Eksplorium
Volume 35 No. 2, November 2014: 85 – 100
ISSN 0854 – 1418

FACIES ANALYSIS, SEDIMENTOLOGY AND PALEOCURRENT OF THE QUATERNARY NENERING FORMATION, PENGKALAN HULU, MALAYSIA

ANALISIS FASIES, SEDIMENTOLOGI DAN ARUS PURBA FORMASI NENERING BERUMUR KUARTER, PENGKALAN HULU, MALAYSIA

Yuniarti Ulfa, Evonne Hooi Rong Yu, Ooi Cheng Kit
School of Physics, Universiti Sains Malaysia, USM Minden 11800
Pulau Pinang, Malaysia
E-mail: yuniartiulfa@usm.my

Naskah diterima: 6 Oktober 2014, direvisi: 9 Oktober 2014, disetujui: 19 November 2014

ABSTRACT

Nenering Formation is essentially made up of semi-consolidated sediments, which are divided into basal conglomerate beds, conglomeratic sandstone, cross-bedded sandstone, and siltstone to muddy layers facies. It is overlie unconformable to the Berapit Formation, but conformable to the Kroh and Grik Formations. The stratigraphy of Nenering Formation is a fining upwards sequence where the thickness of conglomerate beds become thinner upwards and become thicker for conglomeratic sandstone. The thickness varies from 0.5 m to tenths of meters. The more sandy in the upper portion (cross-bedded sandstone) overlie with thin siltstone and mudstone facies. The clast and grain composition suggested that the material making up the sedimentary sequence were derived predominantly from the erosion of granitoid rocks and sedimentary and metamorphic rocks constitute a minor provenance. Imbrications and the trend sizes of clasts indicate that the palaeo-current flow toward northeast. Cross bedding that was found in conglomerate and sandstone indicates the main channel depositional environment. The sequence stratigraphy of this area match with the Saskatchewan fluvial braided channel model.
Keywords: conglomerate, facies, fluvial, paleocurrent, stratigraphy, sedimentology

ABSTRAK

Formasi Nenering tersusun atas sedimen semi-terkonsolidasi yang terdiri atas lapisan basal konglomerat, batupasir konglomeratik, batupasir berlapisan silang siur, batulanau hingga fasies berlapisan lempung. Formasi Nenering terletak tidak selaras di atas Formasi Berapit, tetapi terletak selaras di atas Formasi Kroh dan Formasi Grik. Stratigrafi Formasi Nenering adalah menghalus ke atas, dimana ketebalan batuan konglomerat semakin menipis ke arah atas, sedangkan batupasir konglomeratik menjadi menebal ke arah atas. Ketebalan perlapisan berkisar pada 0,5 meter hingga puluhan meter. Komposisi pasir yang lebih dominan pada bagian atas (batupasir silang siur) terletak di atas fasies lapisan tipis batulanau dan batulempung. Komposisi butiran dan klastika menunjukkan bahwa material yang *menyusun sekuen sedimen didominasi berasal dari erosi batuan granitik, batuan sedimen dan sedikit dari batuan metamorf. Indikasi imbrikasi dan kecenderungan perubahan ukuran material klastika menunjukkan bahwa aliran arus purba mengarah ke timur laut, sedangkan perlapisan silang siur pada batuan konglomerat dan batupasir mengindikasikan lingkungan pengendapan berupa sungai. Sekuen stratigrafi di daerah ini sesuai dengan model lingkungan pengendapan sungai teranyam fluvial Saskatchewan.*

Kata kunci: *konglomerat, fasies, fluvial, arus purba, stratigrafi, sedimentologi*

INTRODUCTION

The Nenering Formation composes of conglomerate rocks (Quaternary age) that have not been hardening, including layers of mud, sand and gravel. On the Malaysian part, these sediments are distributed in a small area at the Lepang Nenering village, and its extend until the Thailand part at the border and to the east of the Betong area but known as Ai Yoe Boe Chang Gravel beds [1].

In this study, three sites have been selected on Malaysian part along the highway that cut Sg. Kuak and extend to the south as to the Felda Nenering village (Figure 1). The objectives of this study are (a) to describe the sedimentary facies based on petrography, grain size, clast count analysis, sorting, grading, clast support and sedimentary structures; (b) to determine the origin and provenance of the pebbles and cobbles; and (c) to interpret the depositional environment of the Quaternary Conglomerate Beds of Nenering Formation at Pengkalan Hulu. A total of 12 samples are collected from the three observation sites.

GEOLOGICAL SETTING

Nenering Formation has many similarities to the well-documented Lawin Tertiary deposit as reported by, thus it is firstly introduced as Nenering Tertiary deposit [2,3]. Later the unconsolidated sediments of Nenering Formation which are in the field evidently unconformable overlying the Kroh or Betong Formation are considered as of younger than Tertiary age [4] which is Quaternary in age [1].

Stratigraphically, the study area is composed by lithologies from Formation, Kubang Pasu Formation, Gerik Formation, Berapit Formation and Nenering beds or later known as Nenering Formation. Table 1 shows the regional stratigraphy of the formations according to the geological age.

Kroh Formation was first introduced by [5] to replace the term Baling Formation. The Kroh Formation of Baling Group representing the Early Paleozoic marine sediments which is consists of black shale, sub-mature arenite, calcareous shale and limestone. The Kroh Formation is divided into four facies: the argillaceous facies, calc-silicate facies, calcareous facies and minor arenaceous facies. The argillaceous facies is the most dominant component of the Kroh Formation. It is composed by dark grey to black shale and mudstone, which often locally metamorphosed into slate, phyllite, pelitic hornfels, metamudstone, and quartz-mica schist. Chert is also present within this rock unit. The distribution map between Kroh Formation and Nenering Beds is shown in figure 2.

