poorly sorted, fine-skewed, medium-to-coarse-grained sand in clay matrix. The percentage of sand is about 50%, and the ratio of sand to mud is nearly 1:1.

### 2) Point Bar Facies Association (LA)

Point bar facies association in the study area is characterized by stacked sheets or massive macroform sandstone bodies. Sedimentary structure identified is parallel lamination in hard, consolidated planar sandstone beds, which represents upper flow regime. However, no sedimentary structures and bedding are identified the massive friable sandstone bodies, this may due to weathering processes which may have destroyed the primary structures such as cross beds and lamination. There are three distinct sandstone bodies identified; the lower section is laminated sandstone beds of total up to >5m thick, with bounding surfaces which could be lateral accretion surfaces due to the erosion along the outer bend of the meander. The laminated sandstone is overlain by a sheet of clay, followed by massive structureless friable sandstone, and further overlain by another massive sandstone bed finer in grain size. The overall fining up macroform sandstone body may be the result of evolution of meander and decreasing in energy of current. According to Jackson [8], the fining-upward point bar profile tend to develop on downstream part of the river bend.

The three sand bodies show fining up characteristic and better sorting compared to channel sand as justified from grain size analysis and petrographic analysis. The laminated sandstone (3-1) is compositionally mature, moderately well sorted, having dominantly medium-grained quartz with very little matrix. The upper finer and friable sands contain sand percentage of >75%.

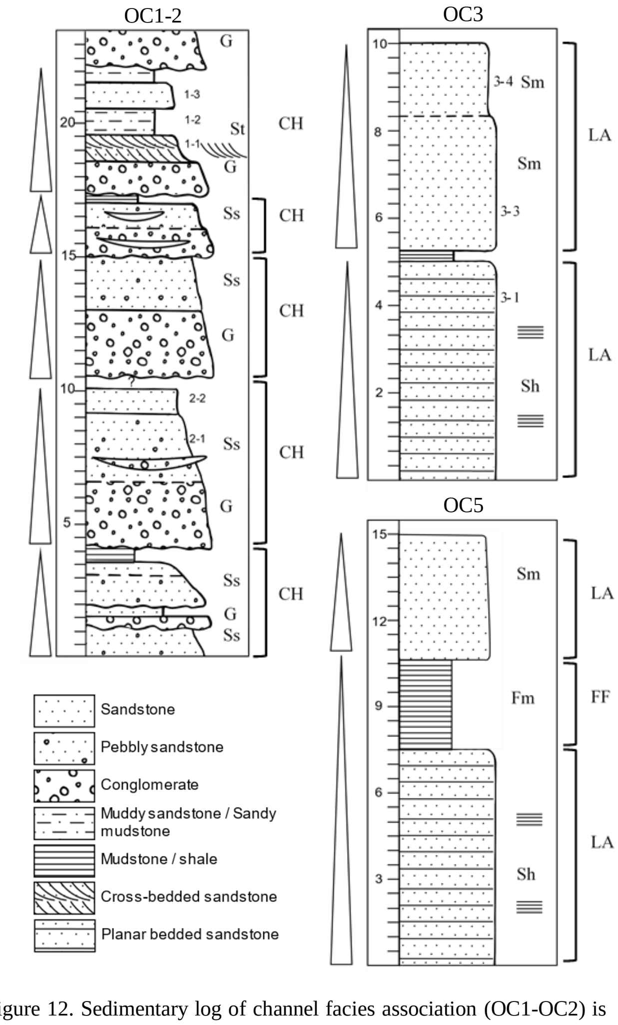


Figure 12. Sedimentary log of channel facies association (OC1-OC2) is composed of cycles of fining upward channel fill from channel lag conglomerate, pebbly sand to fine sand and mud. Point bar facies association (OC3, OC5) are massive sandstone bodies. Facies Sh has dipping planar surfaces which may be lateral accretion surfaces of lower point bar. Massive sandstone facies Sm are finer sands of upper point bar.