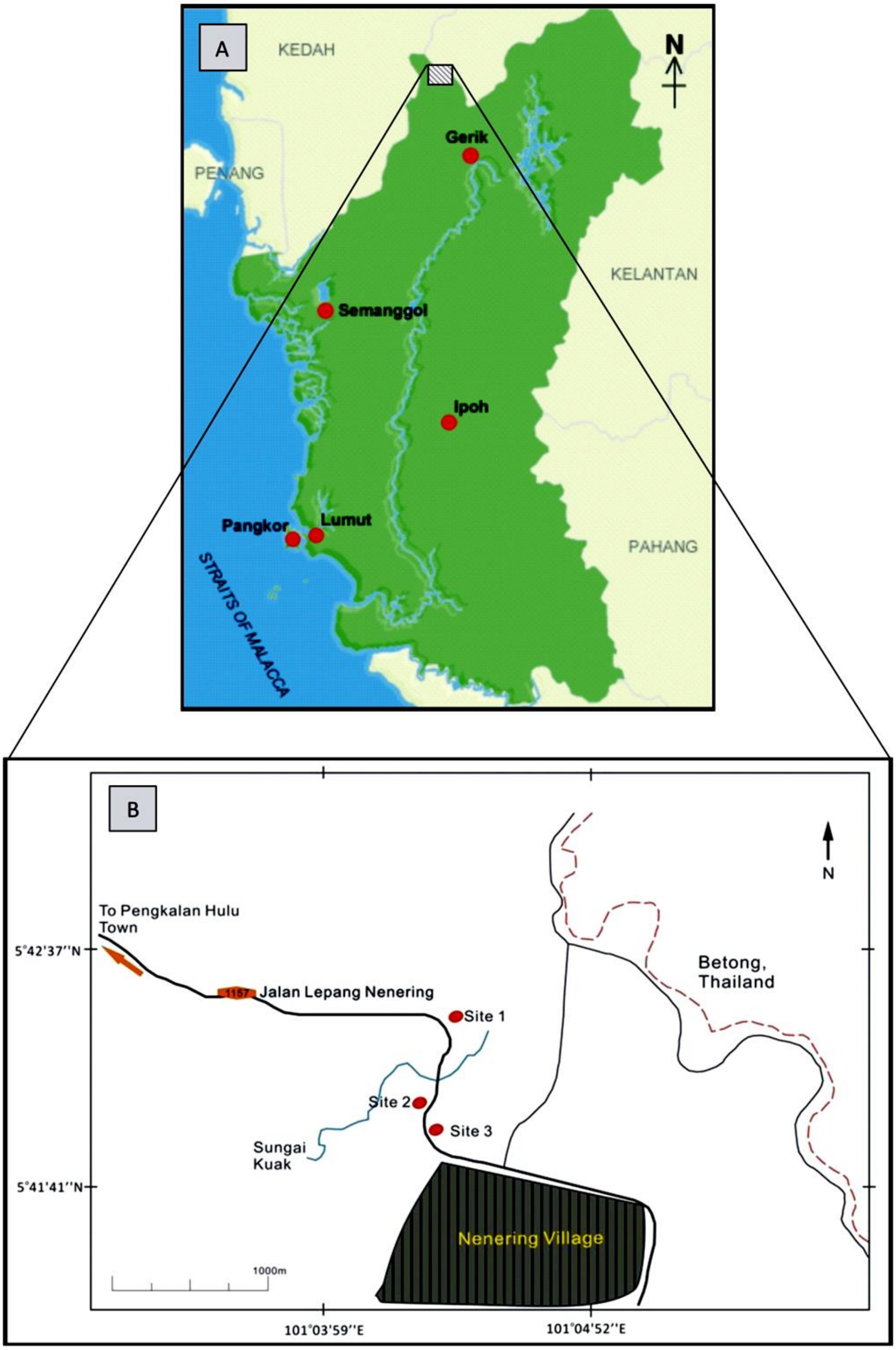

Figure 1. (A) Location map of Pengkalan Hulu area. (B) The detail sites map along the Jalan Lepang Nenering, Pengkalan Hulu.

Table 1. The Regional Stratigraphy of The Study Area According to The Geological Age (Modified from [1])

EON	ERA	PERIOD	FORMATION/UNIT	LITHOLOGY
PHANEROZOIC	CENOZOIC	QUATERNERY	Nenering Beds	Basal gravel beds and gravelly sand layers
		TERTIARY		
	MESOZOIC	CRETACEOUS	Berapit Formation	Very well cemented conglomerate
		JURASSIC		
		TRIASSIC		
	PALEOZOIC	PERMIAN	Gerik Formation	Tuffs of rhyolitic to rhyodacitic composition, limestone and calcareous shale
		CARBONIFEROUS	Kubang Pasu Formation	Thick sandstone interbedded with thin shale
		DEVONIAN	Kroh Formation	Graptolite and *Tentaculites*-bearing black shale, sub-mature arenite, slate, calcareous shale and limestone
		SILURIAN		

Nenering Formation is divided into Basal Gravel Beds and Gravelly Sand Layers facies and assigned as part of the Middle and Upper unit from previous studies [e.g. 6, 7, 8]. In detail, the Nenering Beds are composes of semi-consolidated sediments of gravelly, sandy and clayey layers [2]. Upper unit (Gravelly Sand Layers facies) composes of alternating layers of paraconglomeritic, muddy to silty sand and muddy to silty beds. Middle unit (Basal Gravel Beds) is generally thick stratification of boulder/gravel beds, pebbly and coarse sandstone deposited above basal unconformity. It is initiated by a thick layer of orthoconglomeritic beds lying above the basal plane of unconformity followed by paraconglomerate [7]. Cross bedding was found in sandstone while graded-bedding found in conglomeritic bed. Basal Gravel Beds facies comprises mainly semi-consolidated boulders, gravels and pebbles in sandy to clayey matrix[1].

Nenering Formation was believed to be deposited in fluvial environment according to [9] where the field data indicate that at the basal parts of the sequence, most of the sandstone bodies (in thickness of 1-2 meters) are channel shaped while others parts are more tabular. At the higher sequence, a few tabular sandstone beds shows sudden change in thickness which may be caused by bank collapse during sedimentation.

Nenering Beds was also proposed to be deposited by fast-flowing, short-lived (ephemeral), ever-changing through avulsion, kind of streams/gullies on the foot slopes of uplifted terrain [4]. In addition, the clast and grain composition suggested that the material composes the sedimentary sequence were derived predominantly from the erosion of granitoid terrain.

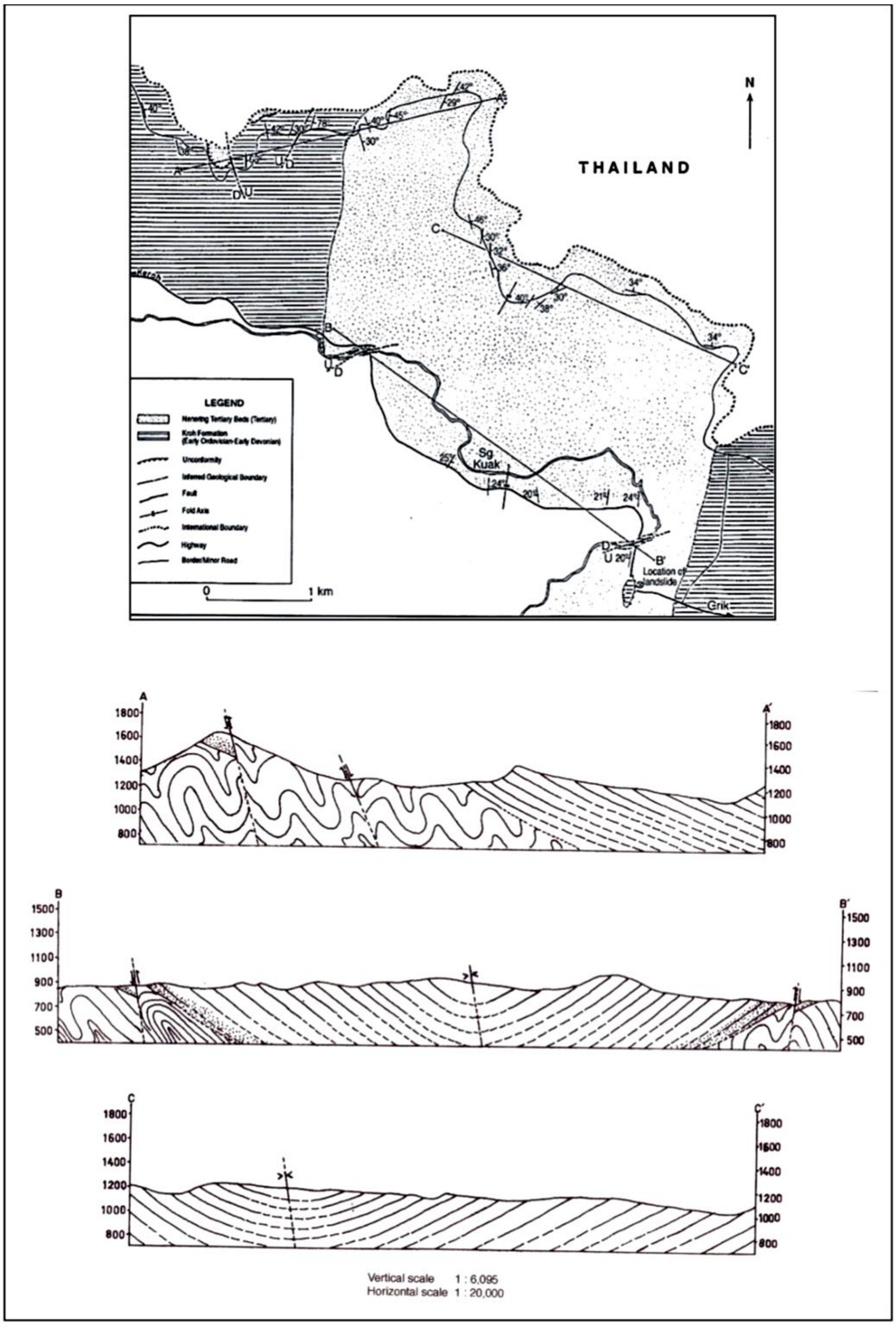

Figure 2. Geological map of the study area shows the distribution of Kroh Formation and Nenering Formation. Cross sections through AA’, BB’, and CC’[7].

METHODOLOGY

During the field work, 12 samples were taken from the study area for further analysis i.e. petrology and sedimentology. Petrology analyses were observed in field and through thin section to describe structure, texture and mineral composition. Petrography is used to determine the rocks; its texture and mineralogy thus allow understanding of its formation origin. A polarized light microscope is used for detail analysis of minerals in thin section from rock sample collected. The thin section is observed and analyzed in plane-polarized light (PPL) and cross-polarized light (XPL).

Sedimentology analyses such as sieving and clast count analysis were performed to determine the grain size distribution of the sample. First, the sample is leave in the oven for 1 day to remove the moisture. Then the weight of the sample is measured and recorded to make sure there is no weight lost. The dried sample is poured into the top sieve which has the largest screen openings. Each lower sieve in the column has smaller openings than the one above. The sample is then washed with pipe water and sieved through appropriate sieves of decreasing size from 2.0mm down to 0.075mm. The rinsing is carried out until the liquid which is discharged through the last sieve is clear. Each sieve is washed carefully to make sure only the sample with grain size greater than the sieve nest is retained on it. Sample residues on each sieve is collected in dish and placed into the oven to dry it. After dried, the weight of dried washed sample of each sieve is recorded and put into a sample bag for further analysis. The weight of sample that passed through the 0.075mm sieve which is the silt and clay materials were calculated from the origin weight of dried sample and the total weight of dried sample from each sieve. Lastly the percentage of each clast size is calculated.

FACIES DESCRIPTION

The three selected outcrops shows repeated fining upwards sequence (Figure 3 and 4) where the lower sequence is coarser than the overlying sequence. The four observed facies are conglomerate (cot), conglomeratic sandstone (css), cross bedded sandstone (cbs), and siltstone (sts). The complete cycle that consists of all four facies was observed in site 1, while the two others sites include incomplete facies. Clear channel and boundaries are observed between the sequences (Figure 5).

Facies 1—Conglomerate (cot)

Conglomerate is a unity of 2–6 meters thickness, which characterized by semi-consolidated materials, with 50% gravel-sized and pebble-sized of subrounded to rounded fragments, composed by igneous rocks, metamorphic rocks and sedimentary rocks (Figure 6–7).

The clast count analysis shows that sample PH1.1 and PH1.3 are conglomerate. Both samples (PH1.1 and PH1.3) have more than 50% clast with size >2.0mm which is 55.29% and 57.68% respectively (Table 2).

Figure 3. Field photos of fining upwards sequence.