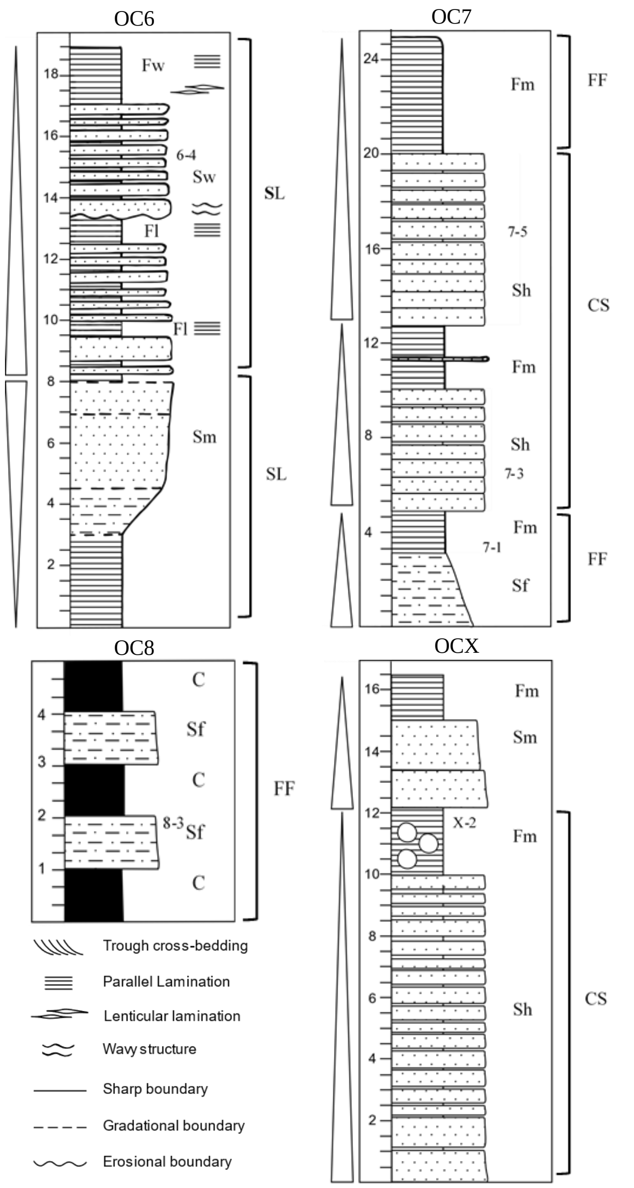


Figure 13. Sedimentary log of shallow lacustrine facies association (OC6) is composed of coarsening upward shale to sand lacustrine mouth bar, overlain by interbedded sandstone and mudstone. Sedimentary logs of floodplain and crevasse splay facies associations (OC7, OCX, OC8) are composed of sheet sand units interbedded with floodplain mud, and interbeds of thick coal and floodplain sandy mud.

### *3) Floodplain Facies Association*

The sedimentary facies of floodplain association vary from fine-grained sand and mud to massive mudstone, claystone or shale, where finer sediments and thicker beds indicate more distal and low energy floodplain facies. The thickness of mudstone or shale may range from less than 1m to more than 5m thick, laminated or non-laminated. The colour varies from greyish white, grey, black, red to brown. The floodplain facies also often occur together with point bar facies and sheet sands of crevasse splay facies. Fine sands in OC 8 are interbedded with thick beds of coal, where the thickness of both sand and coal beds are 1m thick. The sands in floodplain facies are poorly sorted very fine sand and clay. Sand made up about 45% and are mainly very fine-grain ($3\Phi$ –$4\Phi$). These fine-grained sand, silt and mud are common in proximal floodplain and represent deposition from weak traction currents [16].

### *4) Crevasse Splay Facies Association*

The crevasse splay facies association identified is characterized by sheets or lens of sandstone and intercalated with fine-grained floodplain deposits. The sheets of sandstone beds at 2 studied outcrops are less than 2m thick each, having erosional surfaces, and thickness varies laterally. Internal scours are common. Sedimentary structures are not identified. The interbedded sandstone and mudstone reflect the origin of the splays by periodic or irregular sheet flooding. At OCX, the overall trend of the crevasse splay facies association shows fining upward characteristics, where the thickness of bed and grain size decreases upward, which may indicate the crevasse deposits are increasingly distal. The photomicrograph description of sandstone sample 7-3 interpreted as crevasse splay sand are fine-to-medium-grain, which according to Miall [16], is the typical grain size of crevasse spay deposits.

### *5) Shallow Lacustrine Facies Association*

The shallow lacustrine facies association observed at OC6 shows different characteristic compared to other fluvial facies. The rock succession of 20m thick is divided into two sections: the lower section and upper section.