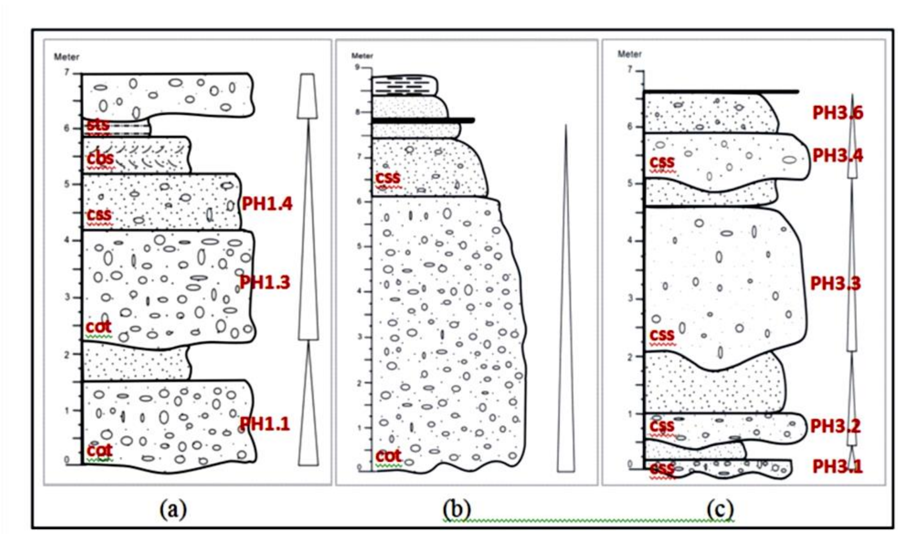

Figure 4. Logging chart of each site (a) Site 1 (b) Site 2 (c) Site 3. PH1 to PH3 represents the sampling code in one locality logging section.

Figure 5. Field photos of channel and boundary.

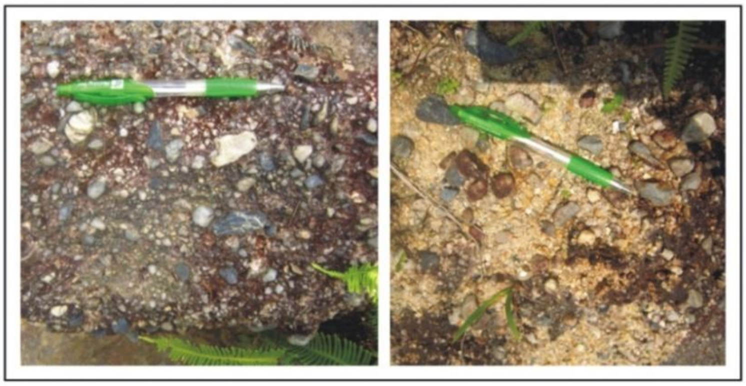

Figure 6. Conglomerate facies (cot).

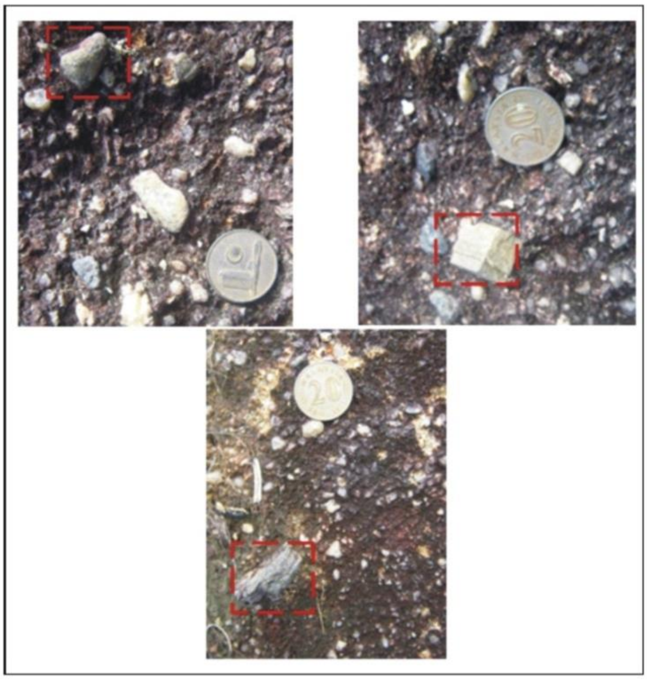

Figure 7. Field photo of rock fragments in conglomerate (a) fragment of igneous rock (b) fragment of sandstone, and (c) fragment of slate.

Table 2. Clast Count Analysis Result. (a) PH1.1 (b) PH1.3

PH1.1		Size (mm)	Sediment (%)
Gravel		> 2.000	55.29
Sand	Very coarse	> 1.000	12.18
	Coarse	> 0.500	6.73
	Medium	> 0.300	4.59
	Fine	> 0.108	4.60
	Very Fine	> 0.075	5.85
Silt			10.77
		Total	100.00

(a)

PH1.3		Size (mm)	Sediment (%)
Gravel		> 2.000	57.68
Sand	Very coarse	> 1.000	9.47
	Coarse	> 0.500	3.64
	Medium	> 0.300	2.26
	Fine	> 0.108	5.15
	Very Fine	> 0.075	7.91
Silt			13.90
		Total	100.00

(b)

Petrography analysis gives a better insight of the grain size of mineral composition of the samples. There is a great contrast between fragment and matrix size under the microscope (Figure 8). Either mineral (i.e. quartz, biotite) or rock fragments are much more dominant compared to cement as it is observed in the thin section. It indicates the sample is clast-supported and not well-consolidated conglomerate.

Facies 2—Conglomeratic sandstone (css)

Conglomeratic sandstones (Figure 9) are coarse-grained sedimentary rocks that consist less than 50% gravel-sized (>2mm) clasts. The thicknesses of conglomeratic sandstone beds observed at the field are in the range of 0.2 to 2.5 meters. It is dominated by medium to very coarse sized grain with some bigger pebbles sized clasts.

Based on clast count analysis, shows that sample PH1.4, PH3.1, PH3.2, PH3.3, PH3.4 and PH3.6 are conglomeratic sandstones, where have less than 50% clast with size >2.0 mm and dominated by clast with clast size <2.0 mm (Table 3).

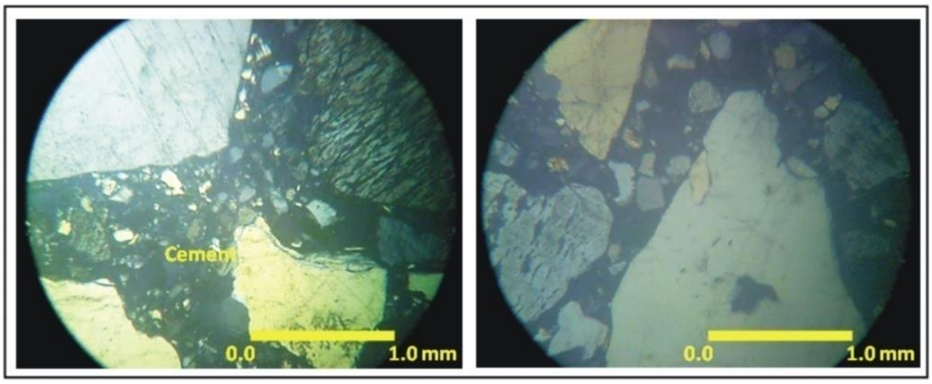

Figure 8. Microphotographs of conglomerate (cot) facies.

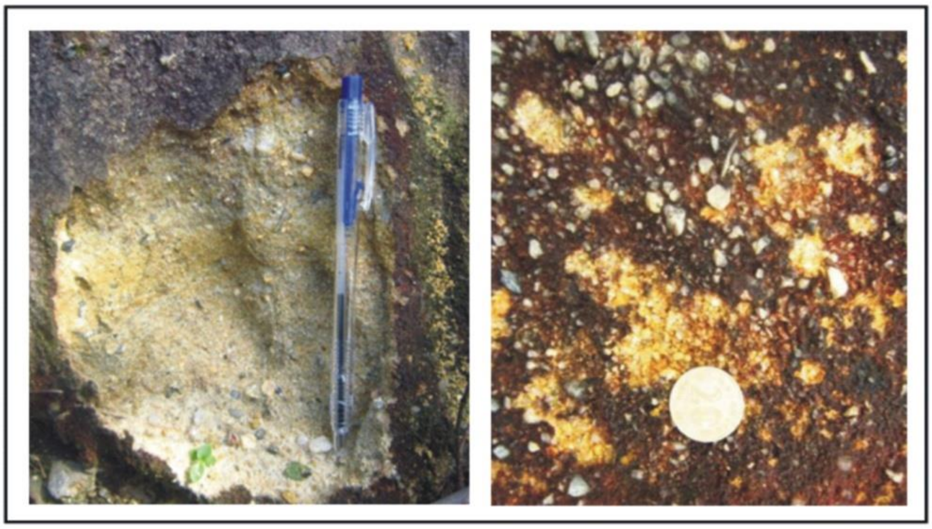

Figure 9. Conglomeratic sandstone facies (css).

Two thin sections which are from rock samples PH3.1 and PH3.4 respectively, are observed under the microscope (Figure 10). The petrography analysis shows that the mineral size is ranged from 0.1mm to 2.0mm. The thin section is observed as matrix-supported fabric and the minerals are moderately sorted where the contrast between the grain sizes is not obvious. The roundness of the grains ranges from sub-angular to sub-rounded.

Facies 3— Cross-bedded sandstone (cbs)

The thickness of the cross bedded sandstone bed observed at the field is around 0.7 m. Cross-bedded structure is observed at the field (Figure 11). The bigger clasts are in the size of 0.3 mm to 0.5 mm while it is mainly composes of sand-sized clast. Figure 12 shows the microphotograph of typical sandstone.

Facies 4—Siltstone (sts)

Siltstone is a sedimentary rock which has a grain size in the silt range, which is finer than sandstone and coarser than claystone [10]. It is grey in color with silt-sized grain in the range of 4 to 63 micrometers. It is massive and no bedding, lamination and structure are observed. The thickness of the silt stone is approximately 0.7 meters. It is conformably underlain by the sandstone and it is conformably overlain by a new sequence with sharp contact (Figure 13).

The descriptions of fabric, sorting, grain shape and sizes of each facies are important in describing the mode and depositional environment of the formation. The sorting reflects the depositional process which included degree of agitation and reworking [10]. The shape and sphericity of pebbles reflects their composition and any planes of weakness, whereas their roundness reflects the degree of reworking and/or transport [12]. Grain packing (fabric) refers to the spacing or density patterns of grains in a sedimentary rock and is as a function of grain size, shape, and the degree of compaction of the sediment [13]. The detail description of the sedimentology and paleocurrent of the area is discussed in provenance and depositional model parts.

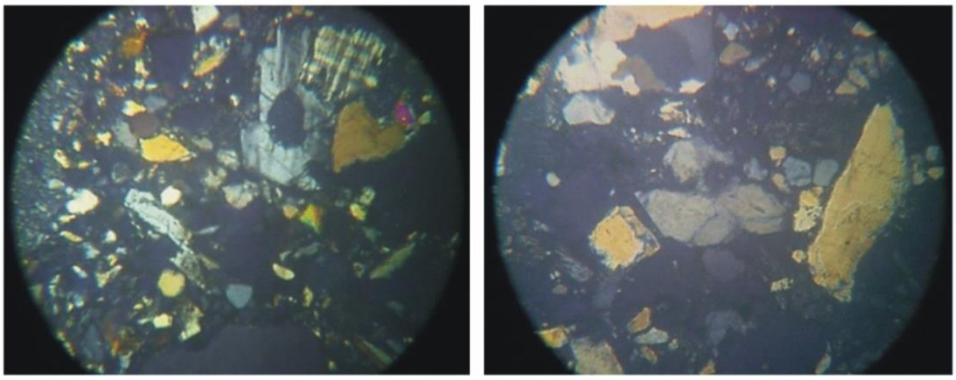

Figure 10. Microphotographs of conglomeratic sandstone (css) facies.