Table 1 Sedimentary facies identified in Bertangga formation.

| Facies code | Facies name | Descriptions |
|---|---|---|
| G | Gravel | Polymictic, grain-supported conglomerate with sub-angular gravel size clasts. Normal grading. Red. |
| Ss | Scour-fill sand | Medium-to-coarse-grained, poorly sorted sand in clayey matrix, may be pebbly. |
| St | Trough-cross bedded sand | Trough-cross bedded sand. Poorly sorted, mixture of medium-to-coarse-grained sand and clay. Red. |
| Sh | Horizontally bedded sand | Horizontally bedded sand. Parallel lamination may present. Fine-to-coarse-grained. Generally hard and consolidated. Light grey to yellow. |
| Sm | Massive sand | Massive sand, with no sedimentary structure. Poorly sorted, fine-to-coarse-grained. Generally friable, which may explain the absence of primary structure due to weathering. Light coloured to yellow. |
| Sf | Fine sand | Mixture of fine-grained sand and mud, with no sedimentary structure. Poorly sorted, generally friable. Light grey to dark brown. |

| | | |
|---|---|---|
| Sw | Wave influenced sand | Fine-grained sand with wavy erosional base and wavy cross beds. Moderately well-sorted. Generally hard and consolidated. Light yellow. |
| Fl | Laminated mud | Mudstone with parallel lamination. Grey. |
| Fw | Wave influenced mud | Massive, laminated clay. Presence of lenticular lamination. |
| Fm | Massive mud, shale | Massive, structureless mudstone, claystone or shale. Colour ranges from white to grey, red, brown and black. |
| C | Coal | Thick coal beds. |

Table 2. Facies Associations of Bertangga formation.

| Facies Association | Facies Assemblage | Descriptions | Interpretation |
|---|---|---|---|
| **Channel (CH)** | G, Ss, St | Lens or sheet-like sandstone with concave up erosional base. Trough-cross bedded. Periodic gradational fining up cycles from gravelly conglomerate to pebbly sandstone, sandstone and mudstone. Ss facies are poorly sorted with 50% of medium-to-coarse-grained sand. | Vertical aggradation and avulsion of channel. |
| **Point Bar (LA)** | Sh, Sm | Stacked sheets or massive macroform sandstone bodies. Sh facies with parallel lamination of upper flow regime and bounding surfaces which may be lateral accretion surfaces. Sm facies are massive friable sandstones with no sedimentary structure. Fining upward profile from medium-grained sand to fine-grained sand. Moderately well-sorted to poorly sorted with >75% sand. | Lower to upper point bar. Lateral accretion. |
| **Floodplain (FF)** | Fm, Sf, C | Fine-grained sand and mud to massive mudstone, claystone or shale. Laminated or non-laminated. Occurs together with point bar and crevasse splay facies assocation. Coal is present. Sandy mud from Sf facies is poorly sorted mixture of very fine-grained sand and clay, with 45% composition of sand. | Overbank flooding and swamp. |
| **Crevasse Spay (CS)** | Sh, Fm | Sheets or lens of sandstone interbedded with fine-grained floodplain deposits Thickness of bed varies laterally. May have erosional surfaces. Overall fining upward. Fine-to-medium-grained. | Sediments introduced into floodplain by crevasse channel. Sheet flood. |
| **Shallow Lacustrine (SL)** | Sw, Sm, Fw, Fl | Lower section: Coarsening upward shale to sand lacustrine delta deposits. Upper section: Interbedded fine-grained, well sorted sandstone with laminated mudstone. Wavy erosional base and wavy cross beds. Thick clay with lenticular lamination. | Lacustrine mouth bar and wave-influenced lacustrine coastline. |

The lower section is a gradational coarsening upward sequence from calcareous shale, sandy shale to thick sandstone body, interpreted as deposits of lacustrine delta results from the diversion of stream channel into lake basin. The calcareous shale represents the bottom of lacustrine deposits (lake bottom) The presence of carbonates may due to the weathering of provenance rock of carbonates or calcium-rich rocks [6]. The increase in sand content, grain size and thickness of bed vertically upward suggest the process of sediment infill and may represent progradation of mouth bars into the lacustrine system. The upper section is dominated by sandstone beds of 10-20cm, intercalated with laminated clay. Wavy erosional base and wavy cross beds are identified. The sandstone from Fw facies are fine-grained and moderately well sorted as described from the thin section sample 6-4. The uppermost thick clay unit shows parallel and lenticular lamination. Interbedded fine-grained sand and mud with wave-influenced primary structures indicating low energy deposition with occasional wave actions. These characteristics are typical in lacustrine coastline influenced by wave action [2], [19].