Table 3. Clast Count Analysis Result (a) PH1.4 (b) PH3.1 (c) PH3.2 (d) PH3.4 (e) PH3.5 (f) PH3.6

PH1.4		Size (mm)	Sediment (%)
Gravel		> 2.000	34.51
Sand	Very coarse	> 1.000	14.96
	Coarse	> 0.500	15.26
	Medium	> 0.300	11.53
	Fine	> 0.108	8.04
	Very Fine	> 0.075	4.38
Silt			11.33
		Total	100.00

(a)

PH3.1		Size (mm)	Sediment (%)
Gravel		> 2.000	39.33
Sand	Very coarse	> 1.000	16.49
	Coarse	> 0.500	12.50
	Medium	> 0.300	7.65
	Fine	> 0.108	6.34
	Very Fine	> 0.075	5.90
Silt			11.79
		Total	100.00

(b)

PH3.2		Size (mm)	Sediment (%)
Gravel		> 2.000	27.68
Sand	Very coarse	> 1.000	14.60
	Coarse	> 0.500	15.37
	Medium	> 0.300	13.23
	Fine	> 0.108	8.20
	Very Fine	> 0.075	6.78
Silt			14.14
		Total	100.00

(c)

PH3.3		Size (mm)	Sediment (%)
Gravel		> 2.000	33.91
Sand	Very coarse	> 1.000	17.37
	Coarse	> 0.500	16.02
	Medium	> 0.300	9.58
	Fine	> 0.108	6.01
	Very Fine	> 0.075	4.72
Silt			12.39
		Total	100.00

(d)

PH3.4		Size (mm)	Sediment (%)
Gravel		> 2.000	18.98
Sand	Very coarse	> 1.000	15.95
	Coarse	> 0.500	16.08
	Medium	> 0.300	11.63
	Fine	> 0.108	10.26
	Very Fine	> 0.075	12.11
Silt			15.00
		Total	100.00

(e)

PH3.6		Size (mm)	Sediment (%)
Gravel		> 2.000	6.01
Sand	Very coarse	> 1.000	7.27
	Coarse	> 0.500	13.96
	Medium	> 0.300	13.21
	Fine	> 0.108	13.10
	Very Fine	> 0.075	19.22
Silt			27.23
		Total	100.00

(f)

Figure 11. Field photos of cross-bedded sandstone (cbs) facies

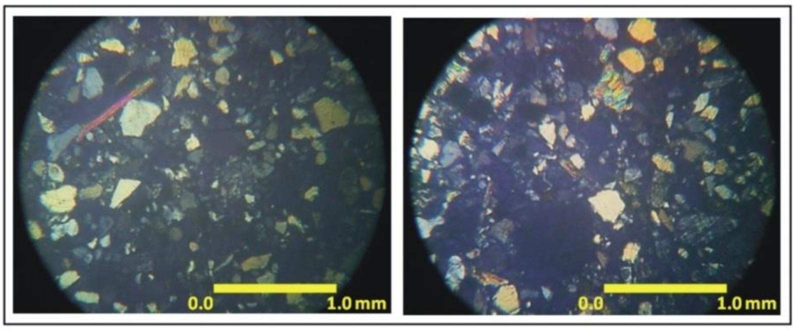

Figure 12. Microphotographs of typical cross-bedded sandstone (cbs) facies

PROVENANCE

Petrography studies on the sample provide unique information about the provenance. Based on the petrographic analyses, the rock minerals that were identified from sample collected are quartz (qtz) 43%, biotite (bio) 30%, microcline (micrc) 12%, plagioclase feldspar (plag) 8%, hornblende (hbl) 3%, muscovite mica (musc) 3% and epidote (epi) 1%.

Petrography analysis shows that quartz is the main composition in the sample and the biggest mineral fragment among all other minerals. In addition, less feldspar (sub-rounded to well-rounded) is observed. These facts shows that the conglomerate is far from the source as feldspar is a low resistance mineral which will be washed away if transported for a long distances. Afterwards, it will just leave behind with quartz that has much higher resistance. Furthermore, the roundness of other minerals is angular to sub-rounded which show that they have been transported for some distance.

The rock fragment of igneous, metamorphic and sedimentary rock is observed clearly under polarized light microscope (Figure 14). The interlocking textures between minerals are observed in the granite fragment, while the foliated texture is observed in the slate fragment. Rock fragments are sourced from the surrounding

 ISSN 0854 – 1418

older formation. The source of granite fragment may come from the igneous rock that expose the around Pengkalan Hulu Hot Spring area. It is the nearest igneous rock source from the study area (less than 20km away). Another possibility, it may derive from the underlying Kroh Formation which contains granite. The source of sandstone fragment may come from the Kubang Pasu Formation which is underlying the Nenering Formation. The slate fragment is may from the locally metamorphosed shale or mudstone of the underlying Kroh Formation.

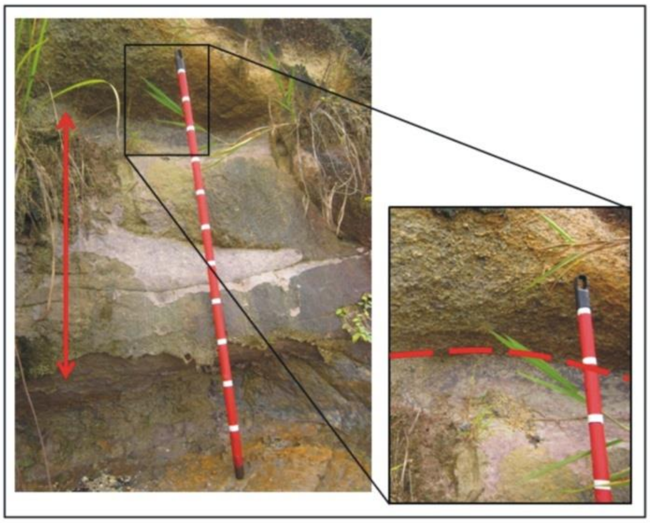

Figure 13. Field photo of siltstone (sts) facies and closer look of the contact between siltstone and sandstone.

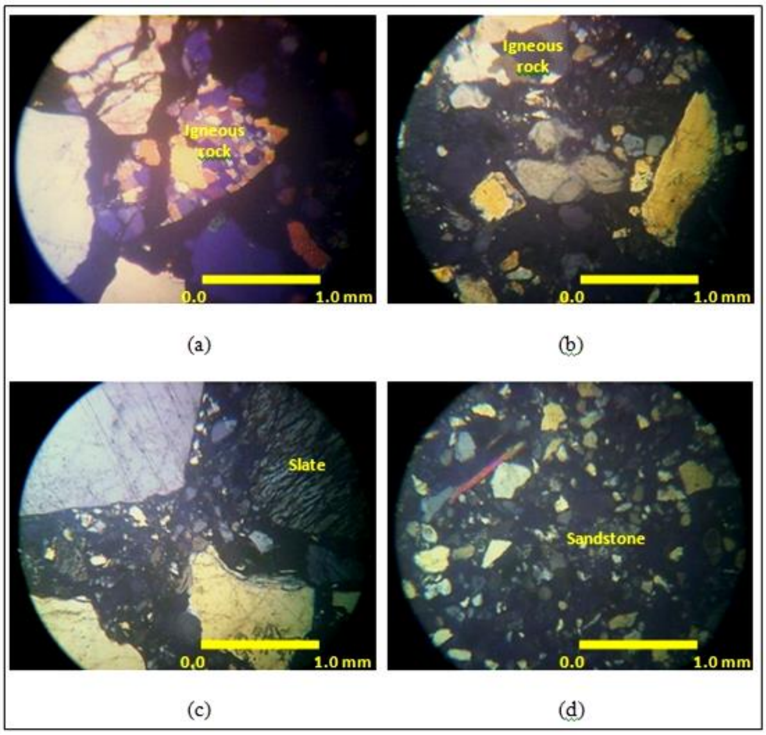

Figure 14. Microphotograph of rock fragments. (a) Igneous rock fragment (granite); (b) Igneous rock fragment (granite); (c) Metamorphic rock fragment (slate); and (d) Sedimentary rock fragment (sandstone).

DEPOSITIONAL MODEL

Depositional environment of study area matched the best with braided streams. Figure 15 shows comparison between (a) fining upward sequence of a channel-fill in a braided river and (b) log chart of field data. Similar facies are observed. Conglomerate facies and conglomeratic sandstone facies are similar to gravel deposit, cross-bedded sandstone is similar to coarse sand deposit and siltstone is similar to silt deposits. The full sequence is made up mainly by gravel.

Conglomerate facies (cot) and conglomeratic sandstone facies (css) occupied 70-80% of each sequence and the conglomerate observed are mostly grain-supported. Horizontally bedded gravels that exhibit good imbrication are observed. Massive siltstone (sts) is observed at the field compared to laminated siltstone.

There are six vertical profile models for braided stream deposits which are Trollheim, Scott, Donjek, S. Saskatchewan, Platte and Bijou Creek. Vertical profile of study area is matched with the major channel of the S. Saskatchewan model (Figure 16). At field, fining upward sequence and clear sharp contact between each sequence by the erosional channel scours is observed. The same sequence is repeated until the present of mud layer as show is the model.

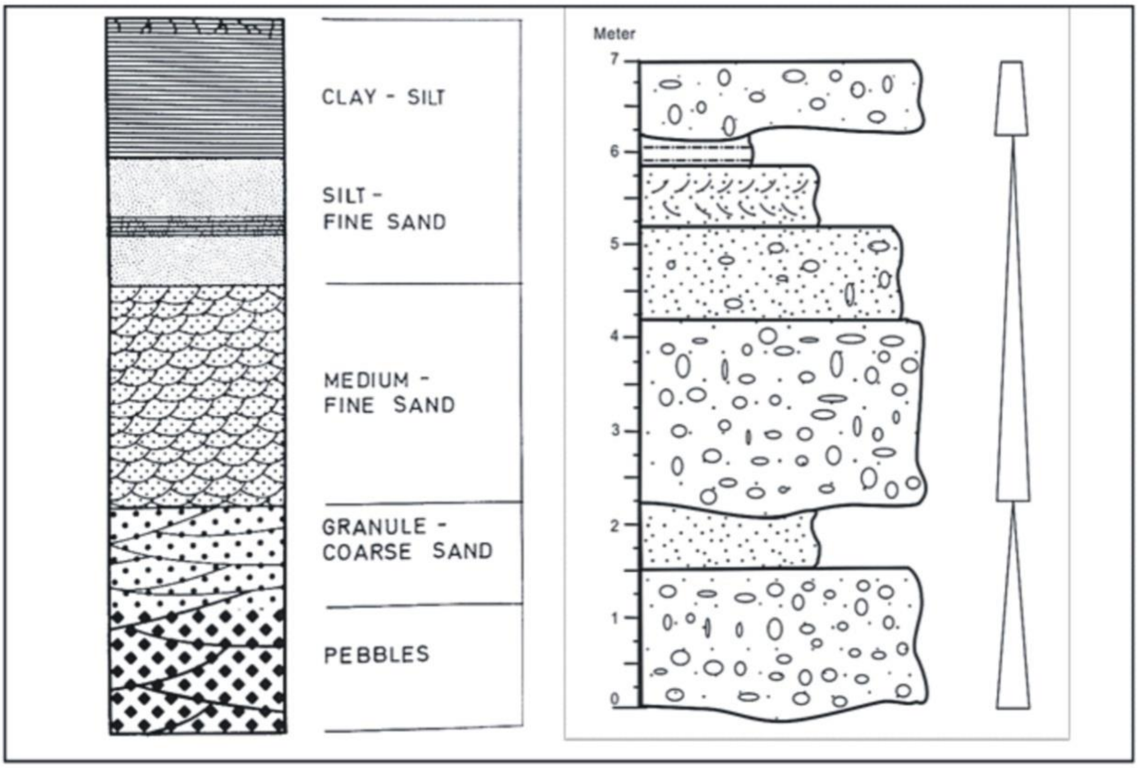

Figure 15. Comparison between (a) fining upward sequence of a channel-fill in a braided river [11] and (b) log chart of field data.