## VII. DISCUSSIONS

Analysis of the facies distribution allows reconstruction of the fluvial system, and a meandering fluvio-lacustrine system is proposed (figure 14). The depositional model is similar to the sand-bed meandering river model developed by Miall [15]. Channel and point bar sediments of the study area are dominantly sand, and conglomerates may be present as channel lag deposits, where they accumulate as a result of cut bank erosion and caving. Crevasse splay and crevasse channel are typical occurrence, as crevassing takes place at well-developed floodplains, forming small abandoned channels and sheet sands of alternating mudstone and sandstone beds. The presence of coal also indicates the development of swamp in humid environment. Lacustrine delta fill sands are formed by channel diversion into lacustrine basin. Other Jurassic-Cretaceous formations such as Tembeling Group, Koh Formation and Ma'Okil Formation have similar lithology and lithofacies that represents non-marine deposits. Studies have limited their environments to alluvial fans, braided to low, sinuous fluvial to lacustrine mouth bar. The facies association identified in Bertangga formation, i.e. meandering channel and lacustrine deposits, can therefore be correlated to these formations in terms of lithofacies.

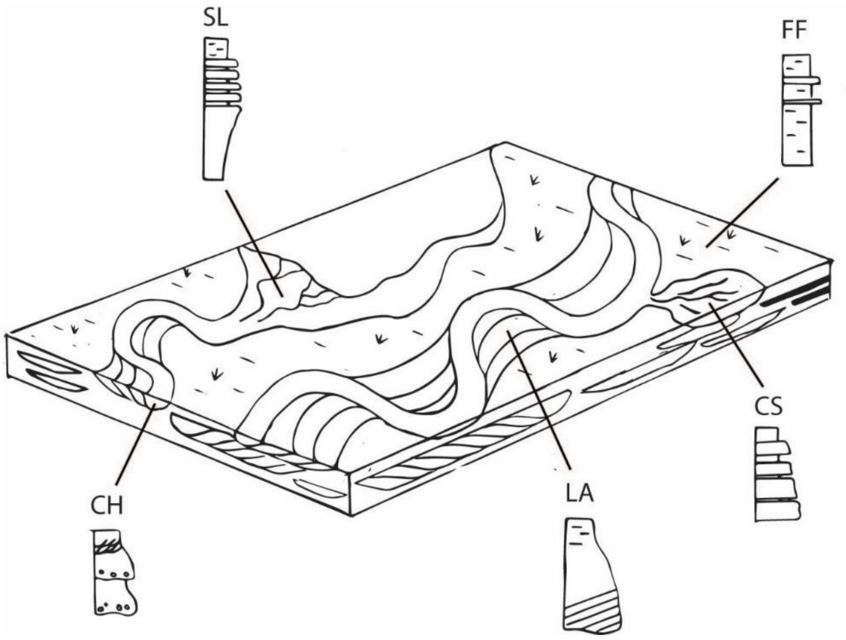


Figure 14. Proposed architectural model constructed for paleo depositional system in Bertangga formation: meandering fluvio-lacustrine system. Facies associations: Channel (CH), Point Bar (LA), Crevasse Splay (CS), Floodplain (FF), and Shallow Lacustrine (SL).

## VIII. CONCLUSIONS

The integration of outcrop descriptions, sedimentary logs, grain size analysis and petrographic analysis led to the detailed facies analysis of the fluvial deposits in Bertangga formation. Five sedimentary facies were identified in the study area, including channel facies association, point bar facies association, floodplain facies association, crevasse splay facies association and shallow lacustrine facies association.

Analysis of the facies distribution allows reconstruction of the fluvial system, and a meandering fluvio-lacustrine system is proposed. The distribution of these facies association shows increasingly distal and fine-grained trend from west to east of the study area, which suggest possible eastward paleofluvial direction. Presence of smectite in eastern part of the study area may also indicate the weathering of volcanic rocks from nearby sources.

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