Eksplorium
Volume 35 No. 2, November 2014: 85 – 100

ISSN 0854 – 1418

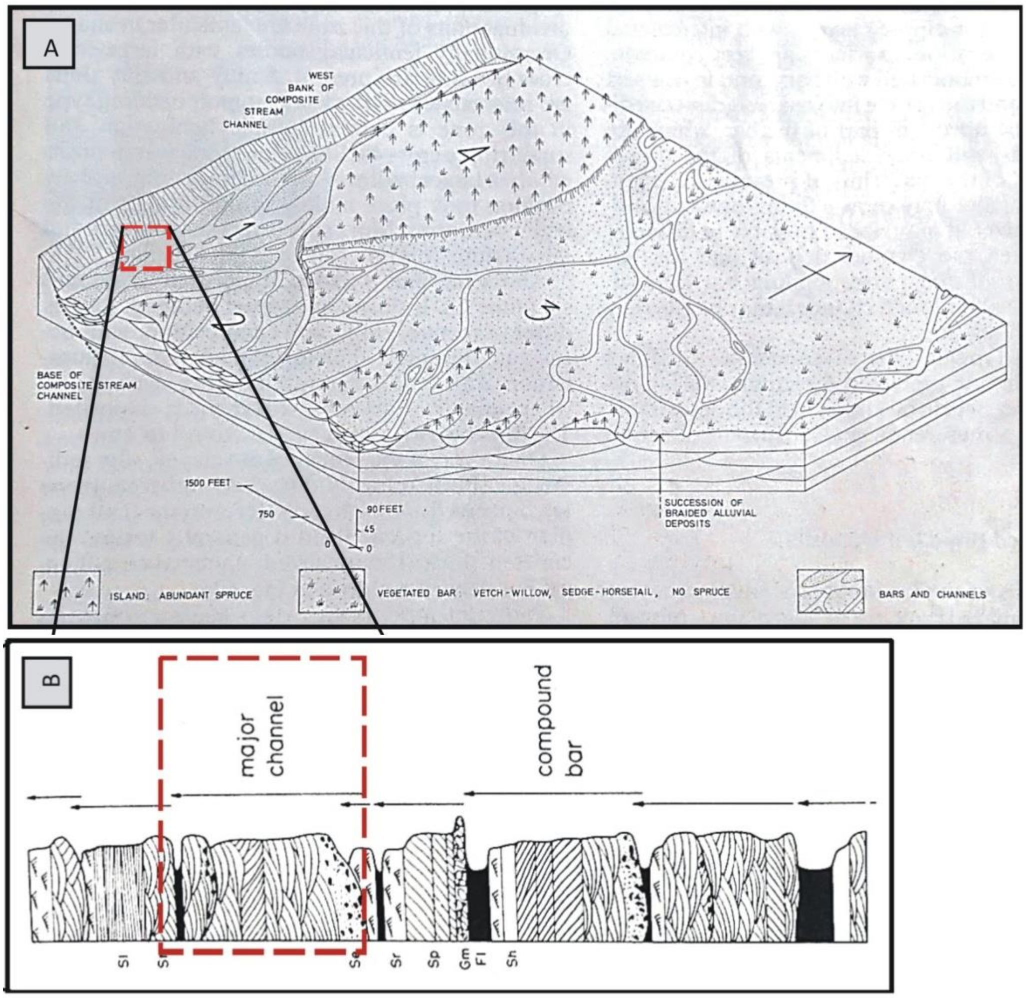

Figure 16. (a) Composite model of braided river deposits (b) S. Saskatchewan model [11]

CONCLUSIONS

Four facies were recognized based on its sedimentological characteristics which are grain size, clast count analysis, sorting, grading, class support and sedimentary structures. They are conglomerate (cot), conglomeratic sandstone (css), cross bedded sandstone (cbs), and siltstone (sts). Sharp contact is observed between each facies. The identified facies with the logging sedimentological section indicates that the formation was deposited in the braided river. The repeated fining upward sequence with clear erosional scouring when a new sequence started is similar to the major channel of S. Saskatchewan model. Petrography study has provided information about mineral and rock fragment properties which correlated to the field observation. The result from mineral analysis that shows more quartz and less feldspar indicated that the formation is relatively far from the source.

In conclusion, Quaternary conglomerate beds of Nenering Formation at Pengkalan Hulu, Perak is an unconsolidated conglomerate which is relatively far from it source and it was deposited at the major channel of braided stream depositional environment system.

ACKNOWLEDGEMENTS

Financial support to this research was given by the School of Physics, Universiti Sains Malaysia. The authors would like to thanks Mr. Shahil Ahmad for his kind assistance.

REFERENCES

1. MTJGSC (Malaysia-Thailand Border Joint Geological Survey Committee), "Geology of the Pengkalan Hulu-Bentong Transect Area along Malaysia-Thailand Border", Geological Paper, 7, 2009.
2. TEH, G.H., SIA, S.G., "The Nenering Tertiary Deposits, Keroh, North Perak-A Preliminary Study", Warta Geologi, 17(2), 49 – 58, 1991.
3. JONES, C.R., "The Geology and Mineral Resources of the Grik Area, Upper Perak, Ipoh", Geological Survey Headquarters, 1970.
4. AHMAD JANTAN, IBRAHIM ABDULLAH, CHE AZIZ ALI, JUHARI MAT AKHIR, "The Nenering Sequence: Sedimentology, Stratigraphy and Probable Basin Initiation - A Second Opinion" (Abstract), Geological Society of Malaysia Warta Geologi, 19, 117, 1993.
5. BURTON, C.K., "Wrench Faulting in Malaya", Journal of Geology 73, 781-198, 1965
6. MOHD BADZRAN MAT TAIB, MOHD ASBI MOHD ZIN, SELVARAJAH, M., "Geology and Mineral Resources of the Kerunai Area (Sheet 19), Perak Darul Ridzuan". Proceeding of the 24th Annual Geological Conference, 1993, Technical papers, 5, 92 – 106 (in Malay), 1993.
7. QALAM AZAD ROSLE, TEH, G.H., "The Stratigraphy, Structure and Significance of the Nenering Tertiary Beds, Pengkalan Hulu (Keroh)", Upper Perak. Bulletin of the Geological Society Malaysia, 42, 161 – 177, 1998.
8. UYOP SAID, CHE AZIZ ALI, "Nenering Continental Deposits; Its Age based on Palynological Evidence" (abstract), Warta Geologi, 23(3), 170 – 171, 1997.
9. IBRAHIM ABDULLAH, JOHARI MAT AKHIR, ABD. RASHID JAAPUR, NOR AZIAN HAMZAH, "The Tertiary Basin in Felda Nenering, Pengkalan Hulu (Keroh), Perak". Geological Society of Malaysia Warta Geologi, *17*, 181-186, 1991.
10. TUCKER, M.E., "Sedimentary Rocks in the Field: The Geological Field Guide Series" (3rd ed.), USA: John Wiley & Sons, 2003.
11. REINECK, H.E. AND SINGH, I.B., "Depositional Sedimentary Environments" (2nd ed.). Germany: Springer-Verlag Berli Heidelberg, 1980.
12. STOW, D.A.V., "Sedimentary Rocks in the Field: A Colour Guide" US: Manson Publishing, 2005.
13. BOGGS Jr., S., "Principles of Sedimentology and Stratigraphy (4th ed.)", Upper Saddle River, Pearson Prentice Hall, 2006